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Middle East Spine Society (MESS), Association of Spine Surgeons of India (ASSI),
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Chinese Spine Society of Medicine Education (CSSME)

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Aims & Scope

Asian Spine Journal (Asian Spine J), the official journal of the Asia Pacific Spine Society (APSS), Middle East Spine Society (MESS), Association of Spine Surgeons of India (ASSI), Taiwan Spine Society (TWSS), Chinese Spine Society of Medicine Education (CSSME), and Korean Society of Spine Surgery (KSSS), is an international peer-reviewed journal which publishes articles related to basic and clinical researches of all spine fields bimonthly in end of February, April, June, August, October, and December. *Asian Spine Journal* was founded in 2007.

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Abstracts

- PS-BP-1** Significance of Vertebral Body Sliding Osteotomy as a Surgical Strategy for the Treatment of Cervical Ossification of the Posterior Longitudinal Ligament **1**
Sehan Park, Dong-Ho Lee, Jae Hwan Cho, Chang-Ju Hwang, Choon-Sung Lee
- PS-BP-2** Comparison of the Clinical and Radiographic Results between Cervical Artificial Disc Replacement and Anterior Cervical Fusion: 10-Year Follow-up Study **1**
Kai Yan, Chi Ma, Xiao Han, Da He, Wei Tian
- PS-BP-3** Deep Learning Pipeline for Automated Detection and Classification of Central Canal, Lateral Recess and Neural Foraminal Stenosis on Lumbar Spine Magnetic Resonance Imaging **2**
Jiong Hao Tan, James Thomas Patrick Decourcy Hallinan, Lei Zhu, Kaiyuan Yang, Andrew Makmur, Diyaa Abdul Rauf Algazwi, Yee Liang Thian, Samuel Lau, Yun Song Choo, Eide Sterling, Qai Ven Yap, Yiong Huak Chan, Naresh Kumar, Beng Chin Ooi, Hiroshi Yoshioka, Swee Tian Quek
- PS-BP-5** Prediction of Final Outcome after Posterior Correction with Lower Instrumented Vertebra L3 or L4 for the Correction of Structural Thoracolumbar/Lumbar Curve-Minimum 5-Year Follow-up **3**
Kun-Bo Park, Choon Sung Lee, Sehan Park
- PS-BP-6** Better Patient Experience Improves Outcomes in Pediatric Patients with Scoliosis **3**
Yi Ling Chua
- PS-BP-7** Clarifying the Therapeutic Effect of Grafted Human-Induced Pluripotent Stem Cell-Derived Neurons in Spinal Cord Injury by Chemically Controlling Neuronal Activity **4**
Takahiro Kitagawa, Narihito Nagoshi, Yasuhiro Kamata, Morio Matsumoto, Hideyuki Okano, Masaya Nakamura
- PS-BP-8** Long-Term Selective Stimulation of Transplanted Neural Stem/Progenitor Cells for Spinal Cord Injury Improves Locomotor Function Mediated by Increased Synaptic Transmission **5**
Momotaro Kawai, Narihito Nagoshi, Kent Imaizumi, Mitsuru Ishikawa, Munehisa Shinozaki, Shinsuke Shibata, Yusuke Saijo, Yu Suematsu, Takayuki Nishijima, Takashi Yoshida, Takahiro Shibata, Shogo Hashimoto, Takahiro Kitagawa, Kentaro Ago, Keita Kajikawa, Reo Shibata, Yasuhiro Kamata, Morio Matsumoto, Hideyuki Okano, Masaya Nakamura
- PS-BP-9** Novel Biomarkers of Health and Degeneration in Human Intervertebral Discs: In-Depth Proteomic Analysis of Collagen Framework of Fetal, Healthy, Scoliotic, Degenerate and Herniated Discs **6**
Dilip Chand Raja Soundararajan, Sharon Miracle Nayagam, Sri Vijayanand Ks, Raveendran Muthurajan, Sunmathi R, Chitraa Tangavel, Ajoy Prasad Shetty, Rishi Mughesh Kanna, Rajasekaran Shanmuganathan
- PS-FP-1-2** Fusion and Subsidence Rates of Vertebral Body Sliding Osteotomy: Comparison of Three Reconstructive Techniques for Multilevel Cervical Myelopathy **6**
Sehan Park, Dong-Ho Lee, Jae Hwan Cho, Chang Ju Hwang, Choon Sung Lee
- PS-FP-1-5** What is the Risk of Cervical Deformity after Posterior Cervical Decompression Surgery?: A Multicenter Study **7**
Shin Oe, Kenta Kurosu, Tomohiko Hasegawa, Satoshi Shimizu, Go Yoshida, Tomotada Fujita, Sho Kobayashi, Tomohiro Yamada, Koichiro Ide, Keiichi Nakai, Kumiko Yotsuya, Yu Yamato, Tatsuya Yasuda, Tomohiro Banno, Hideyuki Arima, Yuki Mihara, Hiroki Ushirozako, Yuh Watanabe, Yukihiko Matsuyama
- PS-FP-1-6** The Effect of Using Lamina Spacer on Postoperative Cervical Alignment and Range of Motion in Double-Door Laminoplasty **8**
Akinobu Matsushita, Kenichi Kawaguchi, Hirokazu Saiwai, Keiichiro Iida, Yasuharu Nakashima
- PS-FP-1-7** K-line (-) in the Neck-Flexed Position Negatively Affects Surgical Outcome of Expansive Open-Door Laminoplasty for Cervical Spondylotic Myelopathy **8**
Satoshi Nori, Narihito Nagoshi, Satoshi Suzuki, Osahiko Tsuji, Eijiro Okada, Mitsuru Yagi, Masaya Nakamura, Morio Matsumoto, Kota Watanabe

- PS-FP-1-8** Preoperative Severity of Spinal Cord Compression and Its Restoration during the Early Postoperative Period Affect the Development of C5 Palsy **9**
Masahiro Mizutani, Takashi Fujishiro, Takuya Obo, Atsushi Nakano, Yoshiharu Nakaya, Sachio Hayama, Yoshitada Usami, Masashi Neo
- PS-FP-1-9** A Multicentre, Prospective, Randomized Controlled Trial Comparing Efficacy and Safety of ProDisc-C to Anterior Cervical Discectomy and Fusion for Treatment of Symptomatic Cervical Disc Disease **10**
Naresh Kumar, Leonard Vornov, Chi Chien Niu, Hee-Kit Wong
- PS-FP-1-13** Gap between Flexion and Extension Range of Motions: A Novel Indicator to Predict the Loss of Cervical Lordosis after Laminoplasty for Cervical Spondylotic Myelopathy **10**
Takashi Fujishiro, Sachio Hayama, Takuya Obo, Yoshiharu Nakaya, Atsushi Nakano, Yoshitada Usami, Ichiro Baba, Masashi Neo
- PS-FP-1-14** Decompression Status of the Spinal Cord after Cervical Laminoplasty in Various Body Positions and Neck Postures Observed Using Percutaneous Ultrasonography: Relationship with Neurological Recovery **11**
Sachio Hayama, Yoshiharu Nakaya, Atsushi Nakano, Takashi Fujishiro, Toma Yano, Masahiro Mizutani, Kenta Fujiwara, Masashi Neo
- PS-FP-1-16** C6 Radiculopathy Can Cause So-Called C5 Palsy: Comparison to C5 Radiculopathy **12**
Takumi Tsubakino, Yasuhisa Tanaka, Takeshi Nakamura, Yasutaka Naba, Kota Miyake, Eiketsu Kinjo, Shigeaki Kojo
- PS-FP-1-17** Posterior Hybrid Technique for Multi-Level Cervical Spondylotic Myelopathy with Instability **12**
Hao Zhang, Feng Zeng Guo
- PS-FP-1-18** The Feasibility Study of Cervical Pedicle Screwed with a New Individual-Oriented Template by Three-Dimensional Printing Technology **13**
Hao Zhang, Wang Zhang
- PS-FP-1-19** Anterior Cervical Discectomy and Fusion with Cervical Uncinectomy for Cervical Radiculopathy with Foraminal Stenosis **13**
Hao Zhang, Feng Zeng Guo
- PS-FP-1-20** Investigation of Diagnostic Imaging Criteria for Developmental Stenosis Based on Cervical Spondylotic Myelopathy in Young Patients **14**
Tsuyoshi Iida, Narihito Nagoshi, Satoshi Suzuki, Osahiko Tsuji, Satoshi Nori, Eijiro Okada, Mitsuru Yagi, Masaya Nakamura, Morio Matsumoto, Kota Watanabe
- PS-FP-1-21** Surgical Strategy for the Cervical Kyphosis Patients Associated with Cervical Spondylolisthesis: Three Cases' Experience **15**
Daichi Takahashi, Akira Matsumura, Takashi Namikawa, Ryo Yanai, Hiroaki Nakamura
Hyeongseok Jeon, Yoon Ha, Dong Wuk Son
- PS-FP-1-24** A Meta-Analysis of the Efficacy of Botulinum Toxin A and Occupational Therapy versus Occupational Therapy Alone in Children with Upper Limb Spastic Cerebral Palsy **15**
Alice Chu, Anugya Mittal, Vaishali Ravikumar, Kunj Jain, Yash Shah, Amy Song, Lauren Hutnik, Anam Purewal, Sarthak Mohanty, Jen Fu Cheng
- PS-FP-1-26** Modified Kurukawa Cervical Laminoplasty Using Iliac Crest Bone Graft as Spacers: Why to Do It Any Other Way? **16**
Aashish Babanrao Ghodke, David Jaffray, Birender Balain
- PS-FP-1-27** Preoperative Transverse Area of Spinal Cord Compression Using Quantitative Magnetic Resonance Imaging in Surgically Treated Cervical Spondylotic Myelopathy: A Descriptive Study **17**
Jon Christian Sanga Manuntag, Lean Angelo Silverio, Ronald Tangente, Romel L. Tan, Ma Ramona Reyes, Wencito Daya

-
- PS-FP-1-28** Impact of Cervical Alignment for Prognosis of Cervical Spondylotic Amyotrophy: Propensity Score Matching Analysis **17**
Masahito Takahashi, Masaaki Tsuji, Kazuhiko Satomi, Takumi Takeuchi, Hideto Sano, Shoichi Ichimura, Naobumi Hosogane
- PS-FP-1-29** Usefulness of the Disabilities of the Arm, Shoulder, and Hand in Evaluating Surgical Outcome of Cervical Spine Disorders **18**
Nao Otomo, Haruki Funao, Kentato Ideura, Kento Yamanouchi, Norihiro Isogai, Yutaka Sasao, Shigeto Ebata, Ken Ishii
- PS-FP-1-30** The Posterolaterally Oriented and Laterally Downward Sloping Facet Joint Is a Risk Factor for Degenerative Cervical Spondylolisthesis and Myelopathy **19**
Hiromi Kumamaru, Takeyuki Saito, Shingo Yoshizaki, Yasuharu Nakashima, Katsumi Harimaya
- PS-FP-1-33** Accuracy of the Adjustable Aiming Device for Caspar Pin Insertion in Anterior Cervical Spine Surgery: Human Cadaveric Study **19**
Torphong Bunmaprasert, Raphi Raphitphan, Nantawit Sugandhavesa, Wongthawat Liawrungrueang
- PS-FP-1-34** The Natural History of Patients with Cervical Radiculopathy Treated Conservatively and Correlating with Clinical and Magnetic Resonance Imaging Features after a Mean Follow-up of 33 Months **20**
Gowtham Ranga Sai Jallipalli, Saumyajit Basu
- PS-FP-1-35** Is Cervical Posterior Fixation Effective for Neck Pain? **20**
Takeo Furuya, Satoshi Maki, Sho Okimatsu, Takaki Inoue, Atsushi Yunde, Masataka Miura, Gundong Kim, Yasuhiro Shiga, Kazuhide Inage, Sumihisa Orita, Yawara Eguchi, Masao Koda, Masashi Yamazaki, Seiji Ohtori
- PS-FP-1-36** Incidence, Prevalence, and Clinical Significance of Modic Changes in Cervical Spine: A Prospective Study **21**
Dilip Chand Raja Soundararajan, Hemanth Kumar Arasavalli, Ajoy Prasad Shetty, Rishi Mugesh Kanna, Rajasekaran Shanmuganathan
- PS-FP-1-37** Efficacy of Ultrasound-Guided Nerve Root Block for Cervical Spondylotic C6 Radiculopathy **22**
Shinichi Ishihara
- PS-FP-2-1** Spinal Column Phenotypes with Lumbar Developmental Spinal Stenosis: Results from 2,387 Magnetic Resonance Imaging **22**
Jason Pui Yin Cheung, Prudence Wing Hang Cheung, Dino Samartzis, Jaro Karppinen, Kenneth Cheung, Marcus Kin Long Lai
- PS-FP-2-2** Increased Population Risk of Radicular Leg Pain in Lumbar Developmental Spinal Stenosis **23**
Jason Pui Yin Cheung, Prudence Wing Hang Cheung, Dino Samartzis, Jaro Karppinen, Kenneth Cheung, Marcus Kin Long Lai
- PS-FP-2-3** Effects of Bone Cement Augmentation for Upper Instrumented Vertebra on Adjacent Segment Degeneration in Lumbar Fusions **23**
Young-Hoon Kim, Sang-Il Kim, Hun-Chul Kim
- PS-FP-2-5** The Problems and Measures of L5 Osteotomy **24**
Takashi Kobayashi, Kazuma Kikuchi, Hayato Kinoshita, Ryota Kimura, Eiji Abe, Hajime Murai, Natsuo Konishi, Takahiro Sato, Yoichi Shimada, Naohisa Miyakoshi
- PS-FP-2-7** Spinal Endoscopic-Full See Technique for the Treatment of Two-Level Lumbar Lateral Recess Stenosis **25**
En Song, Ji Zheng Li, Yan Lin Li, You Qing Huang, Fan Bing Li, Xiao Feng Yuan, Xue Song Chen, En Bin Wang, Xian Guang Yang, Yao Yu Xiang
- PS-FP-2-12** The Role of Gut-Skin-Spine Axis in the Establishment and Evolution of Human Intervertebral Disc Microbiome and Degenerative Disc Disease **25**
Dilip Chand Raja Soundararajan, S. Rajasekaran, Sharon Miracle Nayagam, Tangavel Chitraa, K. S. Sri Vijayanand, Muthurajan Raveendran, Shetty Ajoy Prasad, Kanna Rishi Mugesh

-
- PS-FP-2-13** The Catastrophization Effects of a Magnetic Resonance Imaging Report on the Patient and Surgeon and the Benefits of ‘Clinical Reporting’ **26**
Dilip Chand Raja Soundararajan, S. Rajasekaran, B. T. Pushpa Bhari, Anand Kumar Behera, Shetty Ajoy Prasad, Kanna Rishi Mughesh
- PS-FP-2-14** Sub-Clinical Infection Can Be an Initiator of Inflammation Leading to Degenerative Disc Disease: Evidence from Host Defense Response Mechanisms **26**
Dilip Chand Raja Soundararajan, Sharon Miracle Nayagam, Sri Vijayanand KS, Tangavel Chitraa, Muthurajan Raveendran, Shetty Ajoy Prasaad, Kanna Rishi Mughesh, S Rajasekaran
- PS-FP-2-15** Dynamic Ultrasound Imaging of Lumbar Multifidus for Assessment of Lumbar Spinal Muscles **27**
Yongsoo Choi, Jihoon Park, Sangmin Lee, Seungwoo Shim
- PS-FP-2-16** Examination of Surgical Procedure for Lower Lumbar Osteoporotic Vertebral Body Fractures **27**
Yuji Kasukawa, Naohisa Miyakoshi, Michio Hongo, Yoshinori Ishikawa, Daisuke Kudo, Yoichi Shimada
- PS-FP-2-17** Clinical Relationship between Spinopelvic Alignment and Lumbar Spinal Canal Stenosis in Patients with Rheumatoid Arthritis **28**
Shunsuke Ito, Yoichi Iizuka, Eiji Takasawa, Tokue Mieda, Sho Iiswata, Yusuke Tomomatsu, Kazuhiro Inomata, Hideo Sakane, Koichi Okamura, Hirotaka Chikuda
- PS-FP-2-18** Lumbar Disc Degeneration and Vertebral Fracture at Thoracolumbar Junction Are Risk Factors for Chronic Low Back Pain with Disability: The Wakayama Spine Study **29**
Hiroshi Hashizume, Masatoshi Teraguchi, Hiroyuki Oka, Yuyu Ishimoto, Keiji Nagata, Ryohei Kagotani, Hiroki Iwahashi, Motohiro Okada, Masanari Takami, Shunji Tsutsui, Hiroshi Iwasaki, Akihito Minamide, Yasutsugu Yukawa, Munehito Yoshida, Noriko Yoshimura, Hiroshi Yamada
- PS-FP-2-20** Advanced Glycation End Products Are Associated with the Intensity of Back Pain Symptoms in Patients with Lumbar Spinal Stenosis **29**
Masatoshi Teraguchi, Mamoru Kawakami, Masafumi Nakagawa, Yoshikazu Minetama, Sachika Matsuo, Yoshio Yamamoto, Yoshio Enyo, Yukihiko Nakagawa
- PS-FP-2-21** Patient-Reported Outcome of Lower Extremity Improved after Posterior Decompression and Lumbar Interbody Fusion for Degenerative Lumbar Diseases **30**
Sung-Min Kim, Yong-Chan Kim, Keun-Ho Lee, Ki-Tack Kim, Kee-Yong Ha, Joonghyun Ahn, Qiang Luo, Seungnam Ko, Kyeonguk Min
- PS-FP-2-22** Prevalence and Characteristics of Osteoporotic Vertebral Fracture in Elderly Patients with Sagittal Imbalance **31**
Akito Yabu, Masatoshi Hoshino, Yusuke Hori, Shinji Takahashi, Shoichiro Ohyama, Akinobu Suzuki, Tadao Tsujio, Hidetomi Terai, Sho Dohzono, Ryuichi Sasaoka, Hiromitsu Toyoda, Minoru Kato, Akira Matsumura, Takashi Namikawa, Masahiko Seki, Hiroaki Nakamura
- PS-FP-2-26** Effect of Segmental Lordosis on Early-Onset Adjacent Segment Disease after Posterior Lumbar Interbody Fusion **31**
Shinya Okuda, Yukitaka Nagamoto, Shota Takenaka, Masato Ikuta, Tomiya Matsumoto, Yoshifumi Takahashi, Masayuki Furuya, Motoki Iwasaki
- PS-FP-2-27** Facet Joint Opening on Computed Tomography Is a Predictor for Poor Clinical Outcomes after Less-Invasive Decompression Surgery for Lumbar Spinal Stenosis **32**
Kentaro Yamada, Hiromitsu Toyoda, Shinji Takahashi, Koji Tamai, Akinobu Suzuki, Masatoshi Hoshino, Hidetomi Terai, Hiroaki Nakamura
- PS-FP-2-29** Osseous Union after Posterior Lumbar Interbody Fusion: Pay Attention to Large Interbody Angle **33**
Keichi Nakai, Tomohiko Hasegawa, Yu Yamato, Go Yoshida, Tomohiro Banno, Hideyuki Arima, Shin Oe, Yuki Mihara, Hiroki Ushirozako, Tomohiro Yamada, Koichiro Ide, Yu Watanabe, Kenta Kurosu, Hirotaka Haro, Jun Takahashi, Keijiro Mukaiyama, Yukihiko Matsuyama

-
- PS-FP-2-30** Symptomatic Post-surgical Lumbar Pseudomeningocele Treated by Ultrasound Guided Blood Patch Application: A Case Report **33**
Rohit Akshay Kavishwar, Ajoy Prasad Shetty, S. Rajasekaran
- PS-FP-2-31** Titanium Cages May Be Superior to Polyetheretherketone Cages in Lumbar Interbody Fusion: A Systematic Review and Meta-Analysis of Clinical and Radiological Outcomes **34**
Jun-Hao Tan, Chin Kai Cheong, Dennis Hey
- PS-FP-2-32** Risk Factors for Postoperative Ileus after Oblique Lateral Interbody Fusion: A Multivariate Analysis **35**
Sung Cheol Park, Sam Yeol Chang, GeunWu Gimm, Hyoungmin Kim, Sujung Mok, Bong-Soon Chang, Choon-Ki Lee
- PS-FP-2-36** A Rare Case of Idiopathic Dorsal Spinal Cord Herniation Perforating the Lamina **35**
Kento Yamanouchi, Haruki Funao, Kenshi Daimon, Norihiro Isogai, Yutaka Sasa, Shigeto Ebata, Ken Ishii
- PS-FP-2-37** Discogenic Low Back Pain Can Be Diagnosed with an Ultrasonographic-Guided Disc Pain Induction Test **36**
Keisuke Masuda, Manabu Maeda, Hideki Shigematsu, Akinori Okuda, Sachiko Kawasaki, Yuma Suga, Yusuke Yamamoto, Yasuhito Tanaka
- PS-FP-2-38** Degenerative Lumbar Spondylolisthesis Patients with Movement-Related Low Back Pain Have Less Postoperative Satisfaction after Decompression Alone **36**
Ryosuke Hirota, Mitsunori Yoshimoto, Naohisa Miyakoshi, Yoichi Shimada, Toshihiko Yamashita
- PS-FP-2-39** Extraforaminal Stenosis at L2–L3 Treated with Microendoscopic Surgery: Report of Two Cases **37**
Arihiko Tsukamoto, Mitsunori Yoshimoto, Akimitsu Oyama, Hisashi Obara, Ryunosuke Fukushi, Kouta Kurihara, Ryosuke Hirota, Izaya Ogon, Noriyuki Iesato, Toshihiko Yamashita
- PS-FP-2-40** Giant Thoracic Disc Herniation Surgery **37**
Isao Kitahara
- PS-FP-2-42** Occurrence Rate of Sacroiliac Joint Disorders before and after Lumbar Surgeries and Treatment Strategies **38**
Daisuke Kurosawa, Eiichi Murakami, Hiroshi Ozawa
- PS-FP-2-43** Technical Pitfalls During Sacroiliac Joint Arthrodesis for Patients with Sacral Dysmorphism Induced by Lumbosacral Transitional Vertebrae **39**
Daisuke Kurosawa¹, Eiichi Murakami¹, Hiroshi Ozawa
- PS-FP-2-48** Association between Lumbar Segmental Mobility and Intervertebral Disc Degeneration Quantified by Magnetic Resonance Imaging T2 Mapping **39**
Izaya Ogon, Hiroyuki Takashima, Yoshinori Terashima, Mitsunori Yoshimoto, Tsuneo Takebayashi, Toshihiko Yamashita
- PS-FP-2-49** Diagnostic Performance of Conventional Two-Dimensional Magnetic Resonance Image for L5–S Foraminal Stenosis **40**
Kohei Takahashi, Myo Min Latt, Takumi Tsubakino, Ko Hashimoto, Toshimi Aizawa, Yasuhisa Tanaka
- PS-FP-2-50** The Longitudinal Analysis to Determine Whether the Presence of Current Sexual Activities Among Elderly People Affect Low Back Pain or Not **41**
Shoichiro Ohya, Masatoshi Hoshino, Shinji Takahashi, Hidetomi Terai, Yusuke Hori, Akito Yabu, Tadao Tsujio, Hiroaki Nakamura
- PS-FP-2-51** Unilateral Lumbar Interbody Fusion versus Conventional Posterior Lumbar Interbody Fusion for Two Lumbosacral Segments: Clinical and Radiological Outcomes of 1-Year Follow-up **41**
Seung-Hyun Choi, Sang-Kyu Son, Weon-Wook Park
- PS-FP-2-53** How the Novel Modular Spine Blocks Affect the Adjacent Lumbar Spine on Finite Element Analysis? **42**
Jui-Yang Hsieh, Yi-You Huang, Chen-Sheng Chen, Jyh-Horng Wang, Po-Quang Chen
- PS-FP-2-54** Epidemiology and Burden of Osteoporotic Patients with Spine Fusion Procedures with Pedicle Screws in Japan: A Nationwide Claim Database Analysis **42**
Kotaro Nishida, Anh Bourcet, Mami Ogiri, Hye Jin Park, Kazuko Nishikawa

-
- PS-FP-2-55** Short Segmental Lumbar Surgery Improves Health-Related Quality of Life without Limiting Activities of Daily Living: A Retrospective Study **43**
Ryota Kimura, Naohisa Miyakoshi, Michio Hongo, Yuji Kasukawa, Daisuke Kudo, Yoichi Shimada
- PS-FP-2-56** Coronal Magnetic Resonance Imaging for Diagnosis of Lumbar Foraminal Stenosis: A Comparative Study of Reliability, Reproducibility, and Interpretation between T1 and T2-Weighted Images **44**
Ko Hashimoto, Yasuhisa Tanaka, Toshimi Aizawa, Takumi Tsubakino, Tomowaki Nakagawa, Satoshi Tateda, Kohei Takahashi, Manabu Suzuki, Takahiro Ohnoki, Naoki Morozumi, Yutaka Koizumi, Tetsuro Sato, Hiroshi Ozawa, Haruo Kanno, Shoichi Kokubun, Eiji Itoi
- PS-FP-2-58** Intradiscal Vacuum Phenomenon: Radiological Factors to Predict the Selective Appearance and a New Morphological Classification System **45**
Swapnil Sanjay Hajare, Rishi Kanna, S. Rajasekaran, Ajoy Shetty
- PS-FP-2-60** The Characteristics of Degenerative Disc Disease: Pfirrmann versus Thompson Grading Systems **45**
Kamil Krupa, Dominik Tattera, Przemysław Pękala, Mateusz Paziewski, Wadim Wojciechowski, Tomasz Konopka, Jerzy Walocha, Krzysztof Tomaszewski
- PS-FP-2-61** Efficacy of Caudal Neuroplasty versus Transforaminal Epidural Block for Radiating Pain Caused by Lumbar Foraminal Stenosis **46**
Jihun Park
- PS-FP-2-62** Risk Factors Associated with Low Back Pain in Patients with Osteoporosis **46**
Yusuke Mimura, Masayuki Miyagi, Kosuke Murata, Tomohisa Koyama, Akiyoshi Kuroda, Ayumu Kawakubo, Yuji Yokozeki, Eiki Shirasawa, Wataru Saito, Takayuki Imura, Toshiyuki Nakazawa, Gen Inoue, Masashi Takaso
- PS-FP-2-66** Spinopelvic Parameters and Symptomatic Lumbar Degeneration in Nepalese Patients **47**
Rabindra L. Pradhan, Bimal K. Pandey, Syed Saddam
- PS-FP-2-70** Is Sagittal Spinopelvic Imbalance a Critical Factor for Revision Hip Arthroplasty? **48**
Cheng-Min Hsu, Yu-Cheng Yeh, Yu-Chih Lin, Tsung-Ting Tsai, Yu-Han Chang, Pang-Hsin Hsieh, Po-Liang Lai, Chi-Chien Niu, Hsin-Nung Shih, Lih-Huei Chen, Steve W. N. Ueng, Wen-Jer Chen
- PS-FP-2-72** Prevalence and Clinical Correlation of Lumbosacral Transitional Vertebra: An Ambi-Spective Study Based on 4,027 Whole Spine Magnetic Resonance Imaging **48**
Swapnil Sanjay Hajare, Ajoy Shetty, S. Rajasekaran
- PS-FP-2-73** Efficacy of Analgesic Cocktail on Epidural Patch for Postoperative Pain Control in Posterior Surgery of Degenerative Lumbar Spine: Randomized Control Trial Study **49**
Surawut Ruchirawan, Satawat Jirapan
- PS-FP-2-74** Effect of 3-Months of Romosozumab Treatment on Spinal Surgery: Prospective Study Using Finite Element Analysis **50**
Koji Ishikawa, Soji Tani, Koki Tsuchiya, Chikara Hayamawa, Ryo Yamamura, Akira Matsuoka, Hiroshi Maruyama, Toshiyuki Shirahata, Yoshifumi Kudo, Tomoaki Toyone, Katsunori Inagaki
- PS-FP-3-1** Proposal of New Classification and Treatment Strategy for Transverse Fractures of the C2 Body **50**
Jong-Beom Park, Sung-Kyu Kim
- PS-FP-3-2** An Analysis of 49 Cases with Pedicle Fractures of the c2 Axis: Is Surgery Necessary? **51**
Jong-Beom Park, Sung-Kyu Kim
- PS-FP-3-5** Direct Osteosynthesis in Hangman'S Fracture Risks Vertebral Artery Injury **51**
Tokumitsu Mihara, Shinji Tanishima, Chikako Takeda, Msaki Yoshida, Hideki Nagashima
- PS-FP-3-6** Significance of the Neurological Level of Injury as a Prognostic Predictor for Motor Complete Cervical Spinal Cord Injury Patients **52**
Osamu Kawano, Takeshi Maeda, Hiroaki Sakai, Muneaki Masuda, Yuichiro Morishita, Tetsuo Hayashi, Kensuke Kubota, Kazu Kobayakawa, Kazuya Yokota, Hironari Kaneyama

-
- PS-FP-3-7** Clinical Features and Post-treatment Complications of C2 Odontoid Fractures: A Retrospective Analysis Using a National Inpatient Database in Japan **52**
Akira Honda, Yoichi Iizuka, Nobuaki Michihata, Tokue Mieda, Eiji Takasawa, Sho Ishiwata, Hideo Yasunaga, Hiroataka Chikuda
- PS-FP-3-8** Surgical Strategy as Anterior Submandibular Retropharyngeal Odontoid Osteotomy and Posterior Occipitocervical Fusion with C1 Laminoplasty for Fixed Atlantoaxial Dislocation Associated with Odontoid Fracture Malunion **53**
Kuang-Ting Yeh, Tien-Wu Wu, Chiu-Yu Tzai, Ing-Ho Chen
- PS-FP-3-9** Anterior C2–3 Fusion Surgery Alone for Highly Displaced Hangman's Fracture with Severe Angulation of C2–3 of More Than 30° **53**
Jong-Beom Park, Hyoung-Yeon Seo
- PS-FP-3-10** Is Only Anterior Stabilization Enough in Three Column Injuries of Sub-axial Cervical Spine?: A Long-Term Retrospective Analysis of 78 Patients **54**
Manojkumar Basavareddy Gaddikeri, Sudhir K. Srivastava, Aditya Raj, Sunil Bhosale
- PS-FP-3-11** Efficiency of Long Lateral Mass Screw **55**
Seiya Watanabe, Kazuo Nakanishi
- PS-FP-3-12** Role of Riluzole in Acute Traumatic Cervical Spinal Cord Injury with Incomplete Neurological Deficit: A Prospective, Randomized Control Study **55**
Guna K. Pratheep, Vibhu Krishnan Viswanathan, Rajasekaran Shanmuganathan, Ajoy Prasad Shetty, Rishi Mugesh Kanna
- PS-FP-3-13** Traumatic Cervical Spinal Cord Injury after Cervical Laminoplasty for Ossification of Posterior Longitudinal Ligament **56**
Hironari Kaneyama, Yuichiro Morishita, Osamu Kawano, Takuaki Yamamoto, Takeshi Maeda
- PS-FP-4-5** Mesh-Hold Bone Filling Container Vertebroplasty in the Treatment of Osteoporotic Vertebral Fractures with Posterior Wall Injury: A Study of the Clinical Efficacy and Safety **56**
En Song, Ji Zheng Li, Yan Lin Li, You Qing Huang, Fan Bing Li, Xiao Feng Yuan, Xue Song Chen, En Bin Wang, Xian Guang Yang, Yao Yu Xiang
- PS-FP-4-7** Clinical Safety Study of Photobiomodulation Treatment of Acute Spinal Cord Injury by Scattering Fiber **57**
Zhuowen Liang, Tan Ding, Xueyu Hu, Xiaoshuang Zuo, Zhe Wang
- PS-FP-4-8** A Novel Steerable Percutaneous Balloon Kyphoplasty for Treatment of Thoracolumbar Osteoporotic Vertebral Compression Fractures **58**
En Song, Ji Zheng Li, Fan Bing Li, Xiao Feng Yuan, En Bin Wang, Yao Yu Xiang, Xian Guang Yang
- PS-FP-4-9** Mid-Term Results of Anterior-Posterior Simultaneous Reconstruction for Lower Lumbar Spine Injury in the Elderly **58**
Yu Maeda
- PS-FP-4-10** Comparison of Mini Open Wiltse Approach with Conventional Posterior Approach in Patients with Single Segment Unstable Thoracolumbar Fractures **58**
Muhammad Siddique Hamid, M. Hasnain Abbas, Ali Hassan Butter, Muhammad Hanif Mian, M. Tariq Sohail
- PS-FP-4-12** Comparative Study to Evaluate Surgical Outcomes between Direct Lateral Corpectomy with Percutaneous Pedicle Screws and Posterior Spinal Fusion with Vertebroplasty for Osteoporotic Thoracolumbar Vertebral Fracture **59**
Hiroataka Haro, Tetsuro Ohba, Koji Fujita, Kohtaroh Oda, Nobuki Tanaka
- PS-FP-4-13** Treatment of Unstable Pelvic Ring Fractures (AO Type C) with Minimum Invasive Spino-Pelvic Fixation **60**
Takuya Morita, Takuya Taoka, Tomoyuki Takigawa, Yasuo Ito
- PS-FP-4-14** Surgical Treatment of Post-traumatic Kyphosis in Thoraco-Lumbar Spine: A Retrospective Analysis of Indications and Long-Term Outcome of Surgery **60**
Rohit Akshay Kavishwar, Ajoy Prasad Shetty, S. Rajasekaran

-
- PS-FP-4-15** Preventive Effect on the Vertebral Collapse Progression and Potential in Reducing the Need for Surgery in Conservative Treatment with Initial 2-Week Bed Rest for Osteoporotic Vertebral Fracture **61**
Toru Funayama, Masaki Tatsumura, Kengo Fujii, Shun Okuwaki, Yosuke Shibao, Fumihiko Eto, Katsuya Nagashima, Kousei Miura, Hiroshi Noguchi, Kosuke Sato, Mamoru Kono, Tomoyuki Asada, Hiroshi Takahashi, Masao Koda, Masashi Yamazaki
- PS-FP-4-16** Effect of Teriparatide in Vertebroplasty with Posterior Spinal Fusion for Osteoporotic Thoracolumbar Vertebral Fracture **62**
Yohei Shibuya, Kei Watanabe, Masayuki Ohashi, Hideki Tashi, Tatsuo Makino
- PS-FP-4-17** Comparison of Balloon Kyphoplasty and Conservative Treatment for Osteoporotic Vertebral Fractures in Patients with Dementia **62**
Atsushi Hasegawa, Yoshiaki Kinoshita, Kazumasa Konishi, Takumi Takeuchi, Hideto Sano, Masahito Takahashi, Shoichi Ichimura, Naobumi Hosogane
- PS-FP-4-18** Is Fusion Necessary in AO Type C Injuries of the Thoracolumbar Spine? **63**
Chandhan Murugan, Rishi Kanna, Ajoy Shetty, Rajasekaran Shanmuganathan
- PS-FP-4-19** Alteration of Global and Regional Sagittal Alignment after Correction Surgery for Focal Kyphosis at The Thoracolumbar Junction **63**
Po Hao Huang, Chih Wei Chen, Ming Hsiao Hu, Shu Hua Yang
- PS-FP-4-20** The Osteoporosis-Induced Vertebral Fracture like the Traumatic Burst Fracture (AO-B2) Shows the Prolonged Instability and the Progress Local Kyphosis **64**
Ryutaro Kozuma, Akihisa Yamashita
- PS-FP-5-1** Optimizing the Brace-Weaning Criteria in Adolescent Idiopathic Scoliosis: The Role of Utilizing the New Sanders 7b Staging **65**
Jason Pui Yin Cheung, Prudence Wing Hang Cheung
- PS-FP-5-2** Computed Tomography Analysis of Sacropelvic Parameters in Patients with and without L5 Spondylolysis **65**
Joseph F. Baker
- PS-FP-5-4** Does the Segmental Flexibility Assessed by Fulcrum-bending Radiograph Correlate with Postoperative Each Cobb Angle in Adolescent Idiopathic Scoliosis? **66**
Sachiko Kawasaki, Hideki Shigematsu, Masato Tanaka, Akinori Okuda, Keisuke Masuda, Yuma Suga, Yusuke Yamamoto, Yasuhito Tanaka
- PS-FP-5-6** Postoperative Coronal Imbalance Following Selective Thoracolumbar-Lumbar Fusion in Lenke 5C Adolescent Idiopathic Scoliosis **66**
Akira Matsumura, Takashi Namikawa, Minoru Kato, Yusuke Hori, Masayoshi Iwamae, Ryosuke Yanai, Daichi Takahashi, Hiroaki Nakamura
- PS-FP-5-7** Preliminary Report of Surgical Outcomes of the Relatively Short Fusion (L2-Pelvis Fixation) for the Adult Spinal Deformity Patients **67**
Akira Matsumura, Takashi Namikawa, Minoru Kato, Ryosuke Yanai, Daichi Takahashi, Hiroaki Nakamura
- PS-FP-5-10** Factors Influencing Postoperative Disc Angle in Lenke Type 5C Adolescent Idiopathic Scoliosis **68**
Satoru Demura, Kota Watanabe, Teppei Suzuki, Toshiaki Kotani, Takuya Yamamoto, Koki Uno, Noriaki Kawakami
- PS-FP-5-11** Prevalence and Risk Factors for Subjacent Disc Wedging after Corrective Fusion Surgery in Lenke Type 5C Curve Patients **68**
Tomohiro Banno, Yu Yamato, Hiroki Oba, Tetsuro Ohba, Tomohiko Hasegawa, Go Yoshida, Hideyuki Arima, Shin Oe, Yuki Mihara, Jun Takahashi, Hirotaka Haro, Yukihiro Matsuyama
- PS-FP-5-12** Global Imbalances in the Lower Lumbar Are Risk Factors for Revision Surgeries in Postoperative Adolescent Idiopathic Scoliosis Patients: Clinical Analyses with a Median Follow-up of 17.4 Years **69**
Tsunehiko Konomi, Takashi Asazuma, Shinjiro Kaneko, Yoshihide Yanai, Toshiki Ohkubo, Mitsuru Furukawa, Yoshiyuki Yato

-
- PS-FP-5-13** The Role of Routine Preoperative Echocardiogram in Adolescent Idiopathic Scoliosis Patients Undergoing Deformity Corrective Surgery **69**
Ahmed M. A. Hassan, Siddharth Shah, Mohammed Patel
- PS-FP-5-14** The Role of Preoperative Somatosensory Evoked Potential in Patients Undergoing Adolescent Idiopathic Scoliosis Corrective Surgery **70**
Ahmed M. A. Hassan, Siddharth Shah, Mohammed Patel
- PS-FP-5-15** Computed Tomography Study of the Relationship between Pelvic Incidence and Osseous Contribution to Lumbar Lordosis in Children **70**
Joseph F. Baker
- PS-FP-5-16** Improvement of the Patient Demographics, Radiographic Index and Surgical Invasiveness for Mechanical Failure (PRISM) with Prevention Procedures of Mechanical Failures in Adult Spinal Deformity Surgery **71**
Mitsuru Yagi, Satoshi Suzuki, Eijiro Okada, Satoshi Nori, Osahiko Tsuji, Narihito Nagoshi, Masaya Nakamura, Morio Matsumoto, Kota Watanabe
- PS-FP-5-18** The Effect of Lumbosacral Fusion on Scoliotic Curves in Young Patients with Co-existing Spondylolysis/Spondylolisthesis: A Retrospective Cross-Sectional Study of Clinical, Functional and Radiological Outcomes **71**
Dilip Chand Raja Soundararajan, Ajoy Prasad Shetty, Rishi Mugesh Kanna, Rajasekaran Shanmuganathan
- PS-FP-5-20** Change of Hip and Knee Joint after Surgery for Adult Spinal Deformity and Correlation between Those and Full Body Sagittal Parameters **72**
Joonghyun Ahn, Yong-Chan Kim, Ki-Tack Kim, Kee-Yong Ha, Qiang Luo, Seungnam Ko, Sung-Min Kim, Hyungon Gwak
- PS-FP-5-21** Comparison of 5-Year Surgical Results between Anterior Surgery and Posterior Surgery in Type 5 Adolescent Idiopathic Scoliosis: Stratification with Level of Upper and Lower End Vertebra **73**
Kota Watanabe, Takahiro Iida, Kazuyuki Matsumoto, Hiroki Hayami, Satoru Ozeki, Mitsuru Yagi, Satoshi Suzuki, Masaya Nakamura, Morio Matsumoto
- PS-FP-5-25** Do Different Upper Instrumented Vertebra Anchors Impact the Incidence of Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery? **73**
Ryosuke Yanai, Akira Matsumura, Tkashi Namikawa, Daichi Takahashi, Hiroaki Nakamura
- PS-FP-5-26** Short-Segmental Spinal Fusion for Chronic Low Back Pain with Bone Marrow Edema Adjacent to the Vertebral Endplate **74**
Toshio Nakamae, Naosuke Kamei, Yoshinori Fujimoto, Kiyotaka Yamada, Yuji Tsuchikawa, Taiki Morisako, Takahiro Harada, Toshiaki Maruyama, Nobuo Adachi
- PS-FP-5-28** Evaluation of Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis Lenke Type 5 Using EOS Radiography **75**
Bin Xiao, Kai Yan, Yanbin Zhang, Jile Jiang, Yonggang Xing, Bo Liu, Wei Tian
- PS-FP-5-29** Can Anatomic Reduction with Monosegmental Fusion in High-Grade L5 Spondylolisthesis Restore Global Spinopelvic Alignment? **75**
Hiroshi Moridaira, Satoshi Inami, Daisaku Takeuchi, Haruki Ueda, Hiromichi Aoki, Takuya Iimura, Hiroshi Taneichi
- PS-FP-5-31** Fat Infiltration in Back Muscles and Gluteus Maximus Muscle Is Significantly Related to Deterioration of Spino-Pelvic Sagittal Balance During Gait **76**
Kousei Miura, Tomoyuki Asada, Hideki Kadone, Kosuke Sato, Mamoru Kono, Fumihiko Eto, Yosuke Shibao, Kentaro Mataka, Hiroshi Noguchi, Hiroshi Takahashi, Toru Funayama, Masao Koda, Masashi Yamazaki
- PS-FP-5-32** Single Level Posterior Lumbar Interbody Fusion Can Improve Global Sagittal Alignment in a Patient with Severe Dysplastic Spondylolisthesis **77**
Kazuki Takeda, Eijiro Okada, Satoshi Suzuki, Satoshi Nori, Osahiko Tsuji, Narihito Nagoshi, Mitsuru Yagi, Nobuyuki Fujita, Masaya Nakamura, Morio Matsumoto, Kota Watanabe

-
- PS-FP-5-38** Comparison of Radiographic Outcomes between Traditional Growing Rod and Shilla Graduates by a Single Surgeon **77**
Teppei Suzuki, Koki Uno, Masaaki Ito, Kenichiro Kakutani
- PS-FP-5-42** Surgical Outcome of Spinal Fusion for Osteogenesis Imperfecta with Scoliosis **78**
Masaaki Ito, Koki Uno, Teppei Suzuki
- PS-FP-5-44** Development of a Prediction Model for Postoperative Lumbar Cobb Angle Following Selective Thoracic Fusion in Patients with Adolescent Idiopathic Scoliosis **78**
I-Hsin Chen, Chih-Wei Chen, Ming-Hsiao Hu, Po-Liang Lai, Shu-Hua Yang
- PS-FP-5-45** Does Osteoporosis Affect the Postoperative Course of Adult Spinal Deformity Surgery? **79**
Kenta Kurosu, Go Yoshida, Tomohiko Hasegawa, Yu Yamato, Tomohiro Banno, Hideyuki Arima, Shin Oe, Yuki Mihara, Hiroki Ushirozako, Tomohiro Yamada, Koichiro Ide, Yuh Watanabe, Keiichi Nakai, Yukihiko Matsuyama
- PS-FP-5-47** Predicting the Natural Course of Hemivertebra in Early Childhood: Clinical Significance of Anteroposterior Discordance Based on Three-Dimensional Analysis **80**
Sam Yeol Chang, Hyoungmin Kim, Bong-Soon Chang, Choon-Ki Lee
- PS-FP-5-51** Which Is More Predictive Value for Mechanical Complications: Fixed Thoracolumbar Alignment versus Dynamic Global Balance Parameter **80**
Kwang-Ryeol Kim, Sung-Hyun Noh, Yoon Ha, Kyung-Hyun Kim
- PS-FP-5-52** Mid-Term Health-Related Quality of Life and Its Related Factors Following Adult Spinal Deformity Surgery: A Minimum 5-Year Followup Case Series **81**
Masayoshi Iwamae, Akira Matsumura, Yusuke Hori, Ryosuke Yanai, Takashi Namikawa, Minoru Kato, Hiroaki Nakamura
- PS-FP-5-53** Predicting the Progression of Thoracolumbar Kyphosis in Achondroplasia Patients after Walking Age: Generalized Estimating Equation Analysis **82**
Su Jung Mok, Hyoungmin Kim, Sam Yeol Chang, Sung Cheol Park, Bong-Soon Chang, Tae-Joon Cho, Jung Min Ko
- PS-FP-5-54** Oblique Lumbar Interbody Fusion Combined with Anterior Screws Fixation for Surgical Treatment of Lumbar Degenerative Scoliosis **82**
Yutong Gu
- PS-FP-5-55** Propensity Score-Matched Analysis to Assess the Risk Factor of Postoperative Proximal Junctional Fracture in Adult Spinal Deformity Surgery **83**
Junya Katayanagi, Takahiro Iida, Atsuki Hayamizu, Kazuyuki Matsumoto, Hirokazu Furukawa, Hiroki Konuma, Tsukasa Yanase, Tetsuya Jinno
- PS-FP-5-56** Clinical Outcomes of Extensive Corrective Fusion Surgery from Thoracic Spine to Pelvis for Adult Spinal Deformity at 5 Years Postoperatively **83**
Hideyuki Arima, Tomohiko Hasegawa, Yu Yamato, Go Yoshida, Tomohiro Banno, Shin Oe, Yuki Mihara, Hiroki Ushirozako, Tomohiro Yamada, Koichiro Ide, Yuh Watanabe, Keiichi Nakai, Kenta Kurosu, Yukihiko Matsuyama
- PS-FP-5-59** Upper End Vertebra of Proximal Thoracic Curve at T1 is a Novel Risk Factor of Postoperative Shoulder Imbalance in Type 2 Adolescent Idiopathic Scoliosis **84**
Norihiro Isogai, Mitsuru Yagi, Nao Otomo, Yoshihiro Maeda, Satoshi Suzuki, Satoshi Nori, Osahiko Tsuji, Narihito Nagoshi, Eijiro Okada, Nobuyuki Fujita, Masaya Nakamura, Morio Matsumoto, Kota Watanabe
- PS-FP-5-60** A Novel Intraoperative Spino-Pelvic Parameter “Thoracic 10 Pelvic Angle” Can Predict Proximal Junctional Kyphosis after Adult Spinal Deformity Surgery **85**
Norihiro Isogai, Yutaka Sasao, Kenshi Daimon, Shigeto Ebata, Haruki Funao, Ken Ishii
- PS-FP-5-62** Differences in Natural Walking for Elderlies by the Degree of the Low Back Pain: Gait Analysis with KINECT **85**
Yuh Watanabe, Yu Yamato, Tomohiko Hasegawa, Go Yoshida, Tomohiro Banno, Hideyuki Arima, Yuki Mihara, Shin Oe, Hiroki Ushirozako, Tomohiro Yamada, Koichiro Ide, Keiichi Nakai, Kenta Kurosu, Yuya Takahashi, Haruo Niwa, Hironobu Hoshino, Yukihiko Matsuyama

-
- PS-FP-5-63** Clinical Relationships between Spinopelvic Parameters and Lumbar Disc Degeneration in Different Disc Regions **86**
Kazuhiro Inomata, Yoichi Iizuka, Eiji Takasawa, Tokue Mieda, Sho Ishiwata, Yohei Kakuta, Akira Honda, Yusuke Tomomatsu, Shunsuke Ito, Hiroataka Chikuda
- PS-FP-5-64** Three-Rod Correction Technique for Severe Neuromuscular Scoliosis **87**
Toru Yamaguchi, Haruhisa Yanagida, Kazuyuki Takamura, Tomoyuki Nakamura
- PS-FP-5-66** Influence of Pelvic Obliquity on Postoperative Coronal Radiographic Parameters in Patients with Lenke Type 5 Adolescent Idiopathic Scoliosis at Minimum 5-Year Follow-up **87**
Takahito Iga, Satoshi Suzuki, Satoshi Nori, Osahiko Tsuji, Narihito Nagoshi, Eijiro Okada, Mitsuru Yagi, Masaya Nakamura, Morio Matsumoto, Kota Watanabe
- PS-FP-5-67** Can Bone Improvement after 2-Year Calcium+Vitamin-D Supplementation Be Maintained in Idiopathic Scoliosis after 4-Year of Treatment Discontinuation: A Prospective Randomized Double-Blinded Placebo-Controlled Trial **88**
Tsz Ping Lam, Guangpu Yang, Henry Pang, Wayne Yw Lee, Alec Lik-Hang Hung, Jack Chun-Yiu Cheng
- PS-FP-5-72** The Impact of Growing Rod Surgery for Early Onset Scoliosis on the Cervical Spine Sagittal Alignment **88**
Shuheito Ito, Satoshi Suzuki, Satoshi Nori, Osahiko Tsuji, Narihito Nagoshi, Eijiro Okada, Mitsuru Yagi, Masaya Nakamura, Morio Matsumoto, Kota Watanabe
- PS-FP-5-73** Scoliosis in Osteogenesis Imperfecta: Quality of Life and Surgical Impact **89**
Janus S. H. Wong, Jason P. Y. Cheung, Prudence W. H. Cheung, Ya Peng Zhou, Michael K. T. To
- PS-FP-5-74** Machine Learning for Predicting Mechanical Complication after Adult Spinal Deformity Surgery **90**
Sung Hyun Noh, Yoon Ha, Kyung Hyun Kim
- PS-FP-5-75** Defining Spino-Pelvic Alignment in Adult Population Over 60 Years Old: Prospective Analysis of 214 Volunteers **91**
Sung Hyun Noh, Kyung Hyun Kim, Yoon Ha
- PS-FP-5-76** Which Domain or Factors Of 36-Item Short Form Health Survey Impact on Patient Satisfaction after Adult Spinal Deformity Correction Surgery? **91**
Hyun Jun Jang, Jeong Yoon Park, Dong Kyu Chin, Young Seol Yoon, Keun Su Kim, Yong Eun Cho, Kyung Hyun Kim
- PS-FP-5-80** Preoperative Distraction of Severe Caries Kyphotic Spine Deformities with Modified Halo-Pelvic Distraction Assembly **93**
Amer Aziz, Muhammad Saad Ilyas
- PS-FP-5-82** Which Health-Related Quality of Life Assessment Tool, Patient-Reported Outcomes Measurement Information System, Revised Scoliosis Research Society-22, or Oswestry Disability Index, Is More Sensitive in Assessing Outcomes of Primary versus Revision Adult Spinal Deformity Surgery? **92**
Tsung-Cheng Yin, Munish C. Gupta
- PS-FP-5-83** Experiences of Early Air Travel with Pneumothorax after Anterior Spinal Surgery: A Report of Three Cases **93**
Amy Yoke Foong Wong, Choong Hoon Foo, Nur Aida Binti Faruk Senan, Mohamad Zaki Bin Hj Mohd Amin, Chung Chek Wong
- PS-FP-5-84** Radiological Assessment of Pre- and Postoperative Shoulder Balance Following Posterior Spinal Fusion for Lenke 2 Adolescent Idiopathic Scoliosis **93**
Takashi Namikawa, Akira Matsumura, Minoru Kato, Hiroaki Nakamura
- PS-FP-5-85** Surgical Outcomes in Syndromic Scoliosis with Neurofibromatosis **94**
Tatsuo Kato, Koki Uno, Teppei Suzuki, Masaaki Ito, Kohei Kuroshima
- PS-FP-5-86** Risk Factors for Lateral Translation in Adult Idiopathic Adolescent Scoliosis with thoracolumbar/Lumbar Curves **95**
Toshiaki Kotani, Tsuyoshi Sakuma, Yasushi Iijima, Keita Nakayama, Yasuchika Aoki, Kotaro Sakashita, Takahiro Sunami, Kosuke Sato, Tomoyuki Asada, Tsutomu Akazawa, Kazuhide Inage, Yasuhiro Shiga, Shohei Minami, Seiji Ohtori
- PS-FP-5-87** Predictive Factors for Nighttime Bracing Treatment Outcome in Adolescent Idiopathic Scoliosis **95**
Naoya Taki, Hideaki Watanabe, Ichiro Kikkawa

-
- PS-FP-5-89** Predictors for Total Blood Loss During Posterior Spinal Fusion Surgery for Idiopathic Scoliosis **96**
Eiki Shirasawa, Wataru Saito, Masayuki Miyagi, Yusuke Mimura, Shinsuke Ikeda, Yuji Yokozeki, Akiyoshi Kuroda, Takayuki Imura, Toshiyuki Nakazawa, Gen Inoue, Masashi Takaso
- PS-FP-5-91** Analgesic and Opioid Medication Profile of European Adult Spinal Deformity Patients: Minimum 5 Years Follow-up Study **96**
Caglar Yilgor, Altug Yucekul, Tais Zulemyan, Yasemin Yavuz, Anouar Bourghli, Louis Boissiere, Ibrahim Obeid, Javier Pizones, Frank Kleinstueck, Francisco J. S. Perez-Grueso, Ferran Pellisé, Ahmet Alanay, European Spine Study Group
- PS-FP-5-92** Relationship between Adult Spinal Deformity Surgery and Employment, Sick Leaves, Return to Work and Early Retirement: Minimum 5-Year Follow-up Study **97**
Caglar Yilgor, Altug Yucekul, Tais Zulemyan, Yasemin Yavuz, Javier Pizones, Ibrahim Obeid, Frank Kleinstueck, Francisco J. S. Perez-Grueso, Ferran Pellisé, Ahmet Alanay, European Spine Study Group
- PS-FP-5-93** Complications and Analysis of Risk Factors of Spinal Surgery in Ankylosing Spondylitis: Single Center Case Series of 50 Patients **98**
Kushal Ramesh Gohil, Saumyajit Basu
- PS-FP-5-94** Impact of Endplate Injury during Corrective Surgery Using Oblique Lumbar Interbody Fusion in Adult Spinal Deformity **99**
Gen Inoue, Wataru Saito, Masayuki Miyagi, Takayuki Imura, Eiki Shirasawa, Yusuke Mimura, Akiyoshi Kuroda, Yuji Yokozeki, Toshiyuki Nakazawa, Masashi Takaso
- PS-FP-5-95** Single-Stage Posterior Surgical Treatment for Grade V Spondylolisthesis of L5 in a Patient with Neurofibromatosis Type 1 and Dural Meningocele: A Case Report **99**
Canhua Ye, Chunguang Duan, Hui ren Tao
- PS-FP-5-96** Handgrip Strength Potentially Predicts Curve Progression in Adolescent Idiopathic Scoliosis Girls **100**
Rufina Wing Lum Lau, Ka Yee Cheuk, Vivian Wing Yin Hung, Fiona Wai Ping Yu, Elisa Man Shan Tam, Lyn Lee Ning Wong, Jiajun Zhang, Franco Tsz Fung Cheung, Wing Sze Yu, Wayne Yuk Wai Lee, Jack Chun Yiu Cheng, Tsz Ping Lam
- PS-FP-5-97** Outcome of Posterior Vertebral Column Resection in Neglected Rigid Congenital Scoliosis and Kyphoscoliosis: Our Experience and Review of Literature **101**
Arif Mohammad, Sattar Abdul, Zahid Mohammad, Sameer Kabir, Ihsan Ullah, Asmat Ullah
- PS-FP-5-98** Clinical and Radiological Outcomes in the Patients of Parkinson's Disease Undergoing Instrumented Lumbar Spine Surgery for Spinal Disorders **101**
Ashish Gupta, Saumyajit Basu
- PS-FP-5-99** Evaluating Biomechanics of the Novel Active Apex Correction Technique Using a Patient-Specific Finite Element Approach with 6-Month Follow-up **102**
Daksh Jayaswal, Alaaeldin Ahmad, Aakash Agarwal, Manoj Kodigudla, Amey Kelkar, Vijay Goel
- PS-FP-5-100** Usefulness of Percutaneous Pedicle Screws for Minimizing the Risk of Proximal Junctional Kyphosis after Adult Spinal Deformity Correction Surgery **103**
Tomohisa Harada, Sei Terayama, Yasuo Ohori, Satoshi Makio, Hidenobu Ishibashi, Ryota Takatori, Kenji Takahashi
- PS-FP-5-103** Optimal Position to Insert the Sacral-Alar-Iliac Screw with the Analysis of Computed Tomography View and the Torque of Inserting It **103**
Fumihiko Miyaguchi
- PS-FP-5-106** Is It Really Less Invasive?: Systemic Effects of Anterior-Posterior Lumbar Surgery with Oblique Lateral Interbody Fusion by Nutrition Support Team Perspective **104**
Momo Irie, Muneaki Masuda, Osamu Kawano, Takeshi Maeda

PS-FP-5-108	Distribution of Spinal Sagittal Alignment Based on Hierarchical Clustering Yusuke Hori, Hiromitsu Toyoda, Shinji Takahashi, Masatoshi Hoshino, Shoichiro Ohyama, Hidetomi Terai, Akinobu Suzuki, Tadao Tsujio, Sho Dohzono, Minori Kato, Akira Matsumura, Takashi Namikawa, Kazuhide Inage, Sumihisa Orita, Masayuki Miyagi, Gen Inoue, Seiji Ohtori, Masashi Takaso, Hiroaki Nakamura	104
PS-FP-5-109	The Analysis of Progression of the Pfirmmann's Grade in Distal Unfused Segments in Postoperative Adolescent Idiopathic Scoliosis: A Long-Term Follow-up Magnetic Resonance Imaging Based Study Guna K. Pratheep, Sri Vijay Anand, Rajasekaran Shanmuganathan, Ajoy Prasad Shetty, Rishi Mugesh Kanna	105
PS-FP-5-110	Characteristics of Pedicle Screw Misplacement Using Freehand Technique in Degenerative Scoliosis Surgery Tomohiro Yamada, Tomohiko Hasegawa, Yu Yamato, Go Yoshida, Tomohiro Banno, Hideyuki Arima, Shin Oe, Yuki Mihara, Hiroki Ushirozako, Koichiro Ide, Yuh Watanabe, Keiichi Nakai, Kenta Kurosu, Yukihiro Matsuyama	105
PS-FP-5-113	Increased C7 Tilt Is Associated with Higher Risk of Shoulder Imbalance in Adolescent Idiopathic Scoliosis Patients Receiving Posterior Spinal Fusion Juiyo Hsu, Chih-Wei Chen, Ming-Hsiao Hu, Po-Liang Lai, Shu-Hua Yang	106
PS-FP-6-1	Computed Tomography Based Intraoperative Navigation for Spine Tumors: Perspectives in Surgical Margin Young-Hoon Kim, Sang-Il Kim, Hun-Chul Kim, Hyung-Youl Park	107
PS-FP-6-2	Spinal Extra-Osseous Chordoma Mimicking as Herniated Intervertebral Disc in the Lumbar Spine Kang Kai Lim, Zulkefli Atan, Manoharan Krishnan, Mohamad Azhari Omar, Zulrushdi Md Yusof	107
PS-FP-6-4	Perioperative Complications of Total En Bloc Spondylectomy for Spinal Tumors Satoru Demura, Satoshi Kato, Kazuya Shinmura, Noriaki Yokogawa, Takaki Shimizu, Makoto Handa, Ryohei Annen, Motoya Kobayashi, Yohei Yamada, Hideki Murakami, Norio Kawahara, Hiroyuki Tsuchiya	108
PS-FP-6-6	Long-Term Outcomes of Spinal Meningioma Resection with Outer Layer of Dura Preservation Technique Hirokazu Saiwai, Seiji Okada, Mitsumasa Hayashida, Katsumi Harimaya, Yoshihiro Matsumoto, Ken-ichi Kawaguchi, Akinobu Matsushita, Kei-ichiro Iida, Kazu Kobayakawa, Kazuya Yokota, Takeshi Maeda, Kuniyoshi Tsuchiya, Takeshi Arizono, Taichi Saito, Kazutoshi Nakaie, Yukihide Iwamoto, Yasuharu Nakashima	108
PS-FP-6-7	Prognostic Factors for Short-Term versus Long-Term Readmission-Free Survival after Metastatic Spine Tumor Surgery Naresh Kumar, Andrew Thomas, Liang Shen, Sarah Tang, Sridharan Ramakrishnan, Sirisha Madhu	109
PS-FP-6-8	Clinical Results of Carbon-Ion Radiotherapy with Separation Surgery for Primary Spine/Paraspinal Sarcoma Yoshihiro Matsumoto, Kei-ichiro Iida, Hirokazu Saiwai, Makoto Endo, Toshifumi Fujiwara, Ken-ichi Kawaguchi, Yasuharu Nakashima	110
PS-FP-6-10	The Surgical Strategies for Dumbbell-Shaped Tumors of the Upper Cervical Spine Hao Zhang, Wei Ya Hu	110
PS-FP-6-11	Surgical Outcomes of Spinal Cord Tumor in Elderly Patients Using the Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire Shuheji Ito Narihito Nagoshi, Osahiko Tsuji, Satoshi Nori, Satoshi Suzuki, Eijiro Okada, Mitsuru Yagi, Morio Matsumoto, Masaya Nakamura, Kota Watanabe	111
PS-FP-6-12	A Method for Predicting the Location of Dural Attachment of Spinal Meningioma: Tumor Attachment Angle Kazu Kobayakawa, Takeshi Maeda, Osamu Kawano, Hiroaki Sakai, Muneaki Masuda, Yuichiro Morishita, Tetsuo Hayashi, Kensuke Kubota, Kazuya Yokota, Hironari Kaneyama, Hirokazu Saiwai, Keiichiro Iida, Akinobu Matsushita, Kenichi Kawaguchi, Yoshihiro Matsumoto, Yasuharu Nakashima	111
PS-FP-6-13	Usefulness of Artificial Cerebrospinal Fluid Replacement in Intradural Surgical Procedure Muneaki Masuda, Takeshi Maeda, Osamu Kawano	112
PS-FP-6-14	The Radiographic Characters and Surgical Outcomes of Spinal Meningioma Who Grade 1 Tomohiko Hasegawa, Yu Yamato, Go Yoshida, Sho Kobayashi, Tatsuya Yasuda, Tomohiro Banno, Hideyuki Arima, Shin Oe, Yuki Mihara, Hiroki Ushirozako, Yukihiro Matsuyama	113

PS-FP-6-16	The Utility of Minimal Access and Separation Surgery in the Management of Metastatic Spine Disease Jiong Hao Tan, Andrew Cherian Thomas, Yong Hao Joel Tan, Hwee Weng Dennis Hey, Naresh Kumar	113
PS-FP-6-18	Do aggressive Vertebral Hemangiomas Warrant Aggressive Surgery?: Inferences from a Retrospective Surgical Cohort of 23 Patients Guna K. Pratheep, Sri Vijay Anand, Rajasekaran Shanmuganathan, Ajoy Prasad Shetty, Rishi Mugesh Kanna	114
PS-FP-7-2	Micro-organisms and Outcome of Spinal Infections: A Report of 48 Cases Quang Minh Luong, Duong Van Pham, Hung Dinh Nguyen	115
PS-FP-7-6	A Validated Score for Evaluating Spinal Instability to Assess Surgical Candidacy in Active Spinal Tuberculosis: An Evidence-Based Approach and Multinational Expert Consensus Study Dilip Chand Raja Soundararajan, S. Rajasekaran, Ajoy Prasad Shetty, Rishi Mugesh Kanna	115
PS-FP-7-7	Clinical, Radiological and Microbial Profile of Pyogenic Spondylodiscitis: Single-Center Data Analysis of 48 Patients Dheeraj Manikanta Maddali, Saumyajit Basu	116
PS-FP-7-8	Treatment Results of Percutaneous Posterior Lumbar Pelvic Fusion for Lower Lumbar Purulent/Tuberculous Discitis Yuji Kasukawa, Naohisa Miyakoshi, Michio Hongo, Yoshinori Ishikawa, Daisuke Kudo, Yoichi Shimada	116
PS-FP-7-9	Trends in Infectious Spondylitis from 2000 to 2020 Shinji Tanishima, Tokumitsu Mihara, Chikako Taked, Masaki Yoshida, Hideki Nagashima	117
PS-FP-7-10	Status and Trends of Causative Bacteria of Surgical Site Infection in Spinal Surgery: A Study on 6,411 Cases Takahito Iga, Satoshi Suzuki, Satoshi Nori, Osahiko Tsuji, Narihito Nagoshi, Eijiro Okada, Mitsuru Yagi, Masaya Nakamura, Morio Matsumoto, Kota Watanabe	118
PS-FP-7-11	Gene Xpert/MTB RIF Assay for Spinal Tuberculosis Siddharth Aiyer, Vijay Karthek, Pramod Bhilare, Shailesh Hadgaonkar, Ajay Kothari, Ashok Shyam, Parag Sancheti	118
PS-FP-7-12	Does Forced-Air Warming Increase Surgical Site Infections in Spine Surgery? A Propensity Score-Matched Analysis Kyoichi Handa, Haruo Kanno, Shigetune Matsuya, Kohei Takahashi, Ko Hashimoto, Toshimi Aizawa	119
PS-FP-7-13	“Spine Surgery Checklist” a Step Towards Perfection Through Protocols Jwalant Y. Patel, Arvind G. Kulkarni	119
PS-FP-7-14	Analysis of Clinical Features Regarding Concomitant Spinal and Non-spinal Osteoarticular Infections Ryunosuke Fukushi, Satoshi Kawaguchi, Toshihiko Yamashita	120
PS-FP-7-15	Consecutive Occurrence of Septic Arthritis and Pyogenic Spondylitis in Two Patients Ryunosuke Fukushi, Satoshi Kawaguchi, Toshihiko Yamashita	120
PS-FP-7-16	A Case of Glossopharyngeal and Hypoglossal Nerve Paralysis Secondary to Pyogenic Cervical Facet Joint Arthritis Ryunosuke Fukushi, Izaya Ogon, Toshihiko Yamashita	121
PS-FP-7-17	Clinical Significance of Comprehensive Medicine for the Treatment of Pyogenic Spondylitis in the Elderly Hidekazu Yoshizaki, Tzong-Jing Victor Wang, Manabu Ito	122
PS-FP-7-19	Tuberculous Osteomyelitis of the Ischium: A Case Report and Review of Literature Chandhan Murugan, Ajoy Shetty, Rajasekaran Shanmuganathan	122
PS-FP-7-21	Characterization of Biofilms in Explanted Pedicle Screws Retrieved from Aseptic Pseudarthrosis Cases Daksh Jayaswal, Aakash Agarwal, Megan Mooney, Ashish Agarwal, Arvind Jayaswal, Amey Kelkar, Gayane Saakyan, Vijay Goel, Vithal Shendge, Hossein Elgafy	123

- PS-FP-7-22** How Does the Absence or Presence of Pedicle Screw Guard Effect Bacterial Contamination at the Screw-Bone Interface during Spinal Fusion: A Multicenter Study **123**
Daksh Jayaswal, Aakash Agarwal, Boren Lin, Ashish Agarwal, Amey Kelkar, Gayane Saakyan, Hossein Elgafy, Vijay Goel, Arvind Jayaswal, Christian Schultz, Anand Agarwal
- PS-FP-7-23** Poor Nutritional Status and Chronic Kidney Disease Might Be Risk Factors in Elderly Patients with Pyogenic Spondylitis **124**
Erina Yamada, Toshihiro Imamura, Yukihide Iwamoto
- PS-FP-7-24** Evaluating Reprocessed Pedicle Screws: Characterization of Contaminants and Efficiency of the Process **125**
Daksh Jayaswal, Aakash Agarwal, Amey Kelkar, Ashish Agarwal, Gayane Saakyan, Arvind Jayaswal, Anand Agarwal
- PS-FP-7-26** All-Posterior Approach in Surgical Management of Thoracolumbar Tuberculosis: A Prospective Randomized Study Comparing Posterior-Only Stabilization versus Global Reconstruction **125**
Rohit Akshay Kavishwar, Ajoy Prasad Shetty, S. Rajsekeran
- PS-FP-7-27** Development of Tuberculosis Spine Instability Score (TSIS): An Evidence-Based and Expert Consensus-Based Content Validation Study Among Spine Surgeons **126**
Kaustubh Ahuja, Syed Ifthekar, Samarth Mittal, Gagandeep Yadav, Pankaj Kandwal
- PS-FP-8-1** The Characteristics of the Young Patients with Cervical Ossification of the Posterior Longitudinal Ligament of the Spine: A Multicenter Cross-Sectional Study **126**
Kanji Mori, Toshitaka Yoshii, Takashi Hirai, Jun Hashimoto, Narihito Nagoshi, Kazuhiro Takeuchi, Keiichi Katsumi, Satoshi Maki, Masaya Nakamura, Morio Matsumoto, Atsushi Okawa, Yoshiharu Kawaguchi, JOSL Members
- PS-FP-8-2** Reduction and Fusion of Thoracic Ossification of the Posterior Longitudinal Ligament after Posterior Decompression with Instrumented Fixation by Pedicle Screw Insertion into All Ossified Vertebrae **127**
Osamu Kawano, Takeshi Maeda, Hiroaki Sakai, Muneaki Masuda, Yuichiro Morishita, Tetsuo Hayashi, Kensuke Kubota, Kazu Kobayakawa, Kazuya Yokota, Hironari Kaneyama
- PS-FP-8-3** Does Diabetes Affect the Surgical Outcomes in Cases with Cervical Ossification of the Posterior Longitudinal Ligament? A Multicenter Study from Asia Pacific Spine Study Group **128**
Narihito Nagoshi, Kota Watanabe, Masaya Nakamura, Morio Matsumoto, Nan Li, Sai Ma, Da He, Wei Tian, Hyeonseok Jeon, Jong Joo Lee, Keung Nyun Kim, Yoon Ha, Kenny Kwan, AKP Cheung
- PS-FP-8-5** Comparison of Decompression Alone and Decompression Plus Fusion for Thoracic Myelopathy Due to Ossification of the Ligamentum Flavum **128**
Yuichi Ono, Naohisa Miyakoshi, Yuji Hatakeyama, Yoichi Shimada
- PS-FP-8-7** Factors Having Significant Relationship with Postoperative Neck Pain Deterioration for Cervical Ossification of the Posterior Longitudinal Ligament: Prospective Registry Study **129**
Masao Koda, Toshitaka Yoshii, Satoru Egawa, Kenichiro Sakai, Yukihiko Nakagawa, Kanichiro Wada, Keiichi Katsumi, Atsushi Kimura, Yukitaka Nagamoto, Yasushi Oshima, Masahiko Takahata, Kanji Mori, Takashi Kaito, Sho Kobayashi, Satoshi Kato, Shiro Imagama, Yoshiharu Kawaguchi, Morio Matsumoto, Atsushi Okawa, Masashi Yamazaki
- PS-FP-8-8** Characteristics of Ossification of the Ligamentum Flavum of the Thoracic Spine **130**
Masatoshi Morimoto, Kazuya Kijima, Kiyoshi Yagi, Fumitake Tezuka, Kazuta Yamashita, Koichi Sairyo
- PS-FP-9-3** Posterior Spinal Fusion with Pedicle Screws for Atlantoaxial Instability in Children **130**
Kohei Kuroshima, Koki Uno, Masaaki Ito, Teppei Suzuki
- PS-FP-9-4** Biologic Agents Preserve the C-2 Pedicle in Patients with Rheumatoid Arthritis: A Comparative Imaging Study Using Three-Dimensional Computed Tomography **131**
Takuya Obo, Takashi Fujishiro, Masahiro Mizutani, Toma Yano, Sachio Hayama, Yoshiharu Nakaya, Atsushi Nakano, Masashi Neo

-
- PS-FP-9-5** Non-traumatic Atlantoaxial Rotatory Fixation in an Adult Patient Treated by a Closed Reduction under General Anesthesia in Chronic Phase **131**
Norihiro Isogai, Kenshi Daimon, Yutaka Sasao, Shigeto Ebata, Haruki Funao, Ken Ishii
- PS-FP-10-1** The Ipsilateral Epiphyseal and Central Endplate Hounsfield Units Accurately Predicts Intraoperative Endplate Violation and Delayed Cage Subsidence with Oblique Lateral Interbody Fusion **132**
Jason Pui Yin Cheung, Hao Wu, Teng Zhang, Zhi Shan, Xuyang Zhang, Junhui Liu, Shunwu Fan, Fengdong Zhao
- PS-FP-10-3** A New Full Endoscopy System and Intradiscal Irrigator Combined with a Novel Annular Repair Device for the Treatment of Lumbar Disc Herniation **133**
En Song, Ji Zheng Li, Yan Lin Li, You Qing Huang, Fan Bing Li, Xiao Feng Yuan, Xue Song Chen, En Bin Wang, Xian Guang Yang, Yao Yu Xiang
- PS-FP-10-4** A Novel Annular Repair Technique Combined with Platelet-Rich Plasma Intradiscal Injection: A New Serial Therapeutic Model for the Treatment of Lumbar Disc Herniation **134**
En Song, Ji Zheng Li, Yan Lin Li, En Bin Wang, Fan Bing Li, You Qing Huang, Xiao Feng Yuan, Xue Song Chen, Xian Guang Yang, Yao Yu Xiang
- PS-FP-10-5** Overcorrection of Fractured Vertebrae Increases the Incidence of Adjacent Fractures After Balloon Kyphoplasty: A Retrospective Study **134**
Keiichiro Iida, Hirokazu Saiwai, Akinobu Matsushita, Kenichi Kawaguchi, Yoshihiro Matsumoto, Yasuharu Nakashima
- PS-FP-10-6** Pros and Cons of Full Endoscopic Surgery for Cervical Radiculopathy **135**
Kuniyoshi Tsuchiya
- PS-FP-10-7** Functional Outcomes of Loupe Assisted Discectomy in Patients with Lumbar Disc Herniation **135**
Shehar Yar Abid, Muhammad Tahir Karim, Shahid Ali
- PS-FP-10-8** Indirect Neural Decompression by Transforaminal Lumbar Interbody Fusion Using Minimally Invasive Spine Surgery for Lumbar Degenerative Spondylolisthesis: Comparison with Lateral Lumbar Interbody Fusion **136**
Ichiro Torigoe, Yoshiyasu Arai, Kenichiro Sakai, Masaki Tomori, Kyohei Sakaki, Takuya Oyaizu, Keigo Hirai, Atsushi Okawa
- PS-FP-10-9** Transforaminal Full-Endoscopic Discectomy for the Patients with Down-Migrated Lumbar Disc Herniation under Local Anesthesia **137**
Fumitake Tezuka, Kazuya Kishima, Kiyoshi Yagi, Kosuke Sugiura, Masatoshi Morimoto, Kazuta Yamashita, Koichi Sairyo
- PS-FP-10-10** Transforaminal Full-Endoscopic Ventral Facetectomy: Mid-Term Results and Factors Associated with Fair/Poor Outcome **137**
Kazuya Kishima, Kiyoshi Yagi, Keishi Maruo, Toshiya Tachibana, Masatoshi Morimoto, Fumitake Tezuka, Kazuta Yamashita, Toshinori Sakai, Toru Maeda, Koichi Sairyo
- PS-FP-10-11** Unintentional Facet Fusion without Bone Grafting after Minimally Invasive Lumbar Interbody Fusion: A Retrospective Study of Percutaneous Endoscopic Transforaminal Lumbar Interbody Fusion **138**
Katsuhisa Yamada, Ken Nagahama, Yuichiro Abe, Masahiko Takahata, Norimasa Iwasaki
- PS-FP-10-12** The Advantages of Revisional Transforaminal Full-Endoscopic Spine Surgery for Patients Underwent Posterior Spine Surgery **138**
Kiyoshi Yagi, Kosuke Sugiura, Makoto Takeuchi, Kazuya Kishima, Masatoshi Morimoto, Fumitake Tezuka, Kazuta Yamashita, Yoichiro Takata, Toshinori Sakai, Toru Maeda, Koichi Sairyo
- PS-FP-10-13** Risk Assessment of Abdominal and Retroperitoneal Organ Injuries Performing Transforaminal Full-Endoscopic Spine Surgery **139**
Kiyoshi Yagi, Kosuke Sugiura, Makoto Takeuchi, Kazuya Kishima, Masatoshi Morimoto, Fumitake Tezuka, Kazuta Yamashita, Yoichiro Takata, Toshinori Sakai, Toru Maeda, Koichi Sairyo
- PS-FP-10-14** Is Bipolar Release of Sternocleidomastoid Muscle Necessary for Neglected Congenital Muscular Torticollis? **140**
Haruki Funao, Kenshi Daimon, Kento Yamanouchi, Tomoharu Tanaka, Norihiro Isogai, Yutaka Sasao, Shigeto Ebata, Ken Ishii

-
- PS-FP-10-15** Usefulness and Problems of the Double Endplates Penetrating Screw Technique for Patients with Diffuse Idiopathic Skeletal Hyperostosis **140**
Takumi Takeuchi, Kenichiro Yamagishi, Masaaki Tsuji, Hideto Sano, Masato Takahashi, Shoichi Ichimura, Hitoshi Kouno, Naobumi Hosogane
- PS-FP-10-18** Percutaneous Transforaminal Endoscopic Surgery and Oblique Lateral Interbody Fusion with Self-Lock Cage for Surgical Treatment of L5 Spondylolisthesis **141**
Yutong Gu
- PS-FP-10-20** Full Endoscopic Posterior Cervical Foraminotomy under Lateral Decubitus Position with Local Anesthesia **142**
Do Hyeong Lim, Michael Levitt, Dong Wha Heo, Byeong Cheol Rim
- PS-FP-10-21** Three-Year Clinical Outcomes after Minimally Invasive Sacroiliac Joint Arthrodesis Using Triangular Implants in Japan: A Pilot Study of Five Cases **142**
Daisuke Kurosawa, Eiichi Murakami, Hiroaki Koga, Hiroshi Ozawa
- PS-FP-10-24** Does Prophylactic Use of Topical Gelatin-Thrombin Matrix Sealant Affect Postoperative Drainage Volume and Hematoma Formation after Microendoscopic Spine Surgery?: A Randomized Controlled Trial **143**
Masanari Takami, Hiroshi Hashizume, Yasutsugu Yukawa, Hiroshi Iwasaki, Shunji Tsutsui, Keiji Nagata, Ryo Taiji, Shizumasa Murata, Takuhei Kozaki, Hiroshi Yamada
- PS-FP-10-26** Comparison Between Clinical Outcomes of Simultaneous Parallel Anterior and Posterior Combined Lumbar Spine Surgery Using Intraoperative Three-Dimensional Fluoroscopy-Based Navigation (SPAPS) and Minimally Invasive Posterior/Transforaminal Lumbar Interbody Fusion **144**
Tomohiko Hirose, Hisanori Ikuma
- PS-FP-10-27** Evaluation of Cement Leakage Using Computed Tomography after Balloon Kyphoplasty: Comparison between Patients Underwent within 4 Weeks and Patients Underwent after 4 Weeks **144**
Hiroyuki Yasuda, Sadahiko Konishi, Masaki Terakawa, Hiroaki Nakamura
- PS-FP-10-28** Decompression Procedure Using Unilateral Biportal Endoscopy for Thoracic Myelopathy Caused by Ossification of the Ligamentum Flavum: A Technical Note and Preliminary Clinical Results **145**
Seung-Hyun Choi, Sang-Kyu Son, Weon-Wook Park
- PS-FP-10-29** Treatment Results of Minimally Invasive Lateral Lumbar Disc Herniated Disk in Our Department **145**
Yoshikazu Yanagisawa, Masayoshi Ohga
- PS-FP-10-31** Effectiveness of Foraminoplasty in Transforaminal Full-Endoscopic Discectomy for L5-S1 Disc Herniation Under Local Anesthesia **146**
Takashi Inokuchi, Kazuta Yamashita, Fumitake Tezuka, Masatoshi Morimoto, Kazuya Kishima, Kiyoshi Yagi, Koichi Sairyo
- PS-FP-10-32** Examination of Radiation Exposure in Lateral Lumbar Fusion Surgery Using Intraoperative Computed Tomography Navigation **146**
Satoshi Nomura, Akihiko Hiyama, Kosuke Sako, Masahiro Tanaka, Hiroyuki Kato, Daisuke Sakai, Masato Sato, Masahiko Watanabe
- PS-FP-10-33** The Efficacy of Epiduroscopic Adhesiolysis on Failed Back Surgery Syndrome **147**
Osman Yağız Atlı, Burhan Kurtulus, Hakan Aslan
- PS-FP-10-34** Retrospective Study of Clinical and Radiological Outcomes of Minimally Invasive Transforaminal Lumbar Interbody Fusion for High-Grade Spondylolisthesis: Series of 24 Patients with 2-Year Follow-up **147**
Rajendra Sakhrekar, Vishal Peshattiwar, Mohan Gawande
- PS-FP-11-1** Comparative Study for Navigated Drill and Navigated Probe for Cervical Pedicle Screw Insertion **148**
Tomoyuki Takigawa, Takuya Morita, Yasuo Ito

-
- PS-FP-11-2** Accuracy of Pedicle Screw Placement in Early Onset Scoliosis Using Intraoperative Computed Tomography and Image-Guided Navigation **149**
Takuya Iimura, Hiroshi Moridaira, Satoshi Inami, Daisaku Takeuchi, Haruki Ueda, Hiromichi Aoki, Hiroshi Taneichi
- PS-FP-11-3** C-Arm Free Lumbar Interbody Fusion **149**
Keisuke Nakano, Masaki Mori, Tomohiro Tominaga, Keiji Fujio, Toshimitsu Kawagishi, Toshitada Sawada, Toshihiro Tanaka, Sunao Tanaka, Tohru Asari, Kyouta Ishibashi, Masanori Izeki
- PS-FP-11-4** Robot-Assisted Minimally Invasive Transforaminal Lumbar Interbody Fusion in the Treatment of Lumbar Spondylolisthesis **150**
Guanyu Cui, Xiaoguang Han, Yajun Liu, Da He, Yuqing Sun, Bo Liu, Wei Tian
- PS-FP-11-6** Comparison Between Machine-Vision Image Guided Surgery System and Robotic Guidance System for Pediatric Idiopathic Scoliosis Spine Surgery **151**
Kevin Lim, Alyssa Toh, Nicole Lee
- PS-FP-11-7** Safety of Pin Insertion Position for Iliac Reference Guide in Spinal Navigation **151**
Hiroaki Murakami, Yasushi Fujiwara, Ryo Ota, Shinji Kotaka, Hideki Manabe
- PS-FP-11-8** O Arm Navigation Assisted Minimally Invasive Transforaminal Lumbar Interbody Fusion for Degenerative Lumbar Disease: Study of 83 Patients **152**
Rajendra Sakhrekar, Vishal Peshattiwari, Mohan Gawande
- PS-FP-12-1** Effectiveness of Nitinol in Motion-Preserving Stabilization of Lumbar Spine **152**
Arkadii Kazmin, Sergey Kolesov, Andrey Panteleev, Maxim Sazhnev
- PS-FP-12-2** Is There a Place for Surgical Repair in Adults with Spondylolysis or Grade I Spondylolisthesis?: A Systematic Review and Treatment Algorithm **153**
Naresh Kumar, Sirisha Madhu, Naveen Pandita, Miguel Ramos, Barry Wei Loong Tan, Jonathan Tan, Keith Lopez, Dinesh Shree Kumar, Colum Patrick Nolan
- PS-FP-12-3** A New Surgical Strategy for Type 1 Modic Change Using Transforaminal Full-Endoscopic Disc Cleaning Surgery **154**
Kazuya Kishima, Kiyoshi Yagi, Keishi Maruo, Toshiya Tachibana, Masatoshi Morimoto, Fumitake Tezuka, Kazuta Yamashita, Toshinori Sakai, Toru Maeda, Koichi Sairyu
- PS-FP-12-6** Does Vertebral Body Tethering Cause Disc and Facet Joint Degeneration? A Magnetic Resonance Imaging Study with Minimum 2-Year Follow-up **154**
Caglar Yilgor, Altug Yucekul, Burcu Akpunarli, Atahan Durbas, Tais Zulemian, Irem Havlucu, Gokhan Ergene, Sahin Senay, Pinar Yalinay Dikmen, Sule Turgut Balci, Ercan Karaarslan, Yasemin Yavuz, Ahmet Alanay
- PS-FP-12-7** Is Thoracoscopic Vertebral Body Tethering a Pulmonary Function Declining or Improving Surgery? **155**
Caglar Yilgor, Burcu Akpunarli, Altug Yucekul, Kadir Abul, Peri Kindan, Gokhan Ergene, Sahin Senay, Tais Zulemian, Yasemin Yavuz, Ahmet Alanay
- PS-FP-12-8** Two- to 5-Year Follow-up Results After Thoracoscopic Vertebral Body Tethering: A Single Surgeon's Experience **156**
Caglar Yilgor, Altug Yucekul, Kadir Abul, Ilkay Karaman, Atahan Durbas, Tais Zulemian, Gokhan Ergene, Sahin Senay, Sule Turgut Balci, Pinar Yalinay Dikmen, Yasemin Yavuz, Ahmet Alanay
- PS-FP-12-9** Clinical and Radiographic Outcome at 7 Years of Follow-up after Cervical Total Disc Replacement **157**
Kushal Ramesh Gohil, Saumyajit Basu
- PS-FP-13-1** Fully-Automated Deep Learning Prediction of Spinal Deformity Alignment Irrespective of Image Quality Obtained via Smartphone Photographs **157**
Jason Pui Yin Cheung, Yifei Li, Kenneth Kwan Yee Wong, Teng Zhang

- PS-FP-13-3** Evaluation of the Basal Metabolism of Degenerative Lumbar Intervertebral Discs Based on Pfirmann Grade and Presence of Instability **158**
Chaiyapruk Pundee, Naomi N. Lee, Jacob S. Kramer, Aaron M. Stoker, Christina L. Goldstein, Don K. Moore, Theodore J. Choma, James L. Cook
- PS-FP-13-4** Basal and Cytokine-Stimulated Biomarker Production by Degenerative Lumbar Discs from Microdiscectomy versus Interbody Fusion Patients **159**
Chaiyapruk Pundee, Theodore J. Choma, Jacob S. Kramer, Aaron M. Stoker, Christina L. Goldstein, Don K. Moore, Naomi N. Lee, James L. Cook
- PS-FP-13-5** Ubiquitin Mediated Proteasome Degradation Leading to Glutamic Acid Accumulation Could Be the Cause for Poor Clinical Outcomes in Patients with Modic Changes **160**
Dilip Chand Raja Soundararajan, Sharon Miracle Nayagam, Chitraa Tangavel, Sri Vijayanand K. S., Raveendran Muthurajan, Ajoy Prasad Shetty, Rishi Mugesh Kanna, Rajasekaran Shanmuganathan
- PS-FP-13-6** Histopathological and Cytogenetic Analysis of Lumbar Epidural Lipomatosis **160**
Taketoshi Yasuda, Kayo Suzuki, Shoji Seki, Kenta Watanabe, Hiroto Makino, Takeshi Hori, Masahiko Kanamori, Yoshiharu Kawaguchi
- PS-FP-13-7** Prolonged Use of Narcotics after Spine Surgery: A Requirement or a Privilege **161**
Muhammad Tahir Karim, Shehar Yar Abid, Shahid Ali
- PS-FP-13-8** Posterior Rod Strain in a Long Spinal Fusion to the Pelvis: An In-Vitro Experimental Study Using Synthetic Lumbopelvic Bone Models **162**
Shunji Tsutsui, Ei Yamamoto, Takuhei Kozaki, Akimasa Murata, Hiroshi Yamada
- PS-FP-13-9** The Possible Involvement of the Oxidized LDL/LOX-1 System in Ligamentum Flavum Hypertrophy in the Patients with Lumbar Spinal Canal Stenosis **162**
Sota Nagai, Hiroki Takeda, Daiki Ikeda, Soya Kawabata, Kota Watanabe, Shinjiro Kaneko, Nobuyuki Fujita
- PS-FP-13-12** Laser Resonance Frequency Analysis of Pedicle Screw Stability: A Cadaveric Model Bone Study **163**
Daisuke Nakashima, Katsuhiro Mikami, Shunsuke Kikuchi, Toshiyuki Kitamura, Noboru Hasegawa, Masaharu Nishikino, Morio Matsumoto, Masaya Nakamura, Takeo Nagura
- PS-FP-13-14** Do Academic Pediatric Orthopaedists Who Treat Spine Receive Increased Industry Funding? **164**
Alice Chu, Sean Haimowitz, Michael Fields, Lynn Ann Forrester, Leah Gonzalez, Lauren Seo, Caixia Zhao, Neil Kaushal, Folorunsho Edobor-Osula
- PS-FP-13-15** The Efficacy of C5a Receptor Antagonist for Human iPSC-Derived Neural Stem/Progenitor Cell Transplantation in the Injured Spinal Cord of Mice **164**
Reo Shibata, Narihito Nagoshi, Keita Kajikawa, Yasuhiro Kamata, Shuhei Ito, Mahamad Khazaei, Michael G. Fehlings, Morio Matsumoto, Hideyuki Okano, Masaya Nakamura
- PS-FP-13-16** Cytokine Changes Cultured Cells Harvested from Cervical Spine of Patients with Ossification of the Posterior Longitudinal Ligament **165**
Hideki Saito, Takafumi Yayama, Kanji Mori, Kosuke Kumagai, Masahiro Kitagawa, Shinji Imai
- PS-FP-13-17** Automatic Recognition of Whole Spine Sagittal Alignment and Curvature Analysis through a Deep Learning Technique **166**
Yu-Jui Huang, Yu-Cheng Yeh, Chi-Hung Weng, Chen-Ju Fu, Chao-Yuan Yeh, Tsung-Ting Tsai
- PS-FP-13-19** Prognosis of Iatrogenic Spinal Cord Injury at a Major Rehabilitation Center in United Kingdom **166**
Aashish Babanrao Ghodke, Navin Kumar
- PS-FP-13-23** Accelerated Recovery Protocol Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis Leading to Early Hospital Discharge **167**
Teddy Suratos Fabila, Angela Siok Hoong Yeo, Mini Abraham, Narayani D/O Jayakrishnan, Shin Huey Ng, Kevin Boon Leong Lim

-
- PS-FP-13-24** How Much Experience Is Required to Acquire the Skills for Spinal Surgery? Results of a Survey of Spine Surgeons **168**
Ryunosuke Fukushi, Mitsunori Yoshimoto, Naohisa Miyakoshi, Daisuke Kudo, Yoichi Shimada, Toshihiko Yamashita
- PS-FP-13-25** Novel In Vivo Imaging System of Grafted Human Induced Pluripotent Cells-Derived Neuron Activity after Spinal Cord Injury **169**
Kentaro Ago, Narihito Nagoshi, Morio Matsumoto, Hideyuki Okano, Masaya Nakamura
- PS-FP-13-27** Comparison of the Global Sagittal Alignment and Surgical Outcomes for Osteoporotic Vertebral Body Fracture Between Lower Lumbar and Thoracolumbar Area **169**
Tomoya Matsuo, Koki Uno, Kohei Kawakita, Teppei Suzuki, Masaaki Ito
- PS-FP-13-28** Comparison of the Stability and Osseointegration of Different Intravertebral Fixators **170**
Jui-Yang Hsieh, Yi-You Huang, Jyh-Horng Wang, Po-Quang Chen
- PS-FP-13-29** Do Ovariectomy and Calcium-Restricted Diets Create Osteoporosis in Porcine Model? **170**
Jui-Yang Hsieh, Yi-You Huang, Yao-Horng Wang, Jyh-Horng Wang, Po-Quang Chen
- PS-FP-13-30** Consideration of Cryopreservation Solutions and Methods of Nucleus Pulposus Cells for Industrialization **171**
Kosuke Sako, Daisuke Sakai, Yoshihiko Nakamura, Erika Matsushita, Takayuki Warita, Natsumi Horikita, Masato Sato, Masahiko Watanabe
- PS-FP-13-31** Clinical Efficacy of Ultrasound Guided Bilateral Erector Spinae Block for Single Level Lumbar Fusion Surgery: A Prospective, Randomized, Case-Control Study **172**
Chandhan Murugan, Vipin Goel, Madhan Mohan, Ajoy Shetty, Rajasekaran Shanmuganathan
- PS-FP-13-32** The Effect of Anti-Receptor Activator of Nuclear Factor- κ B Ligand Monoclonal Antibody on Spinal Fusion in a Mouse Spinal Fusion Model **173**
Soji Tani, Koji Ishikawa, Yoshifumi Kudo, Akira Matsuoka, Hiroshi Maruyama, Ryo Yamamura, Chiakara Hayakawa, Koki Tsuchiya, Takashi Nagai, Nobuhiro Sakai, Mayumi Tsuji, Yuji Kiuchi, Tomoaki Toyone, Katsunori Inagaki
- PS-FP-13-34** Efficacy of Human Induced Pluripotent Stem Cell-Derived-Gliogenic NS/PCs for Transplantation in the Chronic Phase of Spinal Cord Injury **173**
Yasuhiro Kamata, Mitsuhiro Inoue, Miho Isoda, Munehisa Shinozaki, Morio Matsumoto, Hideyuki Okano, Masaya Nakamura, Jun Kohyama, Narihito Nagoshi
- PS-FP-13-36** A Retrospective Audit of Effectiveness and Reliability of Telemedicine Consultations in Patients with Spinal Ailments **174**
Rohit Akshay Kavishwar, Ajoy Prasad Shetty, S. Rajasekaran
- PS-FP-14-1** Intradiscal and Epidural Platelet-Rich Plasma Injection for the Treatment of Chronic Discogenic Low Back Pain **175**
En Song, Ji Zheng Li, Yan Lin Li, You Qing Huang, En Bin Wang, Fan Bing Li, Xiao Feng Yuan, Xue Song Chen, Yao Yu Xiang, Xian Guang Yang
- PS-FP-14-2** One-Year Clinical Result of Condoliase for Lumbar Disc Hernia **175**
Atsushi Yoshioka, Kenichiro Tanaka, Yudo Hachiya
- PS-FP-14-3** The Effectiveness of Chemonucleolysis with Condoliase for Treatment of Painful Lumbar Disc Herniation **176**
Eijiro Okada, Satoshi Suzuki, Satoshi Nori, Osahiko Tsuji, Narihito Nagoshi, Mitsuru Yagi, Nobuyuki Fujita, Masaya Nakamura, Morio Matsumoto, Kota Watanabe
- PS-FP-14-4** Transforaminal Full Endoscopic Discectomy and Thermal Annuloplasty for High Signal Intensity Zone Radiculopathy **176**
Kazuta Yamashita, Fumitake Tezuka, Masatoshi Morimoto, Kazuya Kishima, Kiyoshi Yagi, Koichi Sairyo

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PS-BP-1

Significance of Vertebral Body Sliding Osteotomy as a Surgical Strategy for the Treatment of Cervical Ossification of the Posterior Longitudinal Ligament

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Study Design: Retrospective study.

Overview of Literature: Vertebral body sliding osteotomy (VBSO) was previously reported as a technique to decompress ossification of posterior longitudinal ligament (OPLL) by translating the vertebral body anteriorly. However, little is known about its clinical efficacy compared to laminoplasty (LMP) and its significance in surgical strategy for treatment of cervical myelopathy caused by OPLL.

Purpose: Therefore, this study aimed to evaluate the radiological and clinical efficacies of VBSO versus LMP for treating myelopathy caused by OPLL.

Methods: Medical records and radiographic data of 97 patients with symptomatic OPLL-induced cervical myelopathy treated with VBSO or LMP (between 2012 and 2017) with follow-up for more than 2 years were retrospectively reviewed. Results from 40 patients who underwent VBSO (VBSO group) for the treatment of OPLL-induced myelopathy were compared with 57 patients who underwent LMP (LMP group). Graft migration or dislodgement was not observed in the VBSO group. One patient in the VBSO group suffered a dural tear (2.5%, 1/40), and three pseudarthrosis was detected (7.5%, 3/40).

Results: Cervical lordosis significantly increased in the VBSO group postoperatively ($p < 0.01$) but decreased in the LMP group ($p < 0.01$). Cervical lordosis was significantly

higher in the VBSO group at 12 months postoperatively ($p < 0.01$) and at the final follow-up ($p < 0.01$). The minimum interval of the spinal cord increased significantly only in the VBSO group and was significantly greater than that of the LMP group postoperatively ($p < 0.01$). All patients in the VBSO group assessed as mK-line (-) preoperatively were assessed as mK-line (+) postoperatively. Final Japanese Orthopaedic Association (JOA) score (15.1 ± 1.8 vs. 13.8 ± 1.9 , $p = 0.02$) and JOA score improvement (1.7 ± 1.8 vs. 0.9 ± 1.3 , $p = 0.01$) were significantly higher in the VBSO group. Furthermore, JOA recovery ratio (45.1 ± 38.4 vs. 27.4 ± 35.7 , $p = 0.03$) and proportion of patients with a recovery rate $\geq 50\%$ was significantly higher in the VBSO group ($p < 0.01$). An mK-line status change from (-) to (+) was significantly associated with a JOA recovery rate $\geq 50\%$ ($p < 0.01$).

Conclusions: The impacts of VBSO versus LMP included the following: (1) effectively restoring lordosis; (2) inducing mK-line positivity; and (3) facilitating better neurologic recovery. VBSO also demonstrated a low rate of complications. Therefore, VBSO can be included as a surgical strategy for treating OPLL-induced myelopathy that is safe and effective both for sagittal alignment restoration and neurologic recovery.

PS-BP-2

Comparison of the Clinical and Radiographic Results between Cervical Artificial Disc Replacement and Anterior Cervical Fusion: 10-Year Follow-up Study

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Purpose: To compare the long-term clinical and radio-

graphic results of cervical artificial disc replacement (CADR) and anterior cervical discectomy and fusion (ACDF), and to provide our evidence whether CADR could reduce adjacent segment degeneration.

Methods: One hundred and ninety patients with degenerative cervical spondylosis who underwent surgical treatment (Bryan CADR group 110 patients, ACDF group 80 patients) were enrolled during December 2003 to December 2007. The Japanese Orthopaedic Association scores, Neck Disability Index (NDI), and the Odom's score were used to evaluate the clinical efficacy. Cervical radiographs, computed tomography, and magnetic resonance imaging were used to evaluate sagittal curvature, range of motion (ROM), and adjacent segment degeneration.

Results: For final follow-up, the follow-up rate of the CADR group was 80.9%, average age was 46.5 years, average follow-up time was 127 months, 74 (83.1%) were 1-level cases, and 15(16.9%) were bi-level cases. A total of 73.8% of ACDF patients completed the final follow-up with an average age of 52.1 years. The average follow-up time was 124 months. There were 39 patients (66.1%) with 1-level cases and 20 patients (33.9%) with bi-level cases. Compared with preoperative, both groups were satisfied with the clinical efficacy. One-level cases of CADR group NDI scores were significantly better than ACDF group, and reoperation rate was significantly lower than ACDF group. No statistical differences were found in other clinical scores. Both groups have maintained a good sagittal cervical curvature. The mean ROM of index level of CADR group is 8.5°, and ACDF index levels were 100% fused. The ROM of adjacent segments and C2–7 in CADR group was significantly better than that of the ACDF group. Cervical degeneration score (CDS) of the adjacent segments and Miyazaki grade of the intervertebral disc were degenerated postoperatively. The adjacent segment degeneration incidence of one-level cases in CADR group (upper level 31.1%, lower level 28.4%) was significantly lower than ACDF group (upper level 56.4%, lower level 76.9%). The lower-level adjacent segment incidence of CDS and Miyazaki grade in bi-level cases of ACDF group were significantly higher than those in CADR group.

Conclusions: At 10-year follow-up, both Bryan CADR and ACDF patients were obtained excellent clinical outcomes. Compared with ACDF, CADR had maintained a better cervical curvature and ROM, slowing the progress of adjacent segment degeneration, in which one-level cases better than bi-level patients.

PS-BP-3

Deep Learning Pipeline for Automated Detection and Classification of Central Canal, Lateral Recess and Neural Foraminal Stenosis on Lumbar Spine Magnetic Resonance Imaging

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Study Design: Retrospective study.

Overview of Literature: Assessment of lumbar spinal stenosis on magnetic resonance imaging (MRI) is repetitive and time-consuming. Deep learning could improve the productivity and consistency of reporting.

Purpose: To develop a deep learning pipeline (DLP) for automated detection and classification of lumbar central canal, lateral recess, and neural foraminal stenosis.

Methods: Retrospective extraction of MRI lumbar spines was done from September 1, 2015 to September 1, 2018. Five hundred studies were randomly selected with instrumentation or severe scoliosis excluded. Four hundred and forty-six studies were analyzed, encompassing 12,403 axial T2-weighted and 6,161 sagittal T1-weighted images. The training/testing split was 89/11%. Training data were labelled by four board-certified radiologists using pre-defined gradings (normal/mild/moderate/severe). A two-step DLP was developed. First, a convolutional neural network (CNN) was trained to detect the region of interest (ROI), followed by a second CNN for ROI classification. A held-out test set of 50 spines were labelled by a musculoskeletal radiologist with 31-year experience (reference standard), and subspecialist neuro (rad1) and musculoskeletal (rad2) radiologists with 5- and 9-year experience, respectively.

DLP performance on an external dataset of 100 spines was also evaluated. Detection recall (%), inter-rater agreement (Gwet's kappa), and sensitivity/specificity/positive predictive value/negative predictive value (NPV) were calculated. **Results:** DLP ROI detection recall ranged from 99.7%–99.9%, 95.2%–99.3%, and 84.5%–96.2% for central canal, lateral recesses, and neural foramina, respectively, which were comparable with subspecialist radiologists (range, 83.9%–99.9%). On the internal dataset, dichotomous DLP classification (normal/mild versus moderate/severe) showed almost-perfect agreement for rad1, rad2 and the average DLP with kappa of 0.98/0.98/0.96 for central canal, 0.92/0.95/0.92 for lateral recesses, and 0.94/0.95/0.89 for neural foramina, respectively ($p < 0.001$). For external testing, almost-perfect agreement for the average DLP was seen for dichotomous classification of all ROIs (range, 0.95–0.96). The DLP demonstrated high specificity (91.9%–97.9%) and NPV (96.3%–99.7%) for dichotomous classification of all ROIs.

Conclusions: The DLP showed comparable agreement to subspecialist radiologists for detection and classification of central canal and lateral recess stenosis, with slightly reduced agreement for neural foraminal stenosis on lumbar spine MRI.

PS-BP-5

Prediction of Final Outcome after Posterior Correction with Lower Instrumented Vertebra L3 or L4 for the Correction of Structural Thoracolumbar/Lumbar Curve-Minimum 5-Year Follow-up

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Purpose: It is questionable to predict postoperative curve magnitude and balance in standing position while performing intraoperative correction during scoliosis surgery, especially coronal alignment below lower instrumented vertebra (LIV). The purpose of this study was to evaluate the efficacy of intraoperative radiography for the predic-

tion of standing radiography in patients with structural thoracolumbar/lumbar curve (TL/L).

Methods: Patients with idiopathic scoliosis who had undergone the posterior correction and fusion for the structural TL/L curve and followed more than 5 years were recruited. Eighty-three patients were included and the mean age was 16 years 6 months. LIV was L3 in 46 patients and L4 in 35 patients. Preoperative, intraoperative, postoperative, and final follow-up radiographs were used for the evaluation.

Results: At final follow-up, TL/L curve Cobb's angle, disc wedge angle below LIV, and vertebral body tilt below LIV were significantly improved in both groups. In LIV L3 group, however, disc wedge angle below LIV was not improved postoperatively and disc wedge angle at final follow-up was increased compared with postoperative value. In the intraoperative prone radiography, TL/L curve Cobb's angle and vertebral body tilt below LIV were significantly correlated to the postoperative and final follow-up evaluation in both groups, but disc wedge angle below LIV showed a significant correlation only to the value at final follow-up in LIV L3 group ($r = 0.322$, $p = 0.018$).

Conclusions: TL/L Cobb angle and vertebral body tilt below LIV in the intraoperative prone radiography was highly correlated to the standing radiography at postoperation and final follow-up. Disc wedge angle below LIV was not correlated to the postoperative standing radiography. However, the increased final disc wedge angle below LIV may be predicted by prone radiography if the LIV was L3.

PS-BP-6

Better Patient Experience Improves Outcomes in Pediatric Patients with Scoliosis

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Purpose: To investigate if there is a relationship between the experience of patients with adolescent idiopathic scoliosis (AIS) and their outcomes from self-reported questionnaires.

Methods: This study was carried out in a tertiary children's hospital with a one-stop facility for pediatric scoliosis. Between April and August 2020, patients with AIS were ad-

ministered the refined Scoliosis Research Society 22-item (SRS22r) and EuroQol five-dimensional (EQ-5D) questionnaires (patient-reported outcome measures, PROMs) and the National Research Corporation (NRC) outpatient questionnaire for pediatric patients (patient-reported experience measures, PREMs). The SRS22r questionnaire evaluated function, pain, self-image, mental health, and management satisfaction. The EQ-5D contained five questions on function, pain, and mood. The NRC outpatient questionnaire evaluated patient experience and interaction with healthcare staff during outpatient follow-up. Postoperative patients and those awaiting surgery were excluded. Bivariate Pearson correlation was utilized for testing relationships between PREMs and PROMs.

Results: Three hundred completed surveys were analyzed. One hundred and fifty-five patients (51.7%) with an average Cobb angle of 21° were managed by observation, while the remaining 145 (48.3%) with an average Cobb angle of 33° were managed by bracing (per SRS criteria). There were more females in the observation and bracing groups ($p=0.0012$) but no statistical difference in age. Compared with the observation group, the brace group had significantly poorer function (4.5 ± 0.52 vs. 4.3 ± 0.58), self-image (3.6 ± 0.57 vs. 3.4 ± 0.57), and total SRS-22r scores (4.1 ± 0.38 vs. 4.0 ± 0.42) ($p=0.001$ for all). Both groups had similar pain (4.6 ± 0.46 vs. 4.6 ± 0.47 , $p=0.104$), mental health (3.9 ± 0.68 vs. 3.8 ± 0.72 , $p=0.118$), and distribution of EQ-5D values. In the brace group, self-image correlated significantly with how well the care team worked with the patient, whether they interacted with the patient in an age-appropriate manner, if the patient was given a say in her care, and whether her privacy was respected during the clinic visit ($r=0.35$, $p<0.001$). There is correlation between the patient's perception that privacy was ensured by various healthcare staff during the visit and their overall SRS-22r scores ($r=0.32$, $p<0.001$). There was no relationship between PREMs and PROMs in the observation group.

Conclusions: In pediatric patients with AIS on brace treatment, their self-image is influenced by a care team who communicates in an age-appropriate manner, involves her in the management plan, and respects her privacy. In the observation group, there was no demonstrable relationship between PREMs and PROMs. Greater attention and focus to particular aspects of the clinical encounter as outlined above may improve patient-reported outcomes in AIS.

PS-BP-7

Clarifying the Therapeutic Effect of Grafted Human-Induced Pluripotent Stem Cell-Derived Neurons in Spinal Cord Injury by Chemically Controlling Neuronal Activity

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Purpose: The therapeutic effect of human-induced pluripotent stem cell-derived neural stem/progenitor cells (hiPSC-NS/PCs) transplantation to the subacute phase of spinal cord injury (SCI) animals has been previously reported, yet the mechanism of recovery has not been elucidated. Clarifying the therapeutic effect of engrafted cells indicates the necessity of NS/PCs transplantation and could directly link to a further improvement of this therapy. The purpose of the present study was to evaluate the contribution of grafted neuronal function to the recovery of host locomotor activity.

Methods: To determine the functional effect of grafted neuron activity, transplanting NS/PCs were genetically modified by lentiviral vectors. First, NS/PCs coding TRE-GFP-2A-WGA/EF1-rtTA (WGA-NS/PCs), which express a trans-synaptic tracer wheat germ agglutinin (WGA) in control of doxycycline administration, was transplanted to Th10 contusion injury model of mice. Ten weeks after transplantation, the spreading of WGA in the spinal cord section was immunohistologically assessed to evaluate the synaptic formation of the grafted neurons. Second, NS/PCs coding hSyn-hM4Di-mCherry (hM4Di-NS/PCs), which express a chemogenetically-engineered receptor that permits temporal inhibition by synthetic ligand clozapine N-oxide (CNO), and NS/PCs coding hSyn-mCherry (mCherry-NS/PCs), as a control, were transplanted to SCI mice. CNO administration assay, evaluating the change of Basso Mouse Scale (BMS) score and treadmill gait analysis before and after CNO administration, was performed 10 weeks after transplantation.

Results: Immunohistological analysis of WGA-NS/PCs transplanted mice revealed a trans-synaptic migration of WGA to host neurons. WGA migrated not only to the neurons nearby the graft cells but also to the motor neurons in the caudal site; suggesting the integration of graft

neurons to the host motor circuits. By CNO administration assay of hM4Di-NS/PCs and mCherry-NS/PCs transplanted mice, BMS score (pre-CNO=3.3, post-CNO=3.1; $p=0.021$) and parameters of treadmill gait analysis (stride length: pre-CNO=4.0 cm, post-CNO=3.5 cm; $p=0.003$; paw angle: pre-CNO=22.7°, post-CNO=31.0°; $p=0.027$) has significantly deteriorated in hM4Di-NS/PCs transplanted mice. These results suggest that inhibiting the neuronal function of grafted neurons guide to a relapse of functional disorder by SCI.

Conclusions: Grafted neurons derived from hiPSC-NS/PCs transplanted to SCI animals integrate to host neural circuit and contribute to the functional recovery of host animals.

PS-BP-8

Long-Term Selective Stimulation of Transplanted Neural Stem/Progenitor Cells for Spinal Cord Injury Improves Locomotor Function Mediated by Increased Synaptic Transmission

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Purpose: It has been reported that transplantation of human-induced pluripotent stem cell-derived neural stem/progenitor cells (hiPSC-NS/PCs) is effective for functional recovery after spinal cord injury (SCI) and that the efficacy of hiPSC-NS/PCs transplantation is highly dependent on the host spinal cord environment. Meanwhile, the damaged spinal cord tissue is known to be modified by interventions for neural circuits, such as rehabilitations and electrical stimulations. We hypothesized that selective stimulation of transplanted hiPSC-NS/PCs after

SCI can enhance motor function recovery by intensifying interaction between the transplanted hiPSC-NS/PCs and the damaged tissue, and improving the host environment. Therefore, the present study aims to investigate the effect of long-term repetitive and selective stimulation of transplanted hiPSC-NS/PCs on the surrounding damaged spinal cord tissue.

Methods: For selective stimulation of transplanted cells, we used hM3Dq, which is one of the Designer Receptors Exclusively Activated by Designer Drugs. First, hM3Dq was lentivirally transfected to hiPSC-NS/PCs. These hM3Dq-hiPSC-NS/PC-induced neural cells (hM3Dq-neural-cells) were treated with clozapine N-oxide (CNO), and the intracellular response was investigated by RNA sequence and Fluo-8 intracellular calcium indicator. Second, the extracellular response from CNO administered hM3Dq-neural-cells to neighboring neurons was recorded utilizing GCaMP calcium indicator. Next, contusive SCI was induced in NOD-SCID mice, and the hM3Dq-hiPSC-NS/PCs were transplanted into the lesion epicenter 9-day after SCI. After transplantation, CNO was intraperitoneally injected every day for the transplantation-CNO group and phosphate-buffered saline was intraperitoneally injected for the control group. mRNA sequence, protein quantification by capillary electrophoresis, and histological analyses were performed on days 14 and 42 after SCI. Motor function was assessed by the Basso Mouse Scale (BMS) score, Rota-rod test, DigiGait analysis, and kinematics.

Results: RNA sequence revealed that CNO-administered hM3Dq-neural-cells expressed activity-related genes. Besides, CNO-administered hM3Dq-neural-cells enhanced their intracellular calcium concentration and activated neighboring GCaMP-positive neurons in vitro. Expressions of synapse-related genes and proteins were enhanced on day 14 after SCI in the transplantation-CNO group. On day 42, axial spinal cord areas of the transplantation-CNO group were larger. Graft-to-host synapse formation was detected in immunoelectron microscopic examination. Consequently, motor functions significantly improved in the transplantation-CNO group, which was assessed by the BMS score, Rotarod test, DigiGait analysis, and kinematics.

Conclusions: Long-term repetitive and selective stimulation of transplanted hiPSC-NS/PCs enhanced synaptic transmission, increased synapse-related gene and protein expressions, preserved host spinal cord tissue, and improved motor functions. Selective stimulation after cell transplantation can be an effective adjuvant therapy for SCI.

PS-BP-9

Novel Biomarkers of Health and Degeneration in Human Intervertebral Discs: In-Depth Proteomic Analysis of Collagen Framework of Fetal, Healthy, Scoliotic, Degenerate and Herniated Discs

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Purpose: Alterations in the collagen (COL) composition have been co-related to degenerative disc disease. Though 28 different types of COLs are present in humans, most of the literature is focused only on COL-1 and COL-2. The current study aimed to analyze the entire COL composition of human intervertebral disc (IVD) across fetal (developmental phenotype), normal (healthy phenotype), scoliotic (early degeneration), herniated (degenerate phenotype), and degenerated (degenerate phenotype) IVDs using high-end proteomic technology.

Methods: Nucleus pulposus (NP) tissues were segregated from IVDs harvested from five different disc phenotypes. The fetal spine procured from specimens following medical termination of pregnancy underwent microscopic dissection for harvesting NP under sterile conditions. Excised NP tissues were washed with phosphate buffer solution and snap-frozen in liquid nitrogen (LN₂, -196°C) immediately before subjecting to proteomic analysis.

Results: Tandem mass spectrometric analysis revealed a total of 1,050 proteins in fetal discs (FD); 1,809 in ND; 1,487 in segment degeneration (SD); 1,859 in disc herniation (DH); and 1,538 in disc degeneration (DD) group. Since the COLs are the principal constituent of the extracellular matrix, they were screened selectively. Out of 28 major types of COLs reported in the human body, this study identified 24 different types of COL with 34 sub-types in NP of the study samples. FD expressed 14 different major types of COL, compared to 10 (ND), 11 (SD), 15 (DH), and 19 in DD groups. COLs types 1, 2, 6, 11, and 14 were found in all the groups along with their sub-types. COL type 22 was found only in FD group whereas type 15, 25, 26, and 27 were found only in DD group. Amongst

the fibril forming COLs, the abundance of COL-1 and 11 were highest amongst FD representing their role in development of NP. In addition, COL-24 was highly abundant in normal discs indicating their role in homeostasis. Of notable importance was the higher expression of COL-7 (anchoring-fibril forming), COL-10 (network forming), and Col-15 (Multiplexin) in normal discs.

Conclusions: The selective proteomic analysis of COL composition in this study has revealed novel molecular targets for further exploration on its regenerative potential. Apart from COL-1 and COL-2, other important COLs (6,7,10, and 15) required for homeostasis were identified. More importantly, COLs abundantly expressed in fetal phenotype (COL-1, 6, 9, 12, and 14) could be explored for regenerative potential.

PS-FP-1-2

Fusion and Subsidence Rates of Vertebral Body Sliding Osteotomy: Comparison of Three Reconstructive Techniques for Multilevel Cervical Myelopathy

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Purpose: Vertebral body sliding osteotomy (VBSO) was previously reported as a technique to decompress spinal canal by translating the vertebral body anteriorly and is indicated for cervical myelopathy caused by spondylosis or ossification of the posterior longitudinal ligament. However, little is known about its fusion and subsidence rates. The study was conducted to compare the fusion and subsidence rates of VBSO, anterior cervical discectomy and fusion (ACDF), and anterior cervical corpectomy and fusion (ACCF).

Methods: One hundred and sixty-eight patients who underwent VBSO, ACDF, or ACCF for the treatment of cervical myelopathy and were followed-up for more than 2 years were retrospectively reviewed. Fusion and subsidence rates, Visual Analog Scale (VAS) scores for neck pain, Neck Disability Index (NDI), and Japanese Orthopaedic Association (JOA) scores were assessed. Results of the VBSO, ACDF, and ACCF groups were compared.

Results: The fusion rate at 1-year postoperatively and the

final follow-up for VBSO was 92.9% (37/42). VBSO demonstrated a higher 1-year fusion rate than ACDF (77.9% [74/95], $p=0.04$) and ACCF (74.2% [23/31], $p=0.04$). The mean amount of subsidence (ACDF group, 1.5 ± 1.2 mm; VBSO group, 1.5 ± 1.5 mm; $p=1.00$) and rate of significant subsidence of >3 mm (ACDF group, 13.7% [13/95]; VBSO group, 14.3% [6/42]; $p=1.00$) were similar for ACDF and VBSO. Furthermore, the mean amount of subsidence in VBSO was significantly less than that in ACCF (1.5 ± 1.5 mm vs. 2.4 ± 2.0 mm, $p=0.04$). Neck pain VAS, NDI, and JOA scores were not significantly different among the groups.

Conclusions: VBSO demonstrated a higher solid fusion rate at 1-year follow-up than ACDF and ACCF and less subsidence than ACCF. VBSO could be applied safely when the shape/location of the pathologic foci and sagittal alignment favor its application without much concern for pseudarthrosis or subsidence.

PS-FP-1-5

What is the Risk of Cervical Deformity after Posterior Cervical Decompression Surgery?: A Multicenter Study

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noplasty) for cervical spondylotic myelopathy (CSM) and ossification of the posterior longitudinal ligament (OPLL) has been a common surgery; however, it can cause iatrogenic kyphosis and cervical deformity (CD). The purpose of this study was to investigate the risk factors for CD after posterior cervical decompression surgery.

Methods: The participants were 193 patients who underwent cervical posterior laminoplasty or laminectomy at our hospital or satellite hospital for CSM or OPLL between 2010 and 2019. CD was defined as a C2–7 sagittal vertical axis (SVA) ≥ 40 mm or a cervical lordosis angle (CL) $\leq -10^\circ$ on a standing radiograph. The participants were divided into two groups: no cervical deformity (NCD; patients without CD before surgery) and CD (patients with CD before surgery). NCD group was divided based on the presence of CD as follows: iatrogenic CD (ICD) and no ICD (NICD).

Results: There were 153 patients in the NCD group, 40 in the CD group, 126 patients in NICD, and 27 in the ICD group. CD was still found in 34 patients (85%) in the CD group 1 year after surgery. The revision rate was significantly higher in CD group (5%) compared to NCD group ($p=0.042$). There was significant difference in the number of decompressed lamina (NICD:ICD=4.1:4.5), the presence of C2 decompression (2, 11%), and C5 palsy (0, 11%). The risk factors for CD, ICD, and CL $\leq -10^\circ$ 1 year after surgery as assessed by multiple logistic regression analysis were preoperative C2–7 SVA ≥ 30 mm (odds ratio [OR], 19.0; 95% confidence interval [CI], 8.5–42.4), decompression of C2 or C7 lamina (OR, 3.1; 95% CI, 1.2–8.0), and preoperative CL $\leq 2^\circ$ (OR, 42.0; 95% CI, 8.3–211.0), respectively.

Conclusions: To prevent postoperative CD, it is important to avoid decompression of the C2 or C7 lamina as much as possible. Moreover, in cases with CD, C2–7 SVA ≥ 30 mm or CL $\leq 2^\circ$ before surgery, it is important to explain the risks and consider to add fusion surgery.

Purpose: Posterior decompression surgery (such as lami-

PS-FP-1-6

The Effect of Using Lamina Spacer on Postoperative Cervical Alignment and Range of Motion in Double-Door Laminoplasty

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Purpose: The purpose of this study is to examine the effects of the use of lamina spacers on postoperative cervical spine alignment and range of motion in double-door laminoplasty.

Methods: One hundred thirty-five consecutive patients with cervical spondylotic myelopathy (91 males and 44 females; mean age, 69.7 years) who underwent double-door laminoplasty were enrolled. Sixty-seven patients were used the lamina spacer (Kurokawa's method) (S group), and 68 patients were not used the lamina spacer (Kirita-Miyazaki's method) (N group). The follow-up period was 12 months. All patients were allowed to sit up and walk on the second postoperative day using an orthosis, which was removed within the first 10 days. Cervical range of motion (ROM) exercises were performed as a part of the rehabilitation schedule. Radiography was performed before surgery and 12 months after the operation. Cervical alignment in the neutral and flexion-extension view were measured by the Cobb method at C2–C7. The ROM was assessed by measuring the difference in alignment between flexion and extension. In addition, Japanese Orthopaedic Association (JOA) score before and 12 months after surgery and improvement rate of JOA score were examined for clinical evaluation.

Results: There were no significant differences between the two groups in age, sex, and number of operated lamina at the time of surgery. The mean C2–C7 alignment in the neutral position was 15.8° lordotic in the S group and 12.3° lordotic in the N group preoperatively, and was 11.1° lordotic in the S group and 7.4° lordotic in the NS group at 12 months after the operation. There was no significant difference between preoperative and postoperative C2–C7 alignment between the two groups. The mean ROM decreased from a preoperative value of 38.9° to 28.3° at 12 months after the operation in the S group, and 38.3° to 33.4° in the N group. A significant decrease was observed

in the S group. The JOA score improved from 9.21 before surgery to 13.2 after surgery in the S group, and from 9.7 to 13.4 in the N group. There was no difference between the two groups.

Conclusions: In double-door laminoplasty, the use of lamina spacers did not differ in postoperative cervical sagittal alignment and clinical outcome. However, it was suggested that the use of the lamina spacer reduces the postoperative cervical ROM.

PS-FP-1-7

K-line (–) in the Neck-Flexed Position Negatively Affects Surgical Outcome of Expansive Open-Door Laminoplasty for Cervical Spondylotic Myelopathy

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Purpose: The K-line in the neck-flexed position (FK-line) on radiography reflects dynamic factors and cervical alignment. Although the FK-line has been reported to affect the neurological recovery after muscle-preserving selective laminectomy for cervical spondylotic myelopathy (CSM), its influence on surgical outcomes after expansive open-door laminoplasty (ELAP) has not been investigated. The current study aimed to investigate the association between the FK-line and the radiological and surgical outcomes after ELAP. The influence of the FK-line on the surgical outcomes after ELAP was analyzed with a multivariate analysis.

Methods: We reviewed the surgical outcomes in 81 patients with multilevel CSM who underwent C4–C6 ELAP combined with C3 and C7 partial laminectomy using a laminoplasty plate and were followed up for at least 2 years. We defined the FK-line (–) as some portion of a bony spur or the vertebral body crossing the FK-line, whereas the FK-line (+) was defined as that never crossing the FK-line. Patients were divided into the FK-line (+) (n=61) and FK-line (–) groups (n=20), and the surgical outcomes were compared between the group. A multivariate analysis was performed to identify the factors that

influenced the neurological outcomes.

Results: The FK-line (-) group had a smaller C2–C7 angle (preoperatively, $p=0.001$; postoperatively, $p<0.001$), smaller C7 slope (preoperatively, $p<0.001$; postoperatively, $p=0.001$) greater postoperative increase in the C2–C7 sagittal vertical axis ($p=0.001$), greater kyphosis in cervical flexion (preoperatively, $p<0.001$; postoperatively, $p<0.001$) and less lordosis in cervical extension (preoperatively, $p=0.004$; postoperatively, $p=0.005$), and higher incidence of postoperative residual spinal cord compression ($p=0.017$). The preoperative to postoperative changes in the Japanese Orthopedic Association (JOA) score (1.1 ± 0.7 vs. 2.5 ± 1.7 , $p<0.001$) and JOA score recovery rate (RR) (24.9 ± 14.3 vs. 52.3 ± 27.5 , $p<0.001$) were lower in the FK-line (-) group. The multiple linear regression analysis revealed that the FK-line (-) ($\beta=-0.327$, $p=0.011$) and high signal intensity (SI) changes on T2-weighted imaging (WI) combined with the low SI changes on T1–WI in the spinal cord ($\beta=-0.320$, $p=0.013$) negatively affected the JOA score RR.

Conclusions: The FK-line (-) negatively affected the surgical outcomes after ELAP in the patients with CSM. The FK-line can be used for patients with CSM as a useful indicator of surgical outcomes after ELAP.

PS-FP-1-8

Preoperative Severity of Spinal Cord Compression and Its Restoration during the Early Postoperative Period Affect the Development of C5 Palsy

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Purpose: C5 palsy (C5P) is a known complication of cervical decompression surgery. The tethering effect of the C5 nerve root following the posterior shift of the spinal cord is the most accepted pathologic mechanism; however, this mechanism cannot fully explain C5P by itself in clinical practice. Separately, some studies have suggested that preoperative severe spinal cord compression and postoperative morphological changes in the spinal cord affect C5P development; however, no previous study has

quantitatively addressed these possibilities. The aim of this study was to examine whether spinal cord morphology and morphological restoration after surgery affect C5P development.

Methods: We reviewed consecutive patients with degenerative cervical myelopathy who underwent laminoplasty including the C3/C4 and C4/C5 intervertebral disc levels. All participants underwent magnetic resonance imaging both preoperatively and within 4 weeks postoperatively. To assess the severity of spinal cord compression, the compression ratio (CR, spinal cord sagittal diameter/transverse diameter) was calculated. As an index of morphological changes in the spinal cord during the early postoperative period, the change rate of CR (CrCR, %) was calculated as CR within 4 weeks postoperatively/CRpreoperatively $\times 100$. These measurements were performed at both the C3/C4 and C4/C5 intervertebral disc levels. The study cohort was divided into C5P and non-C5P (NC5P) groups; then, CR and CrCR, in addition to other radiographic variables associated with C5P development, were compared between the groups.

Results: A total of 114 patients (mean age, 67.6 years; 58.8% men) were included in the study, with five and 109 patients in the C5P and NC5P groups, respectively. Preoperative CR at both the C3/C4 and C4/C5 levels was significantly smaller in the C5P group than in the NC5P group (0.35 vs. 0.44, $p=0.042$; 0.27 vs. 0.39, $p=0.021$). Patients with C5P exhibited significantly greater CrCR at the C3/C4 level than those without (139.3% vs. 119.0%, $p=0.046$), but the same finding was not noted for CrCR at the C4/C5 level. There were no significant differences in other variables between the groups.

Conclusions: This study reveals that severe compression of the spinal cord and its greater morphological restoration during the early postoperative period affect C5P development. These findings could support the involvement of segmental cord disorder theory, characterized as the reperfusion phenomenon, in the pathomechanism of C5P, besides the tethering effect.

PS-FP-1-9

A Multicentre, Prospective, Randomized Controlled Trial Comparing Efficacy and Safety of ProDisc-C to Anterior Cervical Discectomy and Fusion for Treatment of Symptomatic Cervical Disc Disease

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Purpose: The aim was to compare safety and efficacy of ProDisc-C, a cervical total disc replacement (TDR) device to anterior cervical discectomy and fusion (ACDF) in treating single-level symptomatic cervical disc disease (SCDD) in Asians. We hypothesized ProDisc-C to be non-inferior to ACDF with lower incidence of adjacent segment disease (ASD).

Methods: This multicenter, prospective, randomized controlled trial was initiated in January 2008, after obtaining ethical approval at nine centers (in China/Hong Kong/Korea/Singapore/Taiwan). Patients with single-level SCDD involving C3–C7-vertebral segments were enrolled and randomized in 2:1 ratio into: group A treated with ProDisc-C and group B with ACDF. A protocol modification (January 2010) allowed patients with cervical myelopathy also to be included. Assessments were conducted at baseline, 6 weeks, 3/6/12/18/24 months post-surgery and annually thereafter out to 84 months. The primary endpoint was an overall success, the composite of (1) improvement in Neck Disability Index (NDI) by 20% from baseline; (2) maintained/improved neurologic parameters; (3) no implant removal/revision/re-operation/additional fixation at index-level; and (4) no adverse events related to implant/surgery and no severe/life-threatening events. Secondary endpoints included: (1) incidence of ASD at 24 months; (2) individual endpoints of primary outcome; (3) outcomes of short-form survey (SF-36), Visual Analog Scale (VAS) score (neck/arm-pain intensity/frequency; patient satisfaction); and (4) radiological parameters (range of motion, ROM).

Results: Of the 120 enrolled/treated patients (80 ProDisc-C, 40 ACDF), 76 with ProDisc-C and 37 with ACDF were treated as per protocol (PP). Overall success (PP, last

observation carried forward [LOCF]) was 79% in group A and 83.8% in group B at 24 months ($p=0.10$). ProDisc-C demonstrated non-inferiority to ACDF at 18 months (81.6% vs. 83.8%, $p=0.0398$) with borderline non-inferiority at 3 months (76.3% vs. 78.4%, $p=0.054$). In intent-to-treat-LOCF analysis, overall success at 24 months was 78.2% with ProDisc-C and 81.6% with ACDF ($p=0.06$). ProDisc-C demonstrated non-inferiority to ACDF at both 3 months (75.6% vs. 76.3%, $p=0.0396$) and 18 months (80.8% vs. 81.6%, $p=0.0284$). Secondary outcomes improved after 24 months for both groups with no significant differences between groups for percentage change from baseline. Occurrence of ASD was higher in ACDF versus ProDisc-C, with no statistical significance. The ROM was sustained with ProDisc-C at 24 months when compared to preoperative ROM. Whilst, loss of ROM was noted in group B.

Conclusions: Cervical TDR with ProDisc-C is feasible, safe, and effective for treatment of SCDD in Asians. ProDisc-C was non-inferior to ACDF at 3 and 18 months after index-surgery with no clear non-inferiority at 24 months. Patients treated with ProDisc-C demonstrated significant improvement in terms of NDI, neurologic success, VAS-pain scores, and SF-36, along with preservation of ROM at 24 months post-surgery. Incidence of ASD was comparable between the two groups at 24 months.

PS-FP-1-13

Gap between Flexion and Extension Range of Motions: A Novel Indicator to Predict the Loss of Cervical Lordosis after Laminoplasty for Cervical Spondylotic Myelopathy

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Purpose: Kyphotic deformity resulting from loss of cervical lordosis is a rare but serious complication after cervical laminoplasty (CLP), and it is essential to recognize the risk factors. Previous studies have demonstrated that greater flexion range of motion (fROM) and smaller ex-

tension ROM (eROM) in the cervical spine are associated with the loss of cervical lordosis after CLP. Considering these facts together, it can be hypothesized that an indicator representing the gap between fROM and eROM (gROM) is a highly useful in predicting postoperative cervical lordosis loss. The present study aimed to investigate the risk factors of marked cervical lordosis loss after CLP for cervical spondylotic myelopathy (CSM), including gROM as a potential predictor.

Methods: Patients who underwent CLP for CSM were divided into patients with and without loss of more than 10° of sagittal Cobb angle between C2 and C7 at the final follow-up period compared to the preoperative measurements (cervical lordosis loss [CLL] group and no CLL [NCLL] group, respectively). Demographic characteristics, surgical information, preoperative radiographic measurements, and posterior paraspinal muscle morphology evaluated by magnetic resonance imaging were compared between the two groups. The fROM and eROM were examined on the neutral and flexion-extension views of lateral radiography; gROM was calculated using the following formula: $gROM (^{\circ}) = fROM - eROM$. The performance of variables in discriminating between the CLL and NCLL groups was assessed using the receiver operator characteristic (ROC) curve.

Results: This study included 111 patients (mean age, 68.3 years; 61.3% male), with 10 and 101 patients in the CLL and NCLL groups, respectively. Univariate analyses showed that fROM and gROM were significantly greater in the CLL group than in the NCLL group (40.2° vs. 26.6°, $p < 0.001$; 31.6° vs. 14.3°, $p < 0.001$, respectively). ROC curve analyses revealed that both fROM and gROM had excellent discriminating capacities; gROM was likely to have a higher area under the curve than fROM (0.906 vs. 0.860, $p = 0.094$), with an optimal cutoff value of 27°.

Conclusions: The gROM is a highly useful indicator for predicting a marked loss of cervical lordosis after CLP. For CSM patients with preoperative gROM exceeding 30°, CLP should be carefully considered, since kyphotic changes can develop postoperatively.

PS-FP-1-14

Decompression Status of the Spinal Cord after Cervical Laminoplasty in Various Body Positions and Neck Postures Observed Using Percutaneous Ultrasonography: Relationship with Neurological Recovery

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Purpose: Percutaneous ultrasonography (PUS) is used to evaluate the status of the spinal cord after cervical laminoplasty (CLP). This technique helps assess real-time movements of the spinal cord and provides immediate information regarding the decompression status. Additionally, it can also be utilized to evaluate the status of the spinal cord in various body positions and neck postures. This study aimed to examine changes in the decompression status of the spinal cord after CLP for cervical spondylotic myelopathy (CSM) in different body positions and neck postures using PUS and to assess whether these decompression statuses are related to clinical outcomes at each time point.

Methods: The study included 66 consecutive participants with CSM who underwent double-door CLP with suture anchors. PUS was performed postoperatively at 2 weeks, 3 months, 6 months, and 1 year in sitting (neck flexion [Flexion], neutral [Neutral], and extension [Extension]) and supine (Supine) positions. The decompression status was classified into grade I (noncontact), grade II (contact and apart), and grade III (contact). Clinical outcomes were evaluated using Japanese Orthopaedic Association (JOA) scores.

Results: The decompression status improved until 3 months postoperatively in all body positions and neck postures and was stable onwards. It changed depending on body positions and neck postures and was worse in Flexion and better in Supine at all postoperative time points. Participants with grade I decompression status in Supine had a significantly better recovery rate of JOA scores after 3 months, 6 months, and 1 year postoperatively than those with grade II+III decompression status ($p < 0.05$, all). However, this significant relationship was not observed in

each sitting position.

Conclusions: The spinal cord after CLP is most decompressed in Supine. Sufficient and continuous restoration of the anterior subarachnoid space in supine position may indicate positive clinical outcomes after cervical laminoplasty.

PS-FP-1-16

C6 Radiculopathy Can Cause So-Called C5 Palsy: Comparison to C5 Radiculopathy

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Purpose: Shoulder girdle paralysis with severe weakness of the deltoid muscles (Deltoid) and biceps brachii muscles (Biceps) are widely recognized as C5 palsy, while C6 radiculopathy can also show similar manifestation. In this study, we compared the characteristics of C6 and C5 radiculopathy in patients with shoulder girdle paralysis.

Methods: A serial series of 27 cases with preoperative manual muscle testing (MMT) of Deltoid “3” or less who had got their symptoms improved after single-nerve root decompression through posterior open foraminotomy from September 2006 to March 2018, was analyzed retrospectively. The subjects were divided into two groups; C5 radiculopathy group (group C5) consisted of 23 cases (16 males, 7 females; range, 39–79 years old), and C6 radiculopathy group (group C6) consisted of four cases (two males, two females; range, 34–64 years old). We investigated (1) initial symptoms, (2) numbness of the upper limbs at the first visit, (3) preoperative MMT of Deltoid, Biceps and wrist extensors, (4) biceps tendon reflex (BTR), and (5) MMT of Deltoid and Biceps 1 year after surgery.

Results: In both groups, suprascapular pain was the initial symptom in all cases. In group C5, six cases had no numbness and 17 cases on the lateral aspect of the upper arm. In group C6, one case had numbness on the lateral aspect of the upper and forearm, and three cases on the lateral aspect of the upper limb and thumb. The cases with weaker Deltoid compared to Biceps were found only in group C5 (18 cases). In group C6, Biceps was equivalent (two cases) or weaker (two cases) compared to Deltoid.

Wrist extensors were weak in all the cases in group C6, while no weakness was found in group C5. BTR was diminished in all cases in both groups. MMT of Deltoid and Biceps improved in all cases in both groups after surgery, especially in group C5 with their Biceps improved to “4” or more in all cases. In group C6, the improvement of Deltoid was better than Biceps.

Conclusions: Severe weakness of the Deltoid should be called “shoulder girdle paralysis”, not C5 palsy. Common in C5 and C6 radiculopathy, suprascapular pain is the initial symptom and BTR is diminished, while in C6 radiculopathy, weakness of the Biceps is equivalent or severer than Deltoid, and weakness of wrist extensors can also be observed. In our study, the improvement of Deltoid was better than Biceps after decompression surgery for C6 radiculopathy.

PS-FP-1-17

Posterior Hybrid Technique for Multi-Level Cervical Spondylotic Myelopathy with Instability

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Purpose: Cervical spondylotic myelopathy (CSM) is the most severe consequence of cervical intervertebral disk degeneration as well as the leading cause of spinal cord dysfunction in patients aged >55 years. While the pathological anatomical variation would be the most critical factor for choosing the treatment of multi-level CSM. Laminoplasty, laminectomy or combined with instrumented fusion, which can accomplish the goal to decompress the spinal cord, restore sagittal alignment, and stabilize the spine. Here, we present that the posterior hybrid technique ‘laminoplasty combined with instrumented fusion’, which can attain excellent or good improvement for neurological outcomes and quality of life, for the patients with multi-level CSM in different anatomical aetiology.

Methods: This retrospective study included 12 patients (seven males, five females; mean age, 58.6 years) with three or four-level CSM who had undergone surgery between May 2014 and December 2018, and who had at least 3 months of follow-up records. All of patients in-

cluded were diagnosed CSM at more than three level with segmental instability (C1/2, n=2; C2/3, n=3; C3/4, n=3; C4/5, n=4), and the need for strong stabilization. The Japanese Orthopaedic Association (JOA) scoring system and Visual Analog Scale (VAS) scores for neck pain were used to evaluate the clinical results. The cervical sagittal alignment (such as the percentages of slip, slip angle, and C2–7 lordotic angle) of 10 patients with segmental instability at the C2–7 was measured to evaluate. While the atlas-dens interval (ADI) of two patients was measured before surgery and at the final followed-up. The occurrence of surgical complications, surgical time, and blood loss volume were also investigated.

Results: The mean JOA scores before surgery and at final follow-up were 8.1 and 14.5, respectively. The mean VAS before surgery was 6.5 and 2.4 at the final follow-up. The mean C2–7 lordotic angle was 10.5° at the final follow-up. The mean percentages of slip before surgery were 9.6% and 3.4% at final follow-up. The mean slip angle was 8.5° before surgery and 2.2° at the final follow-up. The mean surgical time was 180.5 minutes. The mean ADI was 5.6 mm before surgery and 3.4 mm after surgery. The mean blood loss volume was 173.5 mL. There were significant improvements at final follow-up. All of patients had no complications after surgery till final follow-up.

Conclusions: The results suggest that laminoplasty combined with instrumented fusion seem to be effective and safe surgical procedure for treating CSM with instability.

PS-FP-1-18

The Feasibility Study of Cervical Pedicle Screwed with a New Individual-Oriented Template by Three-Dimensional Printing Technology

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Purpose: To establish a new individual-oriented template for cervical pedicle screw placement by three-dimensional (3D) printing technology, in order to provide an accurate and safe method for cervical internal fixation operation.

Methods: Six cases of adult cervical specimens, and 64-slice spiral computed tomography (CT) scanning data

were adopted. The 3D digital models of cervical were reconstructed based on the anatomical characteristics of the cervical vertebral lamina. The reverse templates were designed, which reflected accurately morphological features of the posterior cervical spine elements. The navigation modules were obtained with the method of 3D printing, and the direction and depth of the screw channel in the operation were ensured. Using 3D printing navigation templates, 24 cervical pedicle screws were inserted. A postoperative CT scan was used to measure the length of each pedicle screw channel and the width of the pedicle in order to evaluate the relationship between the cervical pedicle and screw position.

Results: The individual 3D printing navigation templates can exactly fuse with the cervical vertebral lamina. Postoperative CT data can confirm that 84 screws are placed entirely within the pedicle. The actual length of pedicle screw insertion was 100%, and the width of pedicle screw insertion was up to 94.05%.

Conclusions: The new 3D printing navigation template of cervical pedicle screw insertion is safe and convenient during the internal fixation operation, and the accuracy of cervical pedicle screw implantation can be improved.

PS-FP-1-19

Anterior Cervical Discectomy and Fusion with Cervical Uncinectomy for Cervical Radiculopathy with Foraminal Stenosis

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Purpose: Cervical radiculopathy is among the most common adult spinal disorders. There are several surgical treatment options available, such as posterior cervical foraminotomy, anterior cervical foraminotomy, anterior cervical discectomy and fusion (ACDF), and cervical disk arthroplasty. This study aims to describe the technique for ACDF with incomplete or complete uncinectomy for the management of cervical radiculopathy due to foraminal stenosis.

Methods: We retrospectively collected clinical and radiological data from June 2018 to June 2020. A total of 10 patients (16 segments) were included. All patients with cervical radiculopathy due to foraminal stenosis were treated

via ACDF with incomplete or complete ipsilateral uncinectomy to achieve complete nerve root decompression. In total, 16 disc levels (C3/4, 2; C4/5, 4; C5/6, 7; C6/7, 3) were investigated. The mean follow-up duration was 6.1 months (range, 4.5–19.2 months). The Neck Disability Index (NDI) and Visual Analog Scale (VAS) scores for neck pain before surgery and at final follow-up were used to evaluate the clinical results. The occurrence of surgical complications, surgical time, and blood loss volume were also investigated.

Results: The mean VAS scores before surgery and at final follow-up were 6.6 and 1.5, respectively. The mean NDI before surgery was 0.38 and 0.08 at the final follow-up. The scores decreased significantly at the final follow-up ($p<0.01$). The mean surgical time and the mean blood loss volume were 125 minutes and 10 mL, respectively. There were significant improvements at final follow-up. There were no vertebral artery injuries, cerebrospinal fluid leaks, or wound infections. One patient with three-level discectomy suffered dysphagia after surgery, while improved at final follow-up. All of the patients were decompressed completely and had a good to excellent outcome.

Conclusions: ACDF with uncinectomy was a safe and effective procedure that can relieve pain and lead to a resolution of neurologic symptoms for patients with cervical radiculopathy. Despite completely decompressed the nerve due to bony foraminal stenosis, this technique did well in the short-term, although longer-term follow-up is required.

PS-FP-1-20

Investigation of Diagnostic Imaging Criteria for Developmental Stenosis Based on Cervical Spondylotic Myelopathy in Young Patients

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Purpose: Cases of cervical spondylotic myelopathy (CSM) with developmental stenosis are commonly observed; however, diagnostic imaging criteria for this pathology

still remains elusive. In the present study, we used imaging data of CSM patients who required surgery at young age, compared to demographically matched healthy volunteers, and verified the imaging features of young developmental cervical stenosis.

Methods: A case-control study was performed for CSM patients who underwent cervical decompression surgery at our institution under 50 years of age from October 2005 to March 2018. After excluding cervical disc herniation with more than 50% occupancy in the spinal canal, localized osteophytes, yellow ligament ossification, posterior longitudinal ligament ossification, cerebral palsy, congenital malformations, cervical kyphosis, achondroplasia, dialytic spondyloarthropathy, and peripheral nerve disease complication cases. Total of 26 cases were selected as the developmental cervical stenosis (DCS) group. Age- and gender-matched healthy volunteers were selected as the control group. Torg-Pavlov ratio at C2 to C7 level and lateral mass-to-posterior vertebral body/canal diameter (LM/CD) ratio at C2 to C7 level were evaluated by X-ray lateral views of cervical spine. Magnetic resonance imaging (MRI)-Pavlov ratio at C2 to C7 level, occupation ratio at C2 to C7 level, and Nouri's spinal cord occupation ratio (SCOR) were evaluated by MRI sagittal views of cervical spine. The receiver operating characteristic (ROC) curve was constructed and area under the ROC curve (AUC) was calculated in all imaging parameters.

Results: The mean age at surgery in DCS group was 41.3 ± 7.0 years. Of the enrolled subjects, 18 cases were male and eight cases were female. At imaging findings, significant differences were observed between the DCS and control groups in Torg-Pavlov ratio at all level (C3 to C7 level) ($p<0.001$), MRI-Pavlov ratio at all level ($p<0.001$) and occupation ratio at all level ($p<0.001$) and SCOR ($p<0.001$). A particularly large statistical difference was observed in the MRI-Pavlov ratio at C4 level ($p=9.21\times 10^{-11}$). In ROC analysis, AUC was the highest in the MRI-Pavlov ratio at C4 level (AUC=0.925), with a specificity of 96.3% and sensitivity of 81.5% when the cutoff value was 0.560.

Conclusions: Our findings suggested that the MRI-Pavlov ratio at the C4 level could be a useful indicator of DCS in young-aged patients who need surgical decompression.

PS-FP-1-21

Surgical Strategy for the Cervical Kyphosis Patients Associated with Cervical Spondylolisthesis: Three Cases' Experience

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Purpose: Surgical strategy for the cervical kyphosis patients associated with cervical spondylolisthesis (degenerative spondylolisthesis, DS) has not yet been established. We surgically treated three cervical kyphosis patients associated with cervical spondylolisthesis. The purpose of this study is to introduce our surgical strategy for this disorder.

Methods: We retrospectively reviewed three cervical kyphosis associated with DS cases (all females; age at surgery, 48, 73, 77 years; follow-up, 12, 12, 24 months). All patients underwent combined anterior-posterior spinal fusion. We evaluated the local curve flexibility using fulcrum backward bending (FBB) films. According to the curve flexibility, we decided the surgical procedure. In two patients who had flexible kyphosis (flexible type), we performed anterior interbody fusion at first and then posterior fusion. In a case who had rigid kyphosis (rigid type), posterior corrective fusion was performed at first and then anterior interbody fusion. The number of fused vertebrae were four, three in the flexible type, and nine in the rigid type, respectively. Radiographic measurements and clinical outcomes using Japanese Orthopaedic Association (JOA) score were evaluated before and after surgery (preoperative/postoperative).

Results: All patients presented local kyphosis associated with C4 slip and cervical myelopathy. Radiographic parameters (preoperative/postoperative) were as follows: C1–2: 34.7°/29.3°, C2–7: -30.7°/0.3°, C2–7 sagittal vertical axis: 27.7°/17.3 mm, and local kyphosis: 32.0°/4.7°. FBB films showed that local kyphosis was 11.5° in the flexible type, and 34° in the rigid type. The JOA score improved from 10.7 points to 13.3 points.

Conclusions: Local kyphosis over 13° was critical value for poor outcome following expansive laminoplasty for the patients with cervical spondylotic myelopathy. Therefore, correction of the local kyphosis is mandatory for the pa-

tients with cervical kyphosis associated with DS. Although it is a quite small number of cases, we suggested our surgical strategy for the patients with cervical kyphosis associated with DS as follows: (1) anterior interbody fusion and subsequent posterior fusion for the flexible type, and (2) posterior corrective fusion and subsequent anterior interbody fusion for the rigid type.

PS-FP-1-24

A Meta-Analysis of the Efficacy of Botulinum Toxin A and Occupational Therapy versus Occupational Therapy Alone in Children with Upper Limb Spastic Cerebral Palsy

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Purpose: Cerebral palsy (CP) is the most common childhood motor disability with many treatment modalities aimed at improving limb function, including botulinum toxin type A (BoNT-A) injections and occupational therapy (OT). The purpose of this review was to assess the effect of BoNT-A in conjunction with OT on occupational performance and quality of upper limb movement in children with CP.

Methods: A literature search was conducted using the Cochrane, PubMed, CIAHL, and Web of Science databases using the keywords "cerebral palsy", "upper extremity", "pediatric", "hand", "treatment". Using this database, papers were identified which included BoNT-A treatment alone and BoNT-A combined with OT in children between 0 and 18 years. Melbourne Assessment of Unilateral Upper Limb Function (Melbourne Assessment) and Canadian Occupational Performance Measure (COPM) were the outcome measures analyzed at baseline, 3 months, and 6 months using 2-way analysis of variance with Bonferroni's Post-Hoc test for multiple comparisons.

Results: Initial literature search yielded 3,855 studies after

the removal of duplicates. Of the 3,855 studies that were screened, a total of eight studies contained mean data for at least one of the outcome measures mentioned above. While comparing studies where BoNT-A was applied in conjunction with occupational therapy (n=6) versus studies where only BoNT-A injections were given (n=3), there was no significant difference between baseline COPM Performance Scores ($p=0.9631$). However, at 3 months ($p<0.001$) and 6 months ($p<0.001$) after treatment, the combination of BoNT-A with occupational therapy outperformed BoNT-A alone. The same trend was seen for COPM Satisfaction Scores at baseline ($p=0.5955$), 3 months ($p<0.001$), and 6 months ($p<0.001$). While the changes in the Melbourne Assessment were not significant at baseline ($p=0.0202$), 3 months ($p>0.9999$), or 6 months ($p>0.999$), studies with BoNT-A alone treatment had a greater mean increase in scores.

Conclusions: BoNT-A plus OT appears to improve individuals' COPM outcomes more than BTX-A alone. However, the impact of BoNT-A and OT on the Melbourne Assessment and other outcome measures must be further investigated as the results were inconclusive. Another systematic review examining the effect of BoNT-A and physiotherapy versus physiotherapy on lower extremities found improved outcomes in range of motion (ROM) and spasticity using the Modified Ashworth Scale (MAS). Therefore, it would be interesting to compare other outcomes measures such as MAS, ROM, and the goal assessment scale.

PS-FP-1-26

Modified Kurukawa Cervical Laminoplasty Using Iliac Crest Bone Graft as Spacers: Why to Do It Any Other Way?

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Purpose: The spinous process splitting laminoplasty was described by Kurukawa in 1982, although the procedure has number of theoretical and practical advantages over the Hirabayashi technique it has not been widely used because of technical difficulties. The theoretical advantage of laminoplasty is that it can preserve the stability of the cervical spine preventing postoperative kyphosis which

can be seen after laminoplasty, and at the same time, it can preserve motion preventing adjacent segment diseases observed as late sequelae after anterior/posterior (AP) fusion surgery. Earlier laminoplasty techniques did not preserve the dynamic stability of the extensor muscles and failed to show superiority over other techniques. Laminoplasty as described in our study showed similar neurological improvement to other studies but by preserving the muscle attachments at C2 and C7 and early postoperative mobilization, showed better stability and better-preserved range of motion (ROM) in comparison to earlier studies. Modifications of Kurukawa cervical laminoplasty include splitting spinous process in the midline with a burr, preserving muscle attachments at C2 and C7, use of iliac crest graft as spacer, and a rigorous postoperative neck ROM exercise regimen.

Methods: Forty-four patients with cervical myelopathy with a mean follow-up of 1.4 years. Patient-reported outcome measurements, radiological and clinical parameters, and complications were evaluated.

Results: Impressive increases were seen in AP canal dimensions, which persisted. Mean modified Japanese Orthopaedic Association score improved from 11.1 to 13.4 with a recovery rate of 34%. Nurick grade improved from 3.9 to 2.7 and Neck Disability Index improved by 15%. The mean C2–C7 lordosis angle changed from 18.5° to 12.0° only, with three patients having loss of lordosis of 20° or more, two clinically doing well and one patient needing anterior cervical discectomy and fusion for worsening myelopathy, C3/4 instability and pain. Only one more patient had neck pain and stiffness. Four patients had a C5-palsy, two improved to grade 5, and two to grade 4. None of the 22 patients had a concomitant foraminotomy at multiple levels had a C5 palsy. No patient had a flat neck deformity. Average operated levels were 3.36 per case. There were a total of 296 hinges created, with 90.5% fully united. Twenty (6.8%) were ununited but undisplaced. Hinges (2.7%) were displaced with no clinical concerns. One patient with loose C5 hinge developed a left C5 palsy 36 hours postoperative despite no compression identified on magnetic resonance imaging scan.

Conclusions: This technique provides excellent clinical and radiological outcomes, is a safe and inexpensive way to achieve a good result with a good functional ROM.

PS-FP-1-27

Preoperative Transverse Area of Spinal Cord Compression Using Quantitative Magnetic Resonance Imaging in Surgically Treated Cervical Spondylotic Myelopathy: A Descriptive Study

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Purpose: The purpose of the study was to describe the specific magnetic resonance imaging (MRI) parameter values in patients who underwent surgical management for cervical spondylotic myelopathy (CSM) in Davao Doctors Hospital from 2012–2018.

Methods: This is a retrospective study that included all patients admitted in the Davao Doctors Hospital from January 2012 to December 2018 for surgically managed CSM. The demographic and clinical data such as age, gender, and pre- and immediate postoperative clinical status were reviewed. Names were excluded to keep anonymity. The specific MRI parameters (transverse area [TA], anteroposterior [AP], compression ratio [CR]) of the patients were measured by two blinded radiologists and then averaged. TA is the spinal cord area identified at the site of maximal compression measured on axial T2-weighted MRI images. CR is the smallest diameter divided by the transverse diameter of the spinal cord using T2-weighted MRI. AP is the measurement of the anterior to posterior distance of the most stenotic level.

Results: There were a total of thirty patients included in the study. Majority of the patients were more than 50 years old and male. TA range is 15.65–62.7 mm². The mean is 34.58 mm² and the median is 34 mm². The standard deviation is 10.69 and the confidence interval (CI) is 3.89. CR range is from 0.1–0.725. The mean is 0.39 with a standard deviation of 0.11. The median is 0.375. The CI is 0.04. It is the most precise and reliable of the three MRI parameters collected and hence is most promising for future prospective research. AP range for our patients was 1.75–7.3 mm. The mean and median were 5.22 mm and 5.05 mm, respectively. The standard deviation is 1.3 and the 95% CI was 0.47. The standard deviation and CI are

both small which mean that the values are representative of the population.

Conclusions: The TA, CR, and AP diameter are commonly used parameters to measure stenosis in the MRI of patients with CSM. These measurements are however not fully utilized in decision making because of issues of standardization and reproducibility. Here we present values representative of our Filipino patient in Davao Doctors Hospital. Prospective analysis can still strengthen their correlation to symptoms and increase its significance in surgical decision-making.

PS-FP-1-28

Impact of Cervical Alignment for Prognosis of Cervical Spondylotic Amyotrophy: Propensity Score Matching Analysis

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Purpose: Cervical spondylotic amyotrophy (CSA), involving dissociated motor loss in the upper extremities, is considered as the stage prior to cervical spondylotic myelopathy (CSM). In some cases of CSA, the symptom has a self-limited natural history. However, the factors associated with the natural history of recovery of CSA have not been reported in the literature. The concept of cervical alignment parameters is recognized over time, and these parameters are implied to be correlated with the health-related quality of life outcomes and pathogenesis of CSM. The purpose of this study was to investigate the impact of cervical sagittal alignment parameters on the prognosis of CSA using propensity score matching analysis.

Methods: Retrospective cohort study. Patients with proximal CSA who were followed conservatively over 6 months from the onset, had a manual muscle test (MMT) score <3, and had confirmed denervation potentials in the deltoid and/or biceps brachii muscles on electromyography were eligible. Patients with diabetes mellitus, a rotator cuff tear, encephalopathy, or a neuromuscular disease were excluded. Age, sex, MMT score, cervical lordosis, number of stenosis levels, and existence of T2-weighted high-intensi-

ty area (T2HIA) in the spinal cord on magnetic resonance imaging (MRI) were investigated. The patients were divided into two groups, recovery and non-recovery group, and a propensity score matching analysis was conducted to examine the prognostic factors of proximal CSA.

Results: A total of 127 patients were diagnosed with proximal type of CSA in our department. Eligible patients were 31, 18 in recovery group and 13 in non-recovery group. The mean degree of cervical lordosis (CL) was significantly lower in non-recovery group (10.2 vs. -2.3, $p<0.01$). The mean number of levels of stenosis on MRI was 2.5 and 3.0 in recovery group and in non-recovery group, respectively. The number of patients having C3/4 stenosis was seven (38.9%) in recovery group and nine (69.2%) in non-recovery group, with tendency to be higher incidence in non-recovery group ($p=0.07$). Only one patient in recovery group had T2HIA on MRI. Twenty-four of 31 patients were matched in a one-to-one ratio in the two groups. Propensity score matching showed that CL was an independent predictor of recovery of CSA (odds ratio, 1.2; 95% confidence interval, 1.02–1.34; $p<0.05$).

Conclusions: Cervical sagittal alignment parameters had a significant influence on the natural course of CSA, and CL might be one of the factors that predict CSA prognosis.

PS-FP-1-29

Usefulness of the Disabilities of the Arm, Shoulder, and Hand in Evaluating Surgical Outcome of Cervical Spine Disorders

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Purpose: Patients with cervical spine disorders may present with upper extremity symptoms including numbness, motor weakness and hand clumsiness, and often have some sort of trouble in activities of daily living (ADL). The disabilities of the arm, shoulder, and hand (DASH)

is a patient-reported questionnaire designed to measure functional disability due to upper extremity conditions. Although the DASH is commonly applied to evaluate ADL in patients with rheumatoid arthritis and entrapment neuropathies in the upper extremity, there are very few reports in cervical spine disorders. The purpose of this study was to examine the usefulness of the DASH in evaluating surgical outcome of cervical spine disorders.

Methods: Fifty-seven consecutive patients who underwent surgery for cervical spine disorders were included in this study. They consisted of 35 men and 22 women, and their mean age at the time of surgery was 59.7 ± 13.3 years old. The DASH score and the Japanese Orthopaedic Association (JOA) score were collected preoperatively and at 6 months postoperatively. The changes of the JOA score and the DASH score at the time of operations and 6 months after surgery were examined. The statistical association between the JOA score and the DASH score was also evaluated. By the analysis of the patients' replies to the DASH, it was also clarified what kind of activities recovered after surgery.

Results: The JOA score and the DASH score were 12.7 ± 2.5 and 21.9 ± 17.4 at the time of operations, and 15.6 ± 1.4 and 16.1 ± 14.1 at 6 months postoperatively. The JOA score and the DASH score significantly improved from baseline to 6 months after surgery ($p<0.01$). There were significant negative correlations between the JOA score and the DASH score at the time of operation ($r=-0.415$, $p<0.01$) and 6 months after surgery ($r=-0.312$, $p=0.02$). The DASH item of carrying heavy stuff was improved in 35.2%, and those of the recreational activities requiring muscular strength of upper extremities improved in 51.9% patients.

Conclusions: In this study, we found a significant correlation between the JOA score and the DASH score in patients with cervical spine disorders. The DASH scoring system would be useful in evaluating surgical outcome of cervical spine disorders, and it could reflect on upper extremity function and ADL in more detail.

PS-FP-1-30

The Posterolaterally Oriented and Laterally Downward Sloping Facet Joint Is a Risk Factor for Degenerative Cervical Spondylolisthesis and Myelopathy

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Facet joints are crucial anatomical structures in determining spinal biomechanical motion, but the potential relationship between facet orientation and the development of cervical spondylolisthesis remains unclear. To explore the relationship between facet orientation and cervical spondylolisthesis as well as myelopathy. Facet orientation in the cervical spine was studied using computed tomography in 105 patients with cervical myelopathy, and the facet inclination was measured on axial, coronal, and sagittal reconstructed images. The subjects were divided into anterolisthesis, retrolisthesis, and no spondylolisthesis groups at each intervertebral level (C2/3–C6/7). The below facet joints of the posterior or anterior slipped vertebral bodies tend to slope posterolaterally and downward laterally compared to non-slipped vertebral bodies from C3/4 to C5/6 level. The posterolaterally oriented and laterally downward sloping facet at C3/4 and C4/5 levels would be a risk factor for the development of cervical spondylolisthesis as well as symptomatic myelopathy.

PS-FP-1-33

Accuracy of the Adjustable Aiming Device for Caspar Pin Insertion in Anterior Cervical Spine Surgery: Human Cadaveric Study

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Purpose: Rectangular shape of disc space preparation during anterior cervical discectomy and fusion or cervical

disc replacement is a desirable goal. Proper insertion of the vertebral distraction or Caspar pin can provide rectangular disc space by putting the pins parallel to the indexed vertebral endplates. Traditional free-hand technique may require multiple insertion attempts that may compromise the vertebral body and increase radiation exposure during pin localization. No published study has reported the method of creating parallel Caspar pin insertion without intraoperative fluoroscopy. The purpose is to study whether the novel adjustable Caspar pin aiming device provides the accuracy and safety for Caspar pin insertion in anterior cervical procedures.

Methods: Forty Caspar pins were placed through the adjustable Caspar pin aiming device in 20 human cadaveric cervical vertebral bodies from C3 to C7 after performing anterior discectomies. The parameters of pin insertion were evaluated by lateral fluoroscopy, including superior endplate slope (SE), inferior endplate slope (IE), Caspar pin slope (CP), and endplate-Caspar pin slope difference (SE/CP, IE/CP). The accuracy of pins was assessed by determining the difference of slope between vertebral endplates and Caspar pin, while considering the difference less than 5° was acceptable.

Results: Five cadaveric specimens, with an average age of 67.2 years, were utilized in the study. The mean SE, IE, and CP were $10.82^\circ \pm 2.3^\circ$, $10.32^\circ \pm 3.2^\circ$, and $15.58^\circ \pm 7.9^\circ$ ($p < 0.0001$), respectively. The average SE/CP difference and IE/CP difference were $6.6^\circ \pm 0.8^\circ$ and $7.7^\circ \pm 0.8^\circ$ ($p = 0.35$), respectively. The most slope difference was observed at SE and IE of C3. No cervical endplate violations occurred.

Conclusions: In a cadaver model, the adjustable Caspar pin aiming device provides high accuracy for Caspar pin placement with the average endplate–CP difference less than 7.7°. This creates placement of the superior and inferior Caspar pins parallel to the indexed vertebral endplates. Furthermore, it may facilitate safe and effective insertion of Caspar pins in anterior cervical procedures. However, pin placement at C3 vertebral body should be done and adjusted carefully through this device.

PS-FP-1-34

The Natural History of Patients with Cervical Radiculopathy Treated Conservatively and Correlating with Clinical and Magnetic Resonance Imaging Features after a Mean Follow-up of 33 Months

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Purpose: Few published studies have focused solely on clinical outcomes after conservative treatment. Selection of study population was not homogenous often myelopathy and radiculopathy patients were clubbed and some studies used variety of treatment options including steroids injections and root blocks. The present study attempts to evaluate the clinical and radiological natural history of cervical radiculopathy managed conservatively.

Methods: Patients of acute cervical radiculopathy with single level disc herniation presenting to our institution from Jan 2012 to Dec 2018 were enrolled in the study. Total of 46 patients were included in the study. With 32 males and 14 females, average age of 42.9 years (range, 25–80 years), mean follow-up period of 33 months (range, 18–58 months). All patients were managed only with analgesics and pregabalin along with physical therapy in form of transcutaneous electric nerve stimulation. At both the index visit and follow-up visit, the functional assessment tool used was Neck Disability Index (NDI), Visual Analog Scale (VAS) scoring was used to assess the severity of neck and arm pain, and Patient-Specific Functional Scale was used to measure the satisfaction level of patients on follow-up. Grading done in magnetic resonance imaging (MRI) for disc degeneration using Miyazaki Score and neural foraminal stenosis (NFS) was graded using Kim's Score. Paired Student t-test was used to compare index and follow up NDI scores and VAS scores. Inter-observer reliability was calculated using Cohen's kappa coefficient. Correlation between clinical and radiological parameters was studied by use of Pearson's coefficient.

Results: The distribution of studied disc levels was 21 at C6–7 level, 22 at C5–6, and three at C4–5 level. At presentation, neck pain and arm pain were present in all the patients with average VAS scores of 6 and 8, respectively. NDI scores at this initial evaluation ranged from 20–90 with a mean value of 56.75. Clinical evaluation at follow-up re-

vealed good relief of neck pain and arm pain. Mean VAS score improved to 2 and 1.3, respectively at follow-up. This change was statistically significant ($p < 0.001$). NDI score showed statistically significant improvement to a mean of 14.23 (range, 0–42.2; $p < 0.001$). NFS grade for the involved side decreased from an average of 1.52 to 1.08 ($p < 0.001$). Miyazaki scores changed from 3.20 and 3.35 ($p = 0.823$).

Conclusions: Clinical improvement was seen as a rule in cervical radiculopathy patients. MRI showed statistically significant regression of neural foraminal stenosis on follow up. However, correlation between the two could not be proved.

PS-FP-1-35

Is Cervical Posterior Fixation Effective for Neck Pain?

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Purpose: One of the chief complaints of cervical spine disease is neck pain and shoulder stiffness. Usefulness of surgery, especially fixation surgery, for neck pain is unclear. The purpose of this study was to evaluate the improvement of neck pain by posterior surgery in patients with cervical myelopathy. And we also evaluated whether the additional posterior fixation contributes to the improvement of neck pain or not.

Methods: We selected patients with cervical myelopathy who underwent cervical posterior surgery in our institute from 2009 to 2018. One hundred and eighteen cases were finally enrolled in this study. We divided those cases into two groups. One was decompression only group (laminoplasty [LM] group, 81 cases) and the other was decompression with instrumented fusion group (posterior decompression with instrumented fusion [PDF] group, 37 cases). We compared preoperative and postoperative Visual Analog Scale (VAS) of neck pain and postoperative Neck Disability Index (NDI) in both groups.

Results: Neck pain VAS in LM group was 47 mm before surgery and 28 mm after surgery in average ($p < 0.0002$). Neck pain VAS in PDF group was 47 mm before surgery and 32 mm after surgery ($p = 0.07$). A statistical evaluation showed that neck pain was reduced after surgery in LM group. The amount of change in neck pain VAS before and after surgery was compared between the two groups: 20 mm in the LM group and 15 mm in the PDF group, with no difference between the two groups. The ratio of postoperative reduction in neck pain was compared between the two groups: 60% of cases in the LM group had less neck pain than before surgery. As well, 49% of patients in the PDF group had less pain than preoperatively. Analysis in the subgroup of pain intensity of NDI showed no statistically significant difference between the two groups.

Conclusions: Both groups showed improvement or a tendency toward improvement in postoperative neck pain. However, the superiority of additional fixation was not obvious. Because the mechanism of improving neck pain after surgery might be different in two groups, the interpretation of the results requires further study. The advantage of this study was that there was no consideration of the presence of neck pain in the selection of surgical procedures. Improvement in postoperative neck pain was achieved in 60% of patients with posterior decompression surgery and in 49% of patients with posterior decompression with instrumented fusion. The superiority of the additional fixation was not clear in this study.

PS-FP-1-36

Incidence, Prevalence, and Clinical Significance of Modic Changes in Cervical Spine: A Prospective Study

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Purpose: Modic changes are widely debated on etiology and pathomechanisms. They have been extensively analyzed in lumbar intervertebral discs. However, there are limited studies on the prevalence and patterns of Modic changes in the cervical spine as compared to the lumbar spine. More importantly, their association with spinal pain, disc level, age, the severity of disc degeneration,

endplate damage, and sagittal parameters like presence or absence of kyphosis, T1 slope and C2–C7 angle, and L1–S1 angle has not been analyzed so far. This study was primarily aimed to investigate the epidemiology of Modic changes in patients with neck pain and identify probable association between Modic changes with disc degeneration, endplate damage, and sagittal parameters.

Methods: The study sample was segregated into three groups: patients primarily presenting to the outpatient department with chronic unresolved neck pain (group A), back pain (group B), and control magnetic resonance imaging was obtained from patients who were admitted for spinal trauma (group C). Patients with pathological lesions, such as tumors, infection, congenital abnormalities, and surgical fusions were excluded. Demographic and clinical parameters like age, sex, duration of symptoms, presence or absence of spinal pain, and severity of pain (Visual Analog Scale score) were documented. Radiologically parameters evaluated include presence and type of Modic changes, disc level, disc degeneration (Pfirmann grade), endplate damage (total endplate score), and sagittal parameters. A case-control analysis for the outcome of Modic changes was performed.

Results: The overall prevalence of Modic changes in lumbar spine (41%) was higher than cervical spine (16%). Both cervical and lumbar Modic changes were more common in symptomatic than asymptomatic individuals. While C6–C7 was the most common disc level involved with Modic changes in symptomatic individuals, C5–C6 was the most common level in patients presenting with back pain. L5–S1 was most common disc level involved in symptomatic individuals and L4–L5 was the commonest involvement in patients presenting with neck pain. Type 2 Modic changes were most common, followed by type 1 and lastly, type 3 irrespective of the study groups. Patients with Modic changes had higher intensity of pain, higher grades of disc degeneration and endplate damage compared to patients without Modic changes.

Conclusions: Our study showed the Modic changes are more common in the lumbar spine than the cervical spine, and common in symptomatic individuals. Patients with Modic changes have a higher intensity of pain, higher grades of disc degeneration and associated endplate damage, and their presence is more common in non-kyphotic individuals than kyphotic individuals.

PS-FP-1-37

Efficacy of Ultrasound-Guided Nerve Root Block for Cervical Spondylotic C6 Radiculopathy

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Purpose: Cervical spondylotic radiculopathy (CSR) is commonly experienced in clinical practice; however, it is often difficult to treat because the pain is usually severe and activities of daily living disability can be serious. Though nerve root blocks (NRB) are sometimes performed using fluoroscopy for intractable root symptoms, complications such as vertebral artery injury are feared. Recently, the widespread of musculoskeletal ultrasound echo has made it possible to safely carry out cervical NRB. The purpose of this study is to examine the effectiveness of ultrasound-guided NRB for CSR.

Methods: We retrospectively reviewed sixteen patients (12 males and four females) who were diagnosed with C6 CSR and underwent ultrasound-guided NRB between April 2018 and July 2019. Xylocaine (0.1%) was used for NRB, and both ultrasound and fluoroscopy were used in all cases. First, we investigated which areas of peri-scapula and upper limb had symptoms: peri-scapula (upper part, body part, intermediate part) and upper limb (upper arm radial side, from the radial side of the forearm to the thumb, from the forearm ulnar side to the little finger, upper ulnar side). Next, the Visual Analog Scale (VAS) scores were evaluated before NRB, immediately after NRB, and 1 month or more after NRB. Finally, the final outcomes (improvement: no need for NRB; no change: continued NRB or not desired; surgery) were examined.

Results: Symptoms appeared in peri-scapula (upper part: 15 cases, intermediate part: one case) and upper limb (upper arm radial side: 10 cases, from the radial side of the forearm to the thumb: six cases, from the forearm ulnar side to the little finger: one case, upper ulnar side: one case) (including duplication). The VAS scores were 77.5 ± 13.0 mm (range, 50–90 mm) before NRB, 15.0 ± 14.4 mm (range, 0–40 mm) immediately after NRB, and 26.3 ± 17.9 mm (range, 10–70 mm) over 1 month, showing significant improvement compared to before NRB. The final outcomes were improvement (12 patients), no change (two patients), and surgery (two patients). No adverse events were observed with NRB in all patients.

Conclusions: Treatment of CSR is often difficult with medication alone, so surgery is often performed. Although minimally invasive surgery using full-endoscope has recently become available, avoiding surgery is clearly in the patient's best benefit, and ultrasound-guided NRB, which can be performed safely, can be an effective treatment method.

PS-FP-2-1

Spinal Column Phenotypes with Lumbar Developmental Spinal Stenosis: Results from 2,387 Magnetic Resonance Imaging

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Purpose: Lumbar developmental spinal stenosis (DSS) is an imaging phenotype appearing as a shortened anteroposterior (AP) vertebral canal diameter at multiple levels. It is likely a result of maldevelopment of the spinal canal. The relationship of canal narrowing with other radiological parameters in the spinal column is unknown.

Methods: This was a radiological analysis of 2,387 subjects who underwent L1–S1 magnetic resonance imaging (MRI). Means and ranges were calculated for their age, gender, body mass index, and MRI measurements. AP vertebral canal diameters were utilized to differentiate cases of DSS from controls. Other imaging parameters included the vertebral body dimensions, spinal canal dimensions, disc degeneration scores, and facet joint orientation. Mann-Whitney U-test and chi-square test were conducted to search for measurement differences between cases and controls. To identify possible associations between DSS and MRI parameters, parameters that were statistically significant in the univariate binary logistic regression were included in a multivariate stepwise logistic regression after adjusting for subject demographics.

Results: Axial AP vertebral canal diameter, interpedicular distance, AP dural sac diameter, lamina angle, and sagit-

tal mid-vertebral body height were significantly different between cases and controls (all $p < 0.05$). Narrower interpedicular distance and AP dural sac diameter were associated with DSS (odds ratio [OR], 0.506–0.745; $p = 0.001–0.002$). Lamina angle (OR, 1.127; $p = 0.002$) and right facet joint angulation (OR, 0.022; $p = 0.002$) were also associated with DSS. No association was observed between disc parameters and DSS.

Conclusions: From this large-scale cohort, the canal size is found to be independent of subject body habitus. Other than spinal canal dimensions, abnormal orientations of lamina angle and facet joint angulation may also be a result of developmental variations, leading to increased likelihood of DSS. Other skeletal parameters are spared. Besides, there is no relationship between DSS and soft tissue changes of the spinal column, which suggested DSS is a unique result of bony maldevelopment. Findings should be validated in other ethnicities and populations.

PS-FP-2-2

Increased Population Risk of Radicular Leg Pain in Lumbar Developmental Spinal Stenosis

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Purpose: Low back pain (LBP) and radiating leg pain are two common health problems around the world. Lumbar developmental spinal stenosis (DSS) may play an important role in pain generation. It is described as pre-existing narrowed vertebral canals at multiple lumbar levels with earlier onset of neurological compromise. Therefore, this study was designed to assess the interaction of DSS and different radiological phenotypes in producing LBP, radiating leg pain and disability.

Methods: This was a population-based study of 2,206 subjects with L1–S1 axial and sagittal magnetic resonance imaging (MRI). Clinical and radiological information regarding subjects' demographics, workload, smoking habit,

anteroposterior (AP) vertebral canal diameter, spondylolisthesis, and other MRI phenotypes was assessed. Mann-Whitney U-test and chi-square test were conducted to search for differences between subjects with and without DSS. Associations of LBP and radicular pain in the past month and the past year with the clinical and radiological information were also investigated by utilizing univariate and multivariate logistic regressions.

Results: Of the 2,206 subjects, 153 had DSS. Subjects with DSS had higher prevalence of radicular leg pain, more pain-related disability and lower quality of life (all $p < 0.05$). Subjects with DSS had 1.5 (95% confidence interval [CI], 1.0–2.1; $p = 0.027$) and 1.8 (95% CI, 1.3–2.6; $p = 0.001$) times higher odds of having radicular leg pain in the past month and the past year, respectively. However, DSS was not associated with LBP. Instead, subjects with spondylolisthesis had 1.7 (95% CI, 1.1–2.5; $p = 0.011$) and 2.0 (95% CI, 1.2–3.2; $p = 0.008$) times more likely to experience LBP in the past month and the past year, respectively.

Conclusions: This large-scale study identified DSS as an independent risk factor of acute and chronic radicular leg pain, and worse disability. DSS is a predictor of radicular pain, and spondylolisthesis is a predictor of LBP. There is an increased likelihood of nerve root compression due to a pre-existing narrowed canal. These subjects are also more likely to have poorer disability and quality of life.

PS-FP-2-3

Effects of Bone Cement Augmentation for Upper Instrumented Vertebra on Adjacent Segment Degeneration in Lumbar Fusions

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Purpose: This study aims to investigate the long-term effects of bone cement-augmented instrumentation in multilevel lumbar fusions. Cement-augmented screw is one of the techniques used to reduce early mechanical failure in multilevel lumbar fusion, especially in the elderly. However, there is little information regarding the long-term effects.

Methods: Fifty patients who underwent more than three levels of lumbar fusion were divided into two groups

according to bone cement-augmented screw fixation involving the upper instrumented vertebra (UIV): 21 patients (cemented group, group 1) and 29 patients (non-cemented group, group 2). The analysis of radiographic adjacent segment degeneration (ASD) involved patients with lumbosacral fusion showing a similar degree of osteoporosis. Radiologic ASD was defined as more than two UCLA grades of progression at 2 years postoperatively. Other sagittal parameters were analyzed such as pelvic incidence-lumbar lordosis (PI-LL) and preoperative magnetic resonance Pfirrmann grades for adjacent level, probably related to ASD.

Results: Even when no significant differences existed in preoperative demographic and radiographic parameters between the two groups, the postoperative kyphotic changes at 3 months were higher in the non-cemented group. In terms of long-term effects, radiologic ASD (20 patients [95.2%] in group 1; 15 [53.6%] in group 2) was significantly higher in the cemented group. Logistic regression analysis of radiologic ASD including other clinical and radiological parameters, postoperative PI-LL mismatch (odds ratio [OR], 5.201; 95% CI, 1.123–24.090; $p=0.035$), and cement augmentation (OR, 20.193; 95% CI, 2.195–185.729; $p=0.008$) showed a significant correlation with the development of radiologic ASD at postoperative 2 years.

Conclusions: Although bone cement-augmented screw implantation can prevent kyphotic deformation at the proximal junction of UIV in early postoperative stages of multi-level lumbar fusion, a discreet selection of patients is required due to possible accelerated degeneration of adjacent segments.

PS-FP-2-5

The Problems and Measures of L5 Osteotomy

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Purpose: To clarify the problems of L5 osteotomy and to describe the countermeasures.

Methods: Twelve cases of L5 osteotomy were reviewed: seven cases of osteoporotic vertebral body fracture (OVF), three cases of kyphosis after fixation, including L5, one case of distal junctional failure, and one case of spontaneous fusion of degenerative spondylolisthesis. The OVF was classified as type A with compression of the cephalo-caudal endplate, type B with compression of the cephalad endplate only, and type C with compression of the caudal endplate, and vertebral column resection was performed for A, L4/5 posterior lumbar interbody fusion (PLIF) for B, and L5/S PLIF for C. For other kyphosis cases, pedicle subtraction osteotomy was performed at L5. The range of fixation was from the thoracic spine to the pelvis in nine cases and from the lumbar spine to the pelvis in three cases. The caudal anchor was S2-alar-iliac (S2AI) screws in all cases.

Results: The age at surgery was 73.1±6.2 years for OVF and 73.0±5.8 years for kyphosis. Two cases of OVF were male, and the other 10 cases were female. The operative time was 280±45 minutes for OVF and 413±60 minutes ($p=0.001$) for other kyphosis cases, and the blood loss was 625±635 g for OVF and 903±297 g for kyphosis cases. All three cases of OVF type A and one case of kyphosis developed postoperative neurological symptoms in the lower extremities, and one case of type A required reoperation due to early postoperative instrumentation failure. One type B patient developed surgical site infection, and one kyphosis patient developed rod fracture 7 months after surgery and required reoperation. In two of the three cases, the upper end of the fixed lumbar vertebrae had instrumentation failure. The radiographic alignment of sagittal vertical axis, pelvic tilt, and lumbar lordosis improved, and Oswestry Disability Index also improved significantly at the last follow-up.

Conclusions: Osteotomy of the L5 vertebra can be useful if the patient has kyphosis due to a fracture of the L5 vertebra or kyphosis in the lower lumbar spine due to inadequate fusion surgery. However, the L5 vertebral body has some problems, such as a large transverse process that makes osteotomy difficult, few caudal anchors, and a strong ligament that makes shortening difficult. In this case, a preoperative computed tomography scan of the bone morphology, use of the S2AI screws as a caudal anchor, and selection of appropriate osteotomy can be useful options.

PS-FP-2-7

Spinal Endoscopic-Full See Technique for the Treatment of Two-Level Lumbar Lateral Recess Stenosis

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Purpose: Lumbar spinal stenosis is a common lumbar vertebrae disease in the elderly population, can lead to leg pain and low back pain especially when walking. The spinal endoscopic-full see technique used the novel endoscopic instruments and equipments for the decompression of spinal stenosis. This study aimed to evaluate the safety and curative effect of this new technique for the treatment of two-level lumbar spinal lateral recess stenosis.

Methods: From August 2018 to August 2019, this retrospective study recruited 21 patients with two-level lumbar spinal stenosis who underwent spinal endoscopic-full see technique via the surgical approach of the posterolateral intervertebral foramen, used the outer endoscopic reamer, full endoscopic bone chisel, and rongeur for foraminotomy and lateral recess stenosis decompression. The postoperation neurological function and pain status were evaluated by the Visual Analog Scale (VAS) score of pain and the Oswestry Disability Index (ODI). The data, including preoperative comorbidities, operation time, the quantity of bleeding, bed rest time, and intraoperative and postoperative complications, were recorded.

Results: The mean operation time was 100 minutes; the mean quantity of bleeding was 30 mL. All patients were followed-up for 4 months to 1 years. The mean preoperative VAS score was 7.3 ± 1.3 , while postoperative 1 months, 3 months, and final follow-up VAS scores were 1.8 ± 0.7 , 1.1 ± 0.6 , and 0.8 ± 0.6 , respectively ($p < 0.001$). The mean

preoperative ODI score was 72.4 ± 1.2 , while postoperative 1 months, 3 months, and final follow-up ODI scores were 28.5 ± 3.9 , 22.6 ± 4.1 , and 12.5 ± 3.3 , respectively ($p < 0.001$).

Conclusions: Spinal endoscopic-full see technique for the treatment of two-level lumbar lateral recess stenosis is an easy, safe, and effective minimally invasive surgery for patients with lumbar spinal stenosis. But this technique has a “long and steep” learning curve.

PS-FP-2-12

The Role of Gut-Skin-Spine Axis in the Establishment and Evolution of Human Intervertebral Disc Microbiome and Degenerative Disc Disease

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Purpose: Microbial etiology has been recently postulated as a cause of degenerative disc disease (DDD) leading to randomized trials of probiotics and antibiotics to treat chronic low back pain. However, the exact bacterial etiology has not been investigated. This study was conducted to trace the origin of the human intervertebral disc (IVD) microbiome and establish microbial biomarkers for DDD.

Methods: Healthy lumbar discs (ND) group (26 NP [nucleus pulposus] tissues and 17 EP [cartilaginous endplates]) excised from 10 magnetic resonance imaging normal asymptomatic organ donors underwent metagenomic analysis. A comparative analysis of the healthy IVD microbiome with that of 21 degenerate discs was performed to identify biomarkers of DDD. The ND microbiome was also compared to that of fetal and adult gut and adult skin microbiome to investigate the existence of gut-skin-spine axis and trace the origin of the human IVD microbiome.

Results: In total, four dominant phyla were detected: Proteobacteria, Firmicutes, Actinobacteriota, and Bacteroidetes. Proteobacteria was identified as the dominant phyla in both NP and EP disc with 72% and 68% mean relative abundance respectively. Overall NP and EP had similar

microbiome. This composition in turn matched fetal gut microbiome rather than adult gut and skin. Firmicutes/Proteobacteria ratio had a higher significance in determining DDD ($p=0.064$) compared to Actinobacteria/Proteobacteria ($p=0.08$) and Actinobacteria/Firmicutes ratio ($p=0.08$).

Conclusions: Our study has traced the origin of nucleus pulposus microbiome to that of human fetal gut through endplate and has also clearly established the role of gut-skin-spine axis in maintaining tissue homeostasis. Further, we have identified Firmicutes/Proteobacteria ratio as a potential biomarker of DDD.

PS-FP-2-13

The Catastrophization Effects of a Magnetic Resonance Imaging Report on the Patient and Surgeon and the Benefits of 'Clinical Reporting'

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Purpose: Inappropriate use of magnetic resonance imaging (MRI) leads to increasing interventions and surgeries for low back pain (LBP). We probed the potential effects of a routine MRI report on the patient's perception of his spine and the functional outcome of treatment. An alternate 'clinical reporting' was developed and tested for benefits on LBP perception.

Methods: In phase I, 44 LBP patients were randomized to group A who had a factual explanation of their MRI report or group B, who were reassured that the MRI findings showed normal changes. The outcome was compared at 6 weeks by Visual Analog Scale, Pain Self-Efficacy Questionnaire-2, and 12-item Short-Form Health Survey. In phase II, clinical reporting was developed, avoiding potential catastrophizing terminologies. In phase III, 20 MRIs were reported by both routine and clinical methods. The effects of the two methods were tested on four categories of health care professionals (HCP) who read them blinded on their assessment of severity of disease, possible treatment required, and the probability of surgery.

Results: Both groups were comparable initial by demographics and pain. After 6 weeks of treatment, group A had a more negative perception of their spinal condition, increased catastrophization, decreased pain improvement, and poorer functional status (p =significant for all). The alternate method of clinical reporting had significant benefits in assessment of lesser severity of the disease, shift to lesser severity of intervention and surgery in three groups of HCPs.

Conclusions: Routine MRI reports produce a negative perception and poor functional outcomes in LBP. Focused clinical reporting had significant benefits, which calls for the need for 'clinical reporting' rather than 'image reporting'.

PS-FP-2-14

Sub-Clinical Infection Can Be an Initiator of Inflammaging Leading to Degenerative Disc Disease: Evidence from Host Defense Response Mechanisms

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Purpose: There is considerable controversy on the role of genetics, mechanical and environmental factors, and, recently, on sub-clinical infection in triggering inflammaging leading to disc degeneration. The present study investigated sequential molecular events in the host, analyzing proteome level changes that will reveal triggering factors of inflammaging and degeneration.

Methods: Ten magnetic resonance imaging normal discs (ND) from braindead organ donors and 17 degenerated discs (DD) from surgery were subjected to in-gel based label-free ESI-LC-MS/MS (electrospray ionization-liquid chromatography tandem mass spectrometry) analysis. Bacterial-responsive host-defense response proteins/pathways leading to inflammaging were identified and compared between ND and DD.

Results: Out of the 263 well-established host defense

response proteins (HDRPs), 243 proteins were identified, and 64 abundantly expressed HDRPs were analyzed further. Amongst the 21 HDRPs common to both ND and DD, complement-factor-3 and heparan-sulphate-proteoglycan-2 were significantly upregulated, and lysozyme, superoxide-dismutase-3, phospholipase-A2, and tissue-inhibitor-of metalloproteinases-3 were downregulated in DD. Forty-two specific HDRPs mainly, complement proteins, apolipoproteins, and antimicrobial proteins involved in the complement cascade, neutrophil degranulation, and oxidative-stress regulation pathways representing an ongoing host response to sub-clinical infection and uncontrolled inflammation were identified in DD. Protein-Protein interaction analysis revealed crosstalk between most of the expressed HDRPs, adding evidence to bacterial presence and stimulation of these defense pathways.

Conclusions: The predominance of HDRPs involved in complement cascades, neutrophil degranulation, and oxidative-stress regulation indicated an ongoing infection-mediated inflammatory process in DD. Our study has documented increasing evidence for bacteria's role in triggering the innate immune system leading to chronic inflammation and degenerative disc disease.

PS-FP-2-15

Dynamic Ultrasound Imaging of Lumbar Multifidus for Assessment of Lumbar Spinal Muscles

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Purpose: It is important for the elderly to maintain sagittal balance with constant exercise to keep good spinal range of motion and strength of back extensor muscle. Dynamic ultrasound imaging is a potentially useful tool for the assessment of spinal muscles. This study was to investigate a feasibility of dynamic ultrasound imaging in lumbar multifidus muscle for assessment of lumbar spinal muscles.

Methods: This study was conducted on 23 volunteers without history of spinal disease. The volume and thickness of lumbar multifidus muscle as a trunk stabilizer and rectus femoris muscle as a thigh stabilizer were measured with dynamic ultrasound imaging, at rest and after exercise of the extensor muscle for strength of the extensor

muscle. Compared to individuals of sarcopenia diagnostic criteria such as gait speed, hand grip strength, and changes in muscles volume and thickness at the state of rest and after the exercise had been analyzed.

Results: At rest, the mean volume and thickness of lumbar multifidus muscle were 357.17 ± 59.25 mm² and 2.54 ± 0.32 cm, respectively. After exercise, the mean volume and thickness of lumbar multifidus muscle varied to 407.35 ± 70.10 mm² and 2.78 ± 0.36 cm, respectively. There was significant increment of lumbar multifidus muscle volume (14.00%, $p=0.01$) and thickness (9.42%, $p=0.01$). At rest, the mean volume and thickness of rectus femoris muscle were 129.50 ± 36.26 mm² and 1.19 ± 0.10 cm, respectively. After exercise, the mean rectus femoris muscle volume and depth varied to 157.58 ± 42.40 mm² and 1.40 ± 0.12 cm, respectively. There was significant increment of rectus femoris muscle volume (21.94%, $p=0.01$) and thickness (17.63%, $p=0.01$). The mean of gait speed was 9.80 ± 1.72 seconds and the mean hand grip strength was 19.30 ± 2.08 kg. There was positive correlation between changes of lumbar multifidus volume and hand grip strength ($r=0.56$, $p=0.01$) and negative correlation between changes of rectus femoris volume and gait speed ($r=-0.87$, $p=0.01$)

Conclusions: These results suggest that dynamic ultrasound imaging of the multifidus muscles could be used to document improvements over time and with intervention as a visual feedback to enhance therapeutic effect for lumbar spinal muscle.

PS-FP-2-16

Examination of Surgical Procedure for Lower Lumbar Osteoporotic Vertebral Body Fractures

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Purpose: Osteoporotic vertebral fractures (OVF) in the lower lumbar spine (L3, 4, 5) may cause radiculopathy due to foraminal stenosis by the fracture. Furthermore, since the fracture causes lumbar kyphosis, the total spinal alignment may be deteriorated, and the activities of daily living and the quality of life are also deteriorated. Therefore, it is necessary

to determine the surgical procedure according to the symptom. The purpose of this study is to investigate the surgical procedure for OVF in the lower lumbar spine and the number and range of fixation levels in the fusion surgery.

Methods: Two-hundred and sixty-eight patients (50 males, 218 females; average age, 76 years) who underwent surgery for OVF during the 10 years from 2009 to 2018 in the Akita Spine Group were evaluated. The number of operations for OVF in the lower lumbar spine, surgical procedure, ratio of fusion surgery, number of fixation levels, and fixation range for OVF in the lower lumbar spine were examined.

Results: The number of surgeries for OVF in the lower lumbar spine was 52 (19%; 8 males, 44 females; average age, 77 years). As for the surgical method, posterior lumbar interbody fusion was the most common in 26 cases, posterior decompression fusion (PSF) in six cases, posterior vertebroplasty+PSF in four cases, lateral vertebral replacement+PSF in two cases, lateral interbody fixation+PSF in one case, decompression only in four cases, and percutaneous vertebroplasty in nine cases (L3: five cases, L4: three cases, L5: one case). Fusion surgery was performed in 39 cases (75%), and the number of fusion levels were one in six cases, two in 11 cases, three in three cases, four in seven cases, and five or more in 12 cases. Upper instrumented vertebra was middle or lower thoracic vertebrae (T8–12) in 11 cases, L1 in four cases, L2 in nine cases, L3 in 11 cases, and L4 in four cases. Lower instrumented vertebra was L3 in one case, L4 in six cases, L5 in 18 cases, S1 in five cases, and pelvis in nine cases.

Conclusions: Surgery for OVF in the lower lumbar spine accounted for 19% of surgery for OVFs. Of these, 75% had fusion surgery, but the range of fixation varied from single to multi-level fixation.

PS-FP-2-17

Clinical Relationship between Spinopelvic Alignment and Lumbar Spinal Canal Stenosis in Patients with Rheumatoid Arthritis

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Purpose: To elucidate the spinopelvic parameters associated with lumbar spinal canal stenosis (LSS) in rheumatoid arthritis (RA) patients.

Overview of Literature: RA is a systemic inflammatory disease that can cause joint destruction and deformity. Cervical spine involvement of RA (e.g., atlantoaxial subluxation) is well documented, but the clinical relationship between the spinopelvic alignment and lumbar spine involvement remains unclear.

Methods: A total of 73 outpatients with RA were enrolled. Patients who underwent any spine surgery were excluded. LSS was diagnosed in cases with clinical symptoms and lumbar magnetic resonance imaging findings (grade ≥ 2 in the Lumbar Stenosis Index), and patients were divided into two groups: group S (with LSS) and group NS (without LSS). The spinopelvic parameters on whole-spine standing radiography were analyzed, including the thoracic and lumbar Cobb angle, C7 sagittal vertical axis (C7-SVA), thoracic kyphosis, pelvic tilt (PT), sacral slope, pelvic incidence (PI), lumbar lordosis (LL), and PI–LL mismatch.

Results: Seventeen of the 73 patients (23.3%) were diagnosed with LSS (S group), leaving 56 patients (76.7%) in the NS group. In the univariate analysis, there were no significant differences in the age or sex between the two groups. However, patients in the S group showed a greater value of PT (47.5 vs. 33.8, $p=0.020$), C7-SVA (48.0 vs. 33.7, $p=0.015$), and PI–LL (49.2 vs. 33.3, $p=0.007$) than those in the NS group. A logistic regression analysis showed that the PT (odds ratio [OR], 1.098; $p=0.015$) and C7-SVA (OR, 1.017; $p=0.021$) were factors independently associated with LSS in RA patients.

Conclusions: As with non-RA patients, sagittal spinopelvic parameters, such as the PT and C7-SVA, were clinically important in RA patients with LSS.

PS-FP-2-18

Lumbar Disc Degeneration and Vertebral Fracture at Thoracolumbar Junction Are Risk Factors for Chronic Low Back Pain with Disability: The Wakayama Spine Study

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Purpose: To elucidate the risk factors of chronic low back pain (CLBP) among degenerative changes on magnetic resonance imaging (MRI) in a general population.

Overview of Literature: It is still controversial about the relationship between the degenerative changes on MRI and CLBP. Disc degeneration (DD), vertebral deformity due to osteoporotic fracture, and spinal stenosis have been reported as possible causes of CLBP. However, these degenerative changes are often coexisting and may confound each other as the cause of CLBP.

Methods: This is a longitudinal study using an established population-based cohort in Japan. A total of 1,009 subjects who participated in the baseline survey of the Wakayama Spine Study (AD 2008-9) were subjected to the MRI evaluation. Lumbar DD (Phirrmann's classification: grade 1-5), and morphometric fracture of the vertebral bodies (semi-quantitative method: SQ grade 0-3) were evaluated on the sagittal MRI. Lumbar spinal stenosis (Suri's classification: grade 0-3) was evaluated on the axial MRI. In the third survey of the Wakayama Spine Study (AD 2015-6), we followed-up 663 subjects (men 219, women 444; age at the baseline, 62±13 years) and got the information on the presence of CLBP (continued more than 3 month) and Oswestry Disability Index (ODI). The relationship between the degenerative changes at the baseline and the presence of chronic LBP with disability (ODI% ≥21) after 7 years was determined using multiple logistic regression analysis including mental component summary scale of

the 8-item Short Form Health Survey, smoking habit, age, sex, and body mass index (BMI) as the explanatory variables.

Results: The prevalence of disabled CLBP was 91/663 (13.7%). Significant risk factors at baseline for the disabled CLBP after 7 years were age (+1 year: odds ratio [OR], 1.07; 95% confidence interval [CI], 1.03-1.10), sex (female: OR, 3.69; 95% CI, 1.83-7.44), BMI (+1 kg/m²: OR, 1.11; 95% CI, 1.02-1.20), sum of the lumbar disc degeneration grade (L1/2-L5/S, +1 point: OR, 1.14; 95% CI, 1.01-1.30), and sum of the SQ grade at the thoraco-lumbar junction (T11-L1, +1 point: OR, 1.32; 95% CI, 1.10-1.60).

Conclusions: Lumbar DD and vertebral fracture at thoracolumbar junction were risk factors for CLBP with disability in the general population. Other factors that may cause CLBP have been reported in addition to our evaluated items. The lack of them is the limitation of this study. However, we consider the results of this study extremely important both epidemiologically and clinically, because there are few longitudinal studies on spinal degeneration and related disability.

PS-FP-2-20

Advanced Glycation End Products Are Associated with the Intensity of Back Pain Symptoms in Patients with Lumbar Spinal Stenosis

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Purpose: Advanced glycation end products (AGEs) affect cells and trigger the generation of free radicals and expression of inflammatory gene mediators and are thought to be one factor in aging. We clarified the association of decreasing muscle mass in men and increasing fat mass in women with increasing AGEs. However, there has been no report of skin autofluorescence (AF) in patients with low back pain. Skin AF associated with the content of AGEs, such as pentosidine in skin biopsies, has been

reported as a non-invasive method of measuring AGE deposition by emission of a characteristic fluorescence. In the present study, we measured the relationship between AGEs and intensity of low back pain, lower limb pain, and numbness in patients with lumbar spinal canal stenosis (LSS) for clarifying the degeneration to muscle or nerve system.

Methods: Among the 160 LSS patients that were treated at our center from September 2017 to May 2019, 44 patients were excluded due to diabetes because diabetes were reported to be associated with AGEs. A total of 116 people were included in this study. LSS was diagnosed by spinal surgeons through examination and magnetic resonance imaging. AF was measured by placing the device RQ-AG01J (Sharp Life Science Corp., Tenri, Japan) for 30 seconds with the AGEs. Intensity of low back pain, lower limb pain and numbness were measured quantitatively by Numerical Rating Scale (NRS), and the relationship with AF value was analyzed by Spearman's rank correlation coefficient. Significance level was 5% or less.

Results: The subjects were 46 men (average age, 73.9 years) and 70 women (73.6 years). The average AF was 0.51 ± 0.12 and the average NRS was 4.6 ± 2.7 for low back pain, 5.1 ± 2.8 for lower limb pain, and 4.2 ± 3.0 for lower limb numbness. The correlation coefficient between AF and NRS was low back pain and $\rho = 0.20$ ($p < 0.05$), on the other hand, lower limb pain and $\rho = 0.15$ ($p = 0.14$), lower limb numbness and $\rho = 0.07$ ($p = 0.5$).

Conclusions: AGEs that accumulate in the body with aging and RAGE which is a receptor for the AGEs, may cause degeneration to muscle or nerve systems. However, in this study, accumulation of AGEs and low back pain were significantly associated with LSS patients, but no significant association with lower limb symptoms was found. Therefore, the accumulation of AGEs may cause degeneration of muscle rather than neurodegeneration.

PS-FP-2-21

Patient-Reported Outcome of Lower Extremity Improved after Posterior Decompression and Lumbar Interbody Fusion for Degenerative Lumbar Diseases

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Purpose: There were no reports to evaluate the lower extremity functional outcome with lower extremity patient-reported outcome measures (PROMs) after lumbar spine surgery. Thus, the purpose of this study is to elucidate the change of hip and knee PROMs after lumbar interbody fusion and to evaluate the spinopelvic sagittal radiographic parameter most correlated with lower extremity PROMs.

Methods: In 2018, the patients who underwent lumbar interbody fusion surgery with three levels or less were consecutively evaluated. Pre- and postoperative 1-year clinical and radiographic data were assessed. Functional outcome of the spine was measured by the PROMs including Oswestry Disability Index, Visual Analog Scale for pain, Scoliosis Research Society form, and that of lower extremity by Harris Hip Score (HHS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). The linear regression was used to evaluate the relationship of the spine and lower extremity PROMs with spinopelvic radiographic parameters.

Results: A total of 67 patients (mean age, 66.4 years) were enrolled. The average number of fused vertebrae was 1.7. Spinopelvic parameters including lumbar lordosis (LL), pelvic tilt (PT), C7 sagittal vertical axis, and sagittal radiograph of hip and knee were significantly improved after surgery. All the PROMs we have checked improved significantly after the surgery including HHS and WOMAC (HHS, $p = 0.042$; WOMAC, $p = 0.033$). With linear regression test, HHS and WOMAC correlated with LL and PT, respectively (HHS with LL, $\beta = 0.554$, $p = 0.043$; WOMAC with PT, $\beta = 1.573$, $p = 0.021$)

Conclusions: The current study demonstrated that posterior decompression and lumbar interbody fusion surgery could expect postoperative improvement of lower extrem-

ity functional outcome as well as radiographic improvement of spine and lower extremities. Among radiographic parameters, however, LL and PT should be noted as whose changes were most associated with the lower extremity PROMs.

PS-FP-2-22

Prevalence and Characteristics of Osteoporotic Vertebral Fracture in Elderly Patients with Sagittal Imbalance

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Purpose: Osteoporotic vertebral fracture (OVF) is a widely known cause of sagittal imbalance in elderly people, but its prevalence and characteristics remain unclear. The aim of this study was to determine the prevalence and characteristics of OVF in elderly patients with sagittal imbalance.

Methods: This study enrolled 1,962 patients who underwent whole-spine radiography at our hospital or related institutions. We included patients aged ≥ 65 years who had no history of spinal fusion or hip/knee surgery and no history of Parkinson's disease. We evaluated the Genant classification of OVF and calculated the spinal deformity index (SDI) for each lesion (thoracic, thoracolumbar, and lower lumbar) by summing the grade of each vertebra. The Visual Analog Scale (VAS) score for low back pain, Oswestry Disability Index (ODI), and EuroQol five-dimension (EQ5D) were used in the clinical evaluation. First, the patients were divided into the following groups: sagittal vertebral axis (SVA) < 40 mm (SVA40 group), $40 \text{ mm} \leq \text{SVA} < 95$ mm (SVA40–95 group), and $95 \text{ mm} \leq \text{SVA}$ (SVA95 group). The prevalence of OVF in each group was investigated. Next, multivariate ordinal logistic regression analysis was performed to analyze the relationship be-

tween the severity of SVA and OVF. Finally, clinical scores were compared with or without OVF in each group.

Results: A total of 965 patients (mean age, 74.4 years; 483 women) were included. The prevalence of OVF (Genant class ≥ 2) was 11.4% in the SVA40 group, 19.1% in the SVA40–95 group, and 37.7% in the SVA95 group. Age (odds ratio [OR], 1.86), female sex (OR, 1.56), and SDI at the thoracolumbar spine (OR, 1.23) significantly affected the severity of SVA ($p < 0.01$). In the SVA40 group, the VAS score for low back pain (41.8 vs. 26.7), ODI (26.3 vs. 17.5), and EQ5D (0.73 vs. 0.82) were significantly poor in patients with OVF ($p < 0.01$), but the differences in all clinical scores with or without OVF were not significant in the SVA95 group.

Conclusions: The prevalence of OVF in elderly patients with severe kyphosis was 37.7%. It was significantly higher than that in the other groups. SDI of the thoracolumbar lesion affected sagittal imbalance. Furthermore, no significant difference in clinical scores was found in patients with severe spinal malalignment due to the presence of OVF. On the other hand, the presence of OVF affected the back pain and quality of life of patients with mild sagittal imbalance.

PS-FP-2-26

Effect of Segmental Lordosis on Early-Onset Adjacent Segment Disease after Posterior Lumbar Interbody Fusion

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Purpose: Although several reports have described adjacent segment disease (ASD) after posterior lumbar interbody fusion (PLIF), there have been only few reports focusing on early-onset ASD. The purpose of this study was to investigate the prevalence, the postoperative pathologies, and the relation with the radiological parameters such as segmental lordosis (SL) of early-onset ASD.

Methods: A total of 256 patients, who underwent single segment PLIF at L4/5 for degenerative lumbar spondy-

olisthesis (DS) and were followed up for at least 5 years, were reviewed. The definition of ASD was symptomatic condition requiring additional operation at the adjacent fusion segment. ASD occurring within 3 years after primary PLIF was categorized as early-onset ASD. As a control group, 54 age- and sex-matched patients who have not suffered from ASD for more than 10 years were selected from this series. The following were investigated: (1) prevalence of ASD at postoperative 3, 5, 10 years and the final follow-up period; (2) postoperative pathologies of early-onset ASD; (3) comparison of the radiological results between the ASD and control groups; and (4) the relation between radiological parameters and early-onset ASD.

Results: There were 42 patients with ASD at the final follow-up. ASD prevalence at postoperative 3, 5, 10 years and the final follow-up period were 5.0%, 8.2%, 14.1%, and 16.4%, respectively. With respect to ASD pathologies, lumbar disc herniation (LDH) was significantly more common in early-onset ASD, while lumbar spinal canal stenosis and DS occurred more frequently in late-onset ASD. Significant differences were detected in postoperative range of motion (ROM) and the change amount of ROM at L3/4 (cranial adjacent fusion segment), and the change amount of SL (Δ SL) at L4/5 (fused segment), while there was no difference in other pre- and postoperative parameters. Stepwise logistic regression analysis showed that Δ SL was identified as an independent variable ($p=0.008$). Δ SL demonstrated significant difference, especially in early-onset ASD (control, 1.1° ; overall ASD, -2.4° , $p=0.002$; early-onset ASD, -6.6° , $p=0.00004$). According to the statistical analysis, increasing Δ SL by 1° resulted in an odds ratio of 0.854 at which ASD occur. The cut-off value for Δ SL on the receiver operating characteristic curve to identify ASD was -0.5° (sensitivity 67%, specificity 62%).

Conclusions: LDH was significantly more common as a pathology in early-onset ASD. Δ SL was a major risk factor for ASD, especially in early-onset ASD. Surgeons should try not to reduce the SL compared to before surgery.

PS-FP-2-27

Facet Joint Opening on Computed Tomography Is a Predictor for Poor Clinical Outcomes after Less-Invasive Decompression Surgery for Lumbar Spinal Stenosis

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Purpose: Postoperative instability after decompression alone procedures for lumbar spinal stenosis (LSS) often become problematic, especially in patients with segmental instability at index lumbar level. It has not been clarified what is the best useful parameter evaluating segmental instability in LSS. Facet joint opening was reported as an indicator for segmental spinal instability by an experimental study. However, no study has investigated the impact of facet joint opening on clinical outcomes after decompression alone surgery. The purpose of this study was to investigate impact facet joint opening on clinical outcomes after less-invasive decompression surgery for LSS in a retrospective longitudinal cohort study

Methods: This study included 296 patients who underwent less-invasive surgery for LSS and have followed up ≥ 5 years in one institution. Facet opening was defined as a width of >2.0 mm at the middle images of each facet joint in the axial plane of preoperative computed tomography. We focused on facet joint opening at index decompression level (d-FJO) and ≥ 3 levels of facet joint opening within lumbar segment (m-FJO). Clinical outcomes were investigated regarding reoperations, improvement ratio of Japanese Orthopaedic Association (JOA) score, and achievement of minimal clinically important difference (MCID) of Visual Analog Scale (VAS) for low back pain (LBP) or leg pain at 5 years. Clinical outcomes were compared between patients with and without d-FJO or m-FJO.

Results: The d-FJO were observed in 129 patients (44%); more common in case with lateral olisthesis. The m-FJO were observed in 62 patients (21%); less common in case with spondylolisthesis. Reoperations were more common in patients with d-FJO (15% vs. 5%). Cox proportional hazard analysis indicated d-FJO were predictor for revision at index decompression level (hazard ratio [HR], 4.04;

$p=0.03$), and m-FJO for revision at other lumbar levels (HR, 3.71; $p=0.03$). Patients with m-FJO showed slightly lower rate of achieving MCID of VAS for LBP (34% vs. 52%, $p=0.03$), and poorer improvement of JOA score (74% vs. 80%, $p=0.03$).

Conclusions: The facet joint openings, not only that at index level but also multi-level facet joint opening, were predictor for poor outcomes. Patients with facet joint opening should be carefully selected surgical strategy, or followed with special attention.

PS-FP-2-29

Osseous Union after Posterior Lumbar Interbody Fusion: Pay Attention to Large Interbody Angle

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Purpose: Posterior lumbar interbody fusion (PLIF) has been reported to have a high rate of osseous union, but there are some cases of poor results due to lack of osseous union. Poor contact between the vertebral endplate and the grafted bone has been reported as a factor for failure of osseous union. In this study, we focused on the local intervertebral angle and the shape of the endplate as factors that may lead to poor contact between the endplate and the grafted bone, and investigated the effects on interbody osseous union after PLIF.

Methods: A total of 116 patients (63 males and 53 females; mean age, 67 years) who underwent single-level PLIF at 11 institutions (Hamamatsu University School of Medicine, University of Yamanashi, Shinshu University, and their affiliated hospitals) were included in the study. The intervertebral angle (the angle between the inferior

endplate of the upper vertebral body and the superior endplate of the lower vertebral body), the depression of the endplate (the distance between the line connecting the anterior and posterior endplates and the most depressed area in the center of the endplate), the gap between the endplate and the cage (the three points of the cage, anterior, middle, and posterior) in the immediate postoperative computed tomography (CT). The intervertebral osseous union was measured by CT 1 year after surgery. The results were divided into two groups: the union group (U group) and the nonunion group (N group).

Results: Fifty-four patients (47%) showed osseous union (U group), while 62 patients (53%) did not (N group). The mean preoperative intervertebral angle was 4.8° in U group and 7.8° in N group ($p<0.05$). The mean preoperative intervertebral angle was 4.8° in U group and 7.8° in N group ($p<0.05$). The depression of the endplate was 2.6 mm in U group and 2.8 mm in N group ($p=0.48$). The anterior cage gap was 0.7 mm in U group and 1.5 mm in N group ($p<0.05$), the middle was 0.7 mm and 1.4 mm ($p<0.05$), and the posterior was 0.4 mm and 0.4 mm ($p=0.14$). The intervertebral bone fusion rate between vertebrae with an intervertebral angle of 10° or less was 54%, whereas the intervertebral bone fusion rate between vertebrae with an intervertebral angle greater than 10° was 19%.

Conclusions: The intervertebral osseous union rate was significantly lower in the intervertebral space with a larger intervertebral angle.

PS-FP-2-30

Symptomatic Post-surgical Lumbar Pseudomeningocele Treated by Ultrasound Guided Blood Patch Application: A Case Report

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Purpose: Post-surgical pseudomeningoceles are extradural collections of cerebrospinal fluid (CSF) that result following an intraoperative dural breach. Though usually asymptomatic and self subsiding, they may present with symptoms of postural headache, blurred vision, diplopia, photophobia, back pain, radiculopathy, and vomiting.

Most of the cases recover with conservative measures like bed rest, hydration, and pressure dressings. Symptomatic patients usually require surgical re-exploration and direct open repair of the durotomy. We report a case of 48-year-old female who presented with lumbar pseudomeningocele following lumbar microdiscectomy. She was treated with pseudomeningocele aspiration and application of blood patch.

Methods: A 48-year-old lady presented at our hospital with a fluctuant, globular swelling on her back 1-month post microdiscectomy for L4–L5 disc prolapse. She also had back pain, left lower limb radiculopathy and postural headache. She had no neurologic defect. Magnetic resonance imaging (MRI) showed left L4 laminectomy defect with a pseudomeningocele having an ill-defined CSF intensity collection in posterior paraspinal region measuring 5.5×4.2×4 cm. We treated the case by ultrasound (USG)-guided CSF aspiration from the pseudomeningocele and application of epidural blood patch.

Results: We treated the case by USG-guided CSF aspiration from the pseudomeningocele and application of an epidural blood patch. Under all aseptic precautions, L3–L4 and L4–L5 spaces were identified, and CSF was aspirated from the pseudomeningocele at L4–L5 space with a Tuohy needle. At the same time, 20 mL of blood was drawn from the antecubital vein, followed by 10 mL blood injection at L4–L5 and 10 mL at L3–L4 epidural space under USG guidance. The patient was made to sit for 15 minutes. Her postural headache and lower limb radiculopathy were immediately relieved following the procedure. She was symptom-free 1 year post-surgery with full resolution of pseudomeningocele on MRI.

Conclusions: Most of the post-surgical pseudomeningoceles are asymptomatic and resolve either spontaneously or with conservative methods. Various treatment options like close observation for spontaneous resolution, conservative measures such as bed rest, lumbar subarachnoid drainage, pressure dressings, hydration, use of an abdominal binder, have been recommended. Re-exploration and surgical repair of defect should be reserved for those cases presenting clinically with the features of intracranial hypotension, neurological worsening, external fistula, or infection. In our case, we successfully treated a pseudomeningocele by aspiration and blood patch application one level above the pseudomeningocele and also inside the cavity.

PS-FP-2-31

Titanium Cages May Be Superior to Polyetheretherketone Cages in Lumbar Interbody Fusion: A Systematic Review and Meta-Analysis of Clinical and Radiological Outcomes

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Purpose: Interbody cages are commonly used to augment interbody fusion. Commonly used materials include titanium (Ti) and polyetheretherketone (PEEK), with their inherent differences. The aim of this study is to perform a systematic review and meta-analysis to compare the various clinical and radiological outcomes of Ti and PEEK interbody spinal cages.

Methods: A systematic review and meta-analysis comparing clinical and radiological outcomes between Ti and PEEK interbody cages in patients undergoing spinal fusion was performed. PubMed, Scopus, Web of Science, Embase, and Cochrane Central Register of Controlled Trials database were searched. All studies that compared the clinical and radiological outcomes of patients who underwent Ti and PEEK cages were included. Subgroup analyses were performed to differentiate between patients who had a cervical and lumbar interbody fusion.

Results: A total of 11 articles were identified, with a total of 743 patients. Spinal fusion rates at final follow-up did not differ between Ti and PEEK cages (odds ratio [OR], 1.50; 95% confidence interval [CI], 0.57–3.94; $p=0.41$), although in patients undergoing lumbar fusion, Ti cages demonstrated superior fusion (OR, 2.12; 95% CI, 1.05–4.28; $p=0.04$). In patients with non-infective etiologies, Ti cages had a higher rate of cage subsidence (relative risk, 2.17; 95% CI, 1.13–4.16; $p=0.02$). Both types of cages had similar operating time, postoperative hematoma formation, neuropathic pain, segmental angle correction, and postoperative clinical outcome improvement.

Conclusions: In non-infective lumbar spine conditions, Ti cage may be the superior option due to the higher fusion rate.

PS-FP-2-32

Risk Factors for Postoperative Ileus after Oblique Lateral Interbody Fusion: A Multivariate Analysis

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Purpose: Oblique lateral interbody fusion (OLIF) has become a widely used, efficient surgical tool for various degenerative lumbar conditions. Postoperative ileus (POI) is a relatively common complication after anterior lumbar interbody fusion due to the manipulation of the intestine during the surgical approach. However, to our knowledge, little is known about POI following OLIF even though it also involves bowel manipulation during a surgical procedure. The aim of the present study is to assess the incidence of POI and identify independent risk factors for POI development after OLIF.

Methods: A retrospective analysis was performed for all consecutive patients who underwent OLIF from August 2012 through October 2019 at a single institution. POI was defined as two or more of the following criteria met on or after the postoperative day 3: (1) nausea or vomiting, (2) the absence of flatus or stool, (3) inability to tolerate an oral diet over a 24-hour period, (4) abdominal distention, and (5) radiologic confirmation. Patients with POI were identified by review of hospital stay medical records. The subjects were divided into two groups: patients with POI and those without POI. Binary logistic regression analyses were performed on demographic, comorbidities, and perioperative factors to identify independent risk factors for POI.

Results: Eighteen (3.9%) of 460 patients experienced POI after OLIF and percutaneous pedicle screw instrumentation. Patients with POI had a significantly longer postoperative length of hospital stay than those without POI (8.61±2.66 vs. 6.48±2.64, $p=0.001$). Multivariate logistic regression analysis identified inadvertent endplate fracture (adjusted odds ratio [aOR], 6.017; $p=0.001$) and the amount of intraoperative remifentanyl (aOR, 1.057; $p=0.024$) as independent risk factors for the occurrence of POI following OLIF.

Conclusions: This study identified inadvertent endplate fracture and the amount of intraoperative remifentanyl as independent risk factors for the development of POI after OLIF.

PS-FP-2-36

A Rare Case of Idiopathic Dorsal Spinal Cord Herniation Perforating the Lamina

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Purpose: Spinal cord herniation (SCH) is a rare condition associated with tethering of the spinal cord at the ventral dural defect. Idiopathic dorsal SCH (IDSCH) is an extremely rare disease condition. To our knowledge, there are no reports of IDSCH perforating the lamina. Here, we describe a rare case of IDSCH perforating the lamina in a 74-year-old female patient with a history of ossification of the ligamentum flavum (OLF) and diffuse idiopathic skeletal hyperostosis (DISH).

Methods: A 74-year-old female presented with difficulty in ambulation. The patient felt a sense of discomfort with her right lower extremity 5 years ago, and she noticed numbness and weakness 6 months prior to presentation. On her neurological examination, the patient showed motor weakness in the right lower extremity. Decreased sensation and impaired proprioception were observed in the right lower extremity. She also had urological symptoms. Her magnetic resonance images demonstrated that the spinal cord deviated from the midline and migrated into the right L1 lamina. Her computed tomography myelogram demonstrated OLF at the thoracolumbar spine.

Results: Because her symptoms progressively deteriorated, a surgical treatment was performed. A laminectomy of Th12 and L1 was performed, followed by the untethering of the spinal cord. Because there was severe adhesion between the ossified dura and lamina, diffuse dural ossification was removed entirely. Although her motor weakness

worsened immediately after surgery, it had recovered and markedly improved at 3 months after surgery compared to preoperative findings. Urological symptoms did not improve, and impaired proprioception in the right lower extremity remained during her follow-up.

Conclusions: Here, we reported a rare case of IDSCH perforating the lamina in a patient who had a history of OLF and DISH. Untethering of the spinal cord was performed by removing the surrounded ossified dura. Although urological symptoms and impaired proprioception remained, motor weakness markedly improved, and progressive neurological deterioration was prevented after surgery. Because this disease condition is extremely rare, it should be differentiated from other spinal disorders and ventral SCH.

PS-FP-2-37

Discogenic Low Back Pain Can Be Diagnosed with an Ultrasonographic-Guided Disc Pain Induction Test

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Purpose: Diagnosis of discogenic pain includes physical findings and magnetic resonance imaging (MRI) findings. However, when there are degenerations in multiple discs, it is difficult to identify the responsible segment. The ultrasonographic-guided disc pain induction test that we have developed manually applies compression to the disc while confirming the level of the disc using ultrasonography from the ventral side. We can easily and accurately detect the responsible segment of discogenic pain by using this method. The purpose of this study is to examine the usefulness of the ultrasonographic-guided disc pain induction test in the diagnosis of discogenic pain.

Methods: The subjects were 27 cases (mean age, 45 years) who visited an orthopedic outpatient clinic with a chief complaint of low back pain. All of them had induced pain in the ultrasonographic-guided disc pain induction test.

Disc tenderness from L1/2 to L5/S was confirmed and MRI was performed in all cases. In addition, disc injection using local analgesic was performed on the applicant, and the Visual Analog Scale (VAS) before and after the injection was measured. The relationship between the tender level of disc and MRI findings was examined, and the effect of disc injection was evaluated by using VAS before and after the injection.

Results: A total of 40 discs had induced pain. Seventeen cases had tenderness at one disc, seven cases had tenderness at two discs, and three cases had tenderness at three discs. Among the 27 discs with the strongest tenderness, all cases had disc degeneration of Pfirrmann classification grade 2 or higher. Regarding the Modic type, of the 27 intervertebral discs, two intervertebral discs were type 1, four intervertebral discs were type 2, one intervertebral disc was type 4, and the rest were type 0. The herniated disc was found in 11 cases, and the high-intensity zone of MRI was found in eight cases. Disc injection was performed in 15 patients, and the pre-injection mean VAS was 9.6 and the post-injection mean VAS was 2.3. There was a significant improvement in pain after the disc injection.

Conclusions: In the ultrasonographic-guided disc pain induction test, there is a high association between the disc of strongest tenderness and disc degeneration. Moreover, it was found that the responsible segment can be identified even when multiple disc degenerations are observed. In conclusion, the ultrasonographic-guided disc pain induction test for discogenic pain can diagnose disc degeneration and identify the responsible segments.

PS-FP-2-38

Degenerative Lumbar Spondylolisthesis Patients with Movement-Related Low Back Pain Have Less Postoperative Satisfaction after Decompression Alone

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Purpose: Surgery for degenerative lumbar spondylolisthe-

sis (DLS) includes decompression alone and a decompression–fixation technique, both of which can yield poor performance. We investigated if preoperative factors could affect postoperative satisfaction after posterior lumbar interbody fusion (PLIF) and microendoscopic muscle-preserving interlaminar decompression (ME-MILD) in DLS patients.

Methods: In this retrospective analysis of prospectively collected multicenter observational data, we included 72 patients who underwent surgery for single-level mild DLS (PLIF: 79 patients; ME-MILD: 37 patients); however, 44 patients (PLIF: 31; ME-MILD: 13) were lost to follow-up. Postoperative satisfaction was considered poor when the Zurich claudication questionnaire subscale score exceeded 2 points. Clinical characteristics were investigated. Preoperative health-related quality of life questionnaires, such as the Japanese Orthopaedic Association back pain evaluation questionnaire (JOABPEQ), Short Form-36 Health Survey (SF-36) questionnaire, and Visual Analog Scale (VAS), were compared between satisfied and non-satisfied groups.

Results: No endogenous factors affected postoperative satisfaction in the PLIF group. In the ME-MILD cohort, the groups differed significantly in terms of preoperative lumbar spine dysfunction items of the JOABPEQ ($p < 0.001$), and the role physical ($p = 0.04$), and role emotional ($p = 0.03$) of the SF-36. Preoperative lumbar spine dysfunction and postoperative satisfaction correlated strongly ($r = 0.59$).

Conclusions: Preoperative lumbar spine function correlated with postoperative satisfaction in the ME-MILD group. In cases with presurgical decreased lumbar spine function, the effect of decompression alone for DLS may be limited. The surgical method should be selected considering the degree of low back pain upon movement.

PS-FP-2-39

Extraforaminal Stenosis at L2–L3 Treated with Microendoscopic Surgery: Report of Two Cases

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Purpose: The many cases of far-out syndrome that have been reported have involved extraforaminal stenosis at L5–S1. We report two cases of extremely rare extraforaminal stenosis at L2–L3.

Case 1: A 59-year-old man presented with a half-year history of right leg pain. Radiological examination revealed stenosis of the right L2 spinal nerve between the osteophyte of the vertebral body and the L3 right transverse process. The right L2 spinal nerve was decompressed with microendoscopic surgery. Postoperatively, the pain in the right lower extremity was relieved.

Case 2: An 80-year-old man presented with a half-year history of right leg pain. He had undergone posterior lumbar fusion (L4–L5 and L5–S1) approximately 30 years earlier. Radiological examination revealed stenosis of the right L2 spinal nerve between the osteophyte of the vertebral body and the L3 right transverse process. The right L2 spinal nerve was decompressed with microendoscopic surgery. Postoperatively, the patient had no symptoms and his course over the next 6 months was good.

Conclusions: In both cases, we performed microendoscopic decompression of the L2 spinal nerve with good postoperative results.

PS-FP-2-40

Giant Thoracic Disc Herniation Surgery

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Purpose: For thoracic disc herniation, we report thoracotomy, the main point of the giant thoracic disc herniation surgery by the transthoracic cavity method including

monitoring and navigation.

Case 1: A 47-year-old man presented with a chest sense of incongruity and gait disturbance. A neurologic finding: Tenoid sensory disturbance is detected in the T4–6. It showed sensory disturbance of the part more plantar than the left waist than lower limbs, the right lumbar part. Imaging: The mass lesion of the diameter 2-cm size with the calcification is remarkable in TH5/6. The surgery strategy is as follows: (1) a preoperative day marking, navigation, MEP, SEP; (2) using air mat, it is left lateral decubitus position; (3) an isolation lung awakening, the right thoracotomy, the right fifth intercostal space anterior thoracotomy, 6th rib rear resection; (4) it rises in the ventral aspect of the patients, and hernia is eliminated; and (5) after the hernial extraction, it is a closed chest.

Surgery: The practiced hand takes the ventral aspect of the patients with isolation lung ventilation, left lateral. Do skin incision in the fifth intercostal space anterior, and cut the fifth intercostal muscle open. After having separated the ligament around the costotransverse joint which we separated the 6th rib in a site of 1/3 rear, we cut a costotransverse ligament open. We cut pleura open at the costal head and separated an abrasion, joint of the head of the rib with costal periosteum and resected the 6th rib rear sequentially. Resected bones toward the body of vertebra than T5/6 foramen transthoracically and, using navigation, identified dura mater. Confirm that do not have liquorrhea, a closed chest. There are not postoperative new neurologic symptoms and becomes Japanese Orthopaedic Association score 10 just after an operation.

Conclusions: We classify a surgical method for the thoracic disc herniation roughly, and there is the 2 methods of a previous method and the latter method. There is little exclusion about the spinal cord, and the front approach method is an excellent surgical method. Because the effective head of surgery machinery and tools gets longer including drill, the simulation of enough machinery and tools is necessary. We reported the main point of the thoracotomy front surgical therapy for the thoracic disc herniation.

PS-FP-2-42

Occurrence Rate of Sacroiliac Joint Disorders before and after Lumbar Surgeries and Treatment Strategies

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Purpose: A scoring system to differentiate sacroiliac joint (SIJ) disorders (SIJDs) from lumbar spine diseases (lumbar disc herniation [LDH] and lumbar spinal stenosis [LSS]) has been developed with a sensitivity of 90.3% and specificity of 86.4% for a total score of 4 or greater. High scores before lumbar spine surgery are suspected to be combined with SIJDs, and high scores after lumbar surgery are suspected to be associated with new-onset SIJDs. The occurrence rates in patients with high SIJ scores before and after lumbar surgery and treatment strategies were investigated.

Methods: One hundred and twenty-four patients (76 men and 48 women; mean age, 67.7 years) who underwent surgery for LDH or LSS between September 2017 and August 2019 were included to investigate the frequency of patients presenting with pre- and postoperative SIJ scores of 4 points or greater.

Results: Six patients (four with LDH, two with LSS) showed neurological symptoms and physical findings suggestive of SIJDs preoperatively, and the physical findings of SIJDs in five of them were not detected after lumbar surgery. The remaining one patient exhibited neurological symptoms and back pain due to adjacent segment disease after L2–S1 fusion, as well as pain in the superior posterior iliac spine bilaterally, which were temporarily relieved after SIJ injections. Additional long fusion from Th10 to the SIJ was performed, and the findings suggestive of SIJD were not detected. Five patients (two with LDH, three with LSS) presented with high SIJ scores postoperatively for the first time, of which four were resolved with definitive diagnoses of SIJDs after SIJ injections.

Conclusions: High SIJ scores were found in 8.9% (11/124) of the patients, and definitive diagnoses of SIJDs were made in 8.0% (10/124). In patients with high preoperative SIJ scores, a combination of lumbar spine disease and SIJD should be suspected; however, if the neurological symptoms are mainly due to lumbar spine disease, lum-

bar spine surgery should be prioritized. In some cases, the neurological symptoms as well as the findings of SIJD were not detected after lumbar surgery, which may have reflected the reduced burden on the SIJ. Before long spinal fusion, the SIJ score should be examined to determine whether the SIJ should be included in long fusion surgery. New onset of SIJD may be possible when lower back pain flares up postoperatively. The SIJ score is useful to differentiate between recurrent LDH and inadequate decompression, thus avoiding unnecessary reoperation.

PS-FP-2-43

Technical Pitfalls During Sacroiliac Joint Arthrodesis for Patients with Sacral Dysmorphism Induced by Lumbosacral Transitional Vertebrae

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Purpose: Lumbosacral transitional vertebrae (LSTV) can cause sacral dysmorphism combined with sacroiliac articular morphological changes. During the sacroiliac joint (SIJ) arthrodesis/fixation through the anterior, posterolateral, or posterior approach, we have occasionally experienced technical pitfalls in patients with sacral dysmorphism induced by LSTV. This study aims to report some pitfalls during SIJ arthrodesis related with sacral dysmorphism induced by LSTV.

Methods: We evaluated 44 consecutive patients (17 men and 27 women; mean age, 44.9±13.6 years) who required SIJ arthrodesis for their severe SIJ pain between November 2005 and July 2017. LSTV was evaluated based on Castellvi's classification. The incidence of any LSTV was checked. The surgical records for the patients with LSTV were reviewed.

Results: Out of 44 patients, LSTV was observed in 7 (15.9%); Castellvi's type Ib in two, IIa in one, IIIb in three, and IV in one. A total of 50 joints were fixed as follows: 21 on the left side, 17 on the right side, and six bilateral. Regarding the surgical approach, 29 joints were fixed via the anterior, four via the posterolateral, seven via the posterior, and 10 via a combination of the anterior and postero-

lateral. During the surgery, three kinds of remarkable pitfalls were found in four out of seven patients with LSTV as follows. In the cases of a 34-year-old man with IIIb and a 39-year-old woman with IV, the most cranial sacral foramen was larger and irregularly round, and the nerve root ran to the lateral side from the deformed foramen more than usual. In these patients, a firm medial traction of the nerve root together with the psoas major muscle for the purpose of attaching a plate and inserting screws on the sacrum side in the anterior approach could cause the temporary radiculopathy. For a 26-year-old woman with a thin sacral alar due to IIIb, the most cranial screw penetrated the anterior margin of the sacrum and caused nerve root injury in the posterolateral approach. For a 35-year-old man with Ib, the screw insertions via the posterior were technically challenging due to the small sacrum body.

Conclusions: This study indicated three kinds of surgical pitfall in the SIJ arthrodesis for sacral dysmorphism induced by LSTV. These facts will be valuable when surgeons perform SIJ arthrodesis for patients with LSTV.

PS-FP-2-48

Association between Lumbar Segmental Mobility and Intervertebral Disc Degeneration Quantified by Magnetic Resonance Imaging T2 Mapping

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Purpose: The relation between segmental mobility and degree of lumbar degenerative change is still unknown. This cross-sectional study aimed to elucidate the association between intervertebral disc degeneration and segmental mobility in chronic low back pain using magnetic resonance imaging (MRI) T2 mapping.

Methods: Subjects comprised 60 patients (29 men, 31 women; mean age, 61.8±1.9 years; range, 41–79 years). T2 values of the anterior annulus fibrosus (AF), the nucleus pulposus (NP) and the posterior AF were evaluated with MRI T2 mapping. Facet joint degeneration was divided

into 4 grades using MRI. We analyzed the correlation between segmental mobility and T2 values of anterior AF, NP and posterior AF using multiple linear regression analysis adjusted for age and facet joint degeneration.

Results: The standardized partial regression coefficient of the anterior AF, NP, and posterior AF T2 values were 0.125 ($p=0.72$), 0.499 ($p<0.01$), and -0.026 ($p=0.11$), respectively, for the L1–2 level; 0.102 ($p=0.27$), 0.395 ($p<0.01$), and -0.094 ($p=0.20$), respectively, for the L2–3 level; 0.108 ($p=0.38$), 0.415 ($p<0.01$), and -0.050 ($p=0.51$), respectively, for the L3–4 level; 0.124 ($p=0.09$), 0.396 ($p<0.01$), and 0.025 ($p=0.73$), respectively, for the L4–5 level; and 0.011 ($p=0.89$), 0.443 ($p<0.01$), and 0.030 ($p=0.72$), respectively, for the L5–S1 level. There was a significantly positive correlation between segmental mobility and the T2 values of NP at L1–L2, L2–L3, L3–L4, L4–L5, and L5–S1. No significant correlations arose between segmental mobility and the T2 values of the anterior AF and the posterior AF at L1–L2, L2–L3, L3–L4, L4–L5, and L5–S1.

Conclusions: Characterization of the relationship between NP degeneration and lumbar segmental mobility may enhance our ability to evaluate the changes seen in kinematics of functional spinal unit.

PS-FP-2-49

Diagnostic Performance of Conventional Two-Dimensional Magnetic Resonance Image for L5–S Foraminal Stenosis

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Purpose: Three-dimensional magnetic resonance images (3D-MRI) has been reported to be useful to diagnose foraminal stenosis of the lumbar spine. Meanwhile, a conventional two-dimensional MRI (2D-MRI) is still used as the first-choice scan, despite a lack of evidence for its diagnostic performance in detecting intraforaminal and/or extraforaminal stenosis at L5–S segment. In this study, the diagnostic performance of 2D-MRI for foraminal stenosis were assessed by comparing with separately scanned 3D-MRI in the identical individuals.

Methods: Forty-six consecutive surgical cases with unilat-

eral L5 radiculopathy due to L5–S foraminal stenosis were included in this study (group F: 22 males and 24 females; mean age, 67 years; range, 25–75 years). The age and gender-matched 46 cases with unilateral L5 radiculopathy due to L4–5 intracanal stenosis were randomly selected (group C: 22 males and 24 females; mean age, 67 years; range, 25–75 years) as control. The sets of 2D- and 3D-MRI obtained from the total of 92 subjects were assessed by two blinded expert spine surgeons in randomized order in 4-week interval. The examiners were informed only of the laterality of the lesion in each patient, and asked to choose either of the following answers in each set of images of each patient; “absence of foraminal stenosis”, “intraforaminal stenosis”, “extraforaminal stenosis”, “coincident intraforaminal”, and extraforaminal stenosis”. Moreover, 2D- and 3D-MRI of randomly selected 10 cases were assessed twice by one examiner in 3-month interval. The intra- and interobserver reliability of 2D-MRI were evaluated using the kappa (κ) statistics. Thereafter, the discrepancies in interpretation on 2D- and 3D-MRI between two examiners were resolved by further discussion. Then, sensitivity and specificity of 2D-MRI in diagnosis of intraforaminal and extraforaminal stenosis was calculated, based on the premise that the evaluation by 3D-MRI is correct.

Results: The κ values for intra- and interobserver agreement for 2D- and 3D-MRI ranged from 0.74 to 1.0, respectively. By 3D-MRI, all the cases in group F were diagnosed to have foraminal stenosis (intraforaminal, 19; extraforaminal, 11; both, 16), and none in group C. Sensitivity and specificity of 2D-MRI for intraforaminal stenosis were 85.7 % and 87.7%, respectively, and for extraforaminal stenosis, 37 % and 98.5 %, respectively.

Conclusions: The diagnostic reliability and accuracy of 2D-MRI for intraforaminal stenosis seemed to be acceptable, but not for extraforaminal stenosis in our study. We need to keep in mind that 2D-MRI is not necessarily reliable in diagnosing extraforaminal stenosis at L5–S.

PS-FP-2-50

The Longitudinal Analysis to Determine Whether the Presence of Current Sexual Activities Among Elderly People Affect Low Back Pain or Not

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Purpose: Japan is one of the most rapidly aging country in the world. Low back pain (LBP) is the most frequent complaint among elderly in Japan, so LBP of the elderly is national burden. Exercise was reported to be effective for reduction of LBP among elderly patients. We hypothesized that sexual activity in the elderly might also be effective in reducing LBP. However, there was no study which investigated the association between sexual activity and LBP among elderly in Japan. The purpose of this study was to examine whether the presence of current sexual activities among elderly people affect LBP in future.

Methods: The subjects were 317 elderly people (aged ≥ 65 years; 130 males, 187 females) who participated in the longitudinal survey of the health status for elderly population in Japan. Based on the results of questionnaires, we classified those who had sexual intercourse within the past year into sexually active group, and those who did not have sexual intercourse in over a year into sexually inactive group. Baseline characteristics such as current Visual Analog Scale (VAS) of LBP, physical decline (the 25-question geriatric locomotive function scale [GLFS]) and marital status were compared between two groups. We investigate whether sexual activity among elderly people affect LBP in future using multiple regression analysis with the VAS of LBP in following year as the objective variable and age, gender, body mass index, baseline VAS of LBP, GLFS, marital status, and the presence of current sexual activities as explanatory variables.

Results: Totally, 23.3% (n=74) of participants reported to have current sexual activity. The current VAS of LBP was significantly higher in the sexually inactive group than active group (22.8/12.4 mm, $p < 0.01$), but just 0.8% (n=2)

of participants reported that their sexual activity was absent due to LBP. The sexually active group showed that they were younger (72.5/75.5 years, $p < 0.01$), less physical decline (GLFS: 5.7/11.5 patients, $p < 0.01$), more males (59.5/35.4%, $p < 0.01$), and more married (90.5/72.4%, $p < 0.01$). Multiple regression analysis showed that the presence of current sexual activity independently affected the VAS of LBP in following year ($\beta = -6.24$, $p = 0.01$).

Conclusions: This is the first to investigate the relationship of sexual activity and LBP among elderly in Japan. Our results showed that the presence of sexual activity among elderly people significantly affect the reduction of LBP. Just as exercise is favorable treatment for LBP, maintaining sexual activity in elderly may also be effective in reducing LBP.

PS-FP-2-51

Unilateral Lumbar Interbody Fusion versus Conventional Posterior Lumbar Interbody Fusion for Two Lumbosacral Segments: Clinical and Radiological Outcomes of 1-Year Follow-up

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Purpose: This study compared clinical and radiological outcomes of unilateral biportal endoscopic lumbar interbody fusion (ULIF) to those of conventional posterior lumbar interbody fusion (PLIF) for two lumbosacral segments.

Methods: Fifty ULIF (age, 67 ± 5 years) and 51 PLIF (68 ± 8 years) patients for two lumbosacral segments followed more than 1 year were selected. Parameters for surgical techniques (operation time, whether transfused), clinical results (Visual Analog Scale [VAS] for back and leg pain, Oswestry Disability Index [ODI]), surgical complications (dural tear, nerve root injury, infection, hematoma), and radiological results (cage subsidence, screw loosening, fusion) between the 2 groups were compared.

Results: The PLIF group demonstrated a significantly shorter operation time and more transfusions done than the ULIF group. The VAS for leg pain in both groups and for back pain in the ULIF group significantly improved at

1-week follow-up, while the VAS for back pain in the PLIF group significantly improved at 1-year follow-up. ODI scores improved at 1-year follow-up in both groups. Complication rates were not significantly different between groups. Fusion rates with definite and probable grades were not significantly different between groups.

Conclusions: ULIF is less invasive while just as effective as conventional PLIF in improving clinical outcomes and obtaining clinical fusion. However, ULIF has a longer operation time than PLIF. The authors suggest that the ULIF, which is a minimally invasive procedure, is an alternative treatment option for conventional PLIF.

PS-FP-2-53

How the Novel Modular Spine Blocks Affect the Adjacent Lumbar Spine on Finite Element Analysis?

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Study Design: Finite element model (FEM) study.

Purpose: To investigate whether novel modular spine blocks (MSB) of various structural designs and implantation methods would alter the force distribution of the treated segment, as well as disk stress and distribution of range of motion at the adjacent segments.

Overview of Literature: MSB is a novel device which can be inserted and assembled within the treated vertebra without requiring overly complex surgical techniques due to its simplistic mechanical design. Open reduction and internal fixation with MSB rather than augmentation with bone cement is an optimal alternative for treating vertebral compression fracture. However, little is known about how the biomechanical effects the MSB might have on the treated vertebrae.

Methods: A three-dimensional nonlinear FEM of the L3 implanted with MSB blocks was constructed. Various

structural designs (solid vs. hollow; 3-layered vs. 6-layered), implantation methods (unilateral vs. bilateral), and their effects were studied. The model was preloaded to 150 Nm before the effects of flexion, extension, torsion, and lateral bending were analyzed at the controlled ranges of motion of 20°, 15°, 8°, and 20°, respectively. Resultant intervertebral range of motion and disc stress, as well as intravertebral force distribution are analyzed at the adjacent segments.

Results: The MSB blocks provided similar levels of stability at the adjacent segments regarding intervertebral range of motion and disc stress. Under stress tests, the force distribution of the solid MSB blocks was shown to be evenly distributed within the vertebrae. The maximum stress value observed of the hollow, three-layered, unilaterally implanted MSBs is generally lower compared to that of solid, six-layered, bilaterally implanted MSBs.

Conclusions: The MSB blocks do not interfere with the intervertebral range of motion and creates no additional loading to the adjacent discs. The overall stabilization effect of the unilaterally implanted hollow three-layered MSBs blocks is not inferior to that of the bilaterally implanted solid six-layered MSB blocks.

PS-FP-2-54

Epidemiology and Burden of Osteoporotic Patients with Spine Fusion Procedures with Pedicle Screws in Japan: A Nationwide Claim Database Analysis

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Purpose: This study aims to describe the epidemiology of patients undergoing spinal fusion surgery with pedicle screws in Japan, their post-operative outcomes and the impact of osteoporosis.

Methods: Patients ≥ 18 years old who had spine fusion procedures with standard pedicle screws between 2010–2017 were identified using the Medical Data Vision Co., Ltd. (Tokyo, Japan) claim database. Osteoporotic patients were identified with diagnostic code M80, M81, or/and receipt of osteoporotic medication. Additional fixation instruments of interest were hooks, wires, hydroxyapatite coating stick, calcium phosphate bone/cement. Baseline characteristics, complications, re-admissions, spine-related re-operations, length of stay (LOS), and healthcare expenditures were extracted. Descriptive statistics and multivariable analysis were calculated to assess these endpoints.

Results: We identified 22,930 patients meeting the study criteria. Mean age was 67.3 years old and 51.22% were male. Osteoporotic patients represented 23.06%, with a mean age of 73.8 ± 8.58 years and mainly female (76.6%). The incidence of osteoporosis has increased by 67% from 2010 to 2016. Additional fixation instruments were required in 22.3% of osteoporotic patients vs. 10.9% of the overall population, with wires most used. In comparison with non-osteoporotic population, osteoporotic patients showed statistically significant higher rate of mechanical failures (1.2% vs. 0.6%, $p < 0.001$) and reoperations (9.0% vs. 6.1%, $p < 0.001$) at 24-month post-surgery. The median LOS (interquartile range) and inpatient total cost were higher with 26.0 days (19.0–42.0) vs. 21.0 (16.0–31.0) and 3.44 million Japanese yen (JPY) (2.59–4.77) vs. 2.70 (2.20–3.62). These poor bone quality patients would receive more often additional fixation instruments. In particular, 11.2% osteoporotic patients use wires in addition to pedicle screws, compared to 5.1% of non-osteoporotic patients; and 8.2% use hydroxyapatite coating stick vs. 3.0%, respectively. Despite these additional fixations, osteoporotic patients still showed statistically higher risk of spine related re-operation (11.9% vs. 8.21%, $p < 0.001$), longer LOS (median 34.0 vs. 24.0, $p < 0.001$), and higher total cost (4.45 vs. 3.19 million JPY, $p < 0.001$) compared to none. The multivariable analysis showed that factors like the complexity of the spinal fusion, osteoporosis, need for additional fixations, and renal failures are significantly associated with re-operations rates within 24 months post-surgery.

Conclusions: This first nationwide real-world claims database study highlighted an increasing burden of osteoporotic patients undergoing spine fusion surgeries in Japan. They had higher rates of postoperative complications and

reoperation than non-osteoporotic patients, even with additional fixations. The LOS is higher and incurred higher total healthcare expenditures. This underscores the need for improved spinal fixation for this high-risk patient group.

PS-FP-2-55

Short Segmental Lumbar Surgery Improves Health-Related Quality of Life without Limiting Activities of Daily Living: A Retrospective Study

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Purpose: Lumbar surgery improves the postoperative quality of life (QOL), but activities of daily living (ADL) is limited in long fusion. In the case of short segmental fusion, the effect on postoperative ADL is considered to be small, but there have been few reports and no comparison was made before and after the operation. To compare pre and postoperative ADL and QOL between lumbar short fusion and decompression.

Methods: Two hundred seventy-two patients who underwent surgery filled self-administered questionnaires (1-year preoperative and postoperative conditions), and 102 patients (the fusion group [F group] 53 cases, the decompression group [D group] 49 cases) participated in the study. ADL such as socks, nail clippers, and deep bows, etc. and manual work such as snow shoveling, weeding, and farming, etc. were examined. The Reflux Disease Questionnaire (RDQ), the 36-item Short Form Health Survey (SF-36: physical component summary [PCS], mental component summary [MCS], role/social component summary [RCS]), and spinal alignments were evaluated. Pre- and postoperative conditions were statistically compared.

Results: There were no significant differences between the two groups in age, sex, and the number of operation levels, ADL, and QOL. RDQ (the F group $10.8 \rightarrow 6.8$, the D group $11.0 \rightarrow 6.8$), PCS (the F group $26 \rightarrow 34$, the D group $26 \rightarrow 32$), and MCS (the F group $51 \rightarrow 54$, the D group $47 \rightarrow 54$) significantly improved in both groups postoperatively. RCS was significantly improved only in the D group ($35 \rightarrow 41$).

ADL tended to improve compared to preoperatively. In manual labor, the number of people who performed farming increased postoperatively, and the number of people who weeded and plowed snow decreased, but there is no significant difference between pre and postoperation. The spinopelvic sagittal parameters were not significantly different between the two groups pre and postoperation.

Conclusions: Short segmental lumbar surgery did not change ADL and improved QOL. The fixation had equivalent ADL and QOL to those after decompression, and there was no restriction due to fixation. Short-segmental lumbar surgery can be selected according to the patient's condition because the ADL required after surgery does not change depending on the surgical procedure.

PS-FP-2-56

Coronal Magnetic Resonance Imaging for Diagnosis of Lumbar Foraminal Stenosis: A Comparative Study of Reliability, Reproducibility, and Interpretation between T1 and T2-Weighted Images

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Purpose: As for imaging diagnosis of lumbar foraminal stenosis, T2-weighted coronal magnetic resonance imaging (MRI) of the lumbar spine, such as magnetic resonance–myelography has been mainly reported. Meanwhile, our group has been utilizing T1-weighted coronal imaging which seemed to distinguish nerve root and nerve-compressing factors easier. To date, there has been

no study compared the reliability or reproducibility between T1- and T2-weighted images objectively. This study aims to compare the reliability, reproducibility, and the features of diagnostic trends between T1- and T2-weighted lumbar coronal MRI.

Methods: The patients planned for posterior decompression surgery for unilateral L5 radiculopathy were prospectively registered. T1- and T2-weighted lumbar coronal MRI was obtained from each patient preoperatively. The patients who had immediate neurological improvement after posterior decompression surgery were included in this study as following: (1) 22 patients with L4–5 intracanal stenosis who underwent ipsilateral intracanal decompression (fenestration) and (2) 22 patients with L5–S foraminal stenosis who underwent ipsilateral lateral decompression. The lumbar coronal MRI of these 44 patients were assessed twice by five expert spine surgeons independently in random order with considerable time interval, for absence/presence of foraminal stenosis, and the side and the feature of stenosis when the examiner(s) judged as foraminal stenosis. Also, T1- and T2-weighted coronal MRI were compared about (1) the diagnostic accuracy, (2) intra- and inter-observer agreement by kappa (κ) statistics in round-robin of five examiners \times 2 trials, and (3) nerve compression factor(s) judged for foraminal stenosis, for diagnosis of L5–S foraminal stenosis.

Results and Conclusions: On diagnosis of L5–S foraminal stenosis by lumbar coronal MRI, the accuracy of T1- and T2-weighted images (WI) were 73.4% and 70.0%, respectively. The mean κ -values of T1- and T2-WI were 0.815 and 0.699 for intra-observer agreement ($p=0.039$), and 0.639 and 0.595 for inter-observer agreement ($p=0.002$), respectively. The intra- and inter-observer agreement were significantly higher in T1-WI. In the 12 patients with L5–S foraminal stenosis of which the accuracy rates were $\geq 80\%$ both in T1- and T2-WI, swollen nerve root and disc protrusion were detected more sensitively in T1-WI. In the nine patients with L4–5 intracanal stenosis of which the accuracy rates were $\leq 50\%$ both in T1- and T2-WI (i.e., misconceived as foraminal stenosis), there was no difference in misconceived nerve compression factors (false-positive) between T1 and T2-WI.

PS-FP-2-58

Intradiscal Vacuum Phenomenon: Radiological Factors to Predict the Selective Appearance and a New Morphological Classification System

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Purpose: Intradiscal vacuum phenomenon (IDVP), though frequently observed in the spinal radiographs, very little has been known about its pathophysiology and lacks a patient-oriented classification system required for documentation, referral, and research. We studied the radiological factors associated with the selective appearance of IDVP to understand the pathophysiology and evaluated a novel classification system.

Methods: We performed a retrospective case-control study on patients with low back pain with or without radiculopathy and divided them into cases and controls based on the presence of IDVP in the lumbar discs. The base demographic factors, radiographic factors including eccentric disc space narrowing and coronal listhesis on anteroposterior view, levels affected, diagnosis, sagittal angular motion difference (SAMD), and sagittal translational motion difference (STMD) on lateral stress views were documented. Magnetic resonance imaging evaluated for Pfirrmann grading, anterior longitudinal ligament (ALL) disruption, Modic changes, and IDVP signal intensity. IDVP was categorized into three major types (dot, linear, and dense) and five sub-types (anterior, middle, posterior, partial, and Pan), based on the morphology and location of vacuum phenomenon.

Results: Total 1,049 patients formed the study population, and 28.4% (295) patients had IDVP. Presence of IDVP was found to be significantly associated with older age (>60 years, $p<0.001$), eccentric disc space narrowing (26.3%, $p<0.001$), coronal listhesis (7.1%, $p<0.001$), all disruption (32.2%, $p<0.001$), higher Pfirrmann grade (≥ 3 , $p<0.001$) and type II Modic changes (68.9%, $p<0.001$), and higher SAMD (10.81 ± 4.61 , $p<0.001$). STMD was significantly less than the control group (0.88 ± 1.31 , $p<0.001$), but on sub-group analysis, the dense type had significantly more STMD (0.89 ± 1.51 , $p<0.001$) than a dot and linear type. IDVP was divided into three types based on morphology: dot (21.8%), linear (30.9%), and dense (47.4%). The dot

type was further divided into anterosuperior (19.21%) and anteroinferior (2.7%). The dense type was subdivided into anterior (10.9%), middle (25.8%), posterior (1.6%), partial (4%), and Pan (5.1%). The dense type had significant correlation with coronal listhesis (12.7%, $p<0.001$), higher SAMD (12.3 ± 4.26), STMD (0.89 ± 1.51 , $p<0.001$), and Pfirrmann grade.

Conclusions: The prevalence of IDVP was 28.4%. Irrespective of the primary lumbar disease, critical radiographic features including eccentric disc space narrowing, coronal listhesis, higher SAMD and STMD, all disruption, higher Pfirrmann grade, and Modic changes were essential for the development of IDVP. Dense type is common in patients with spinal instability, while dot and linear were noted more disc degeneration. IDVP needs to be categorized for documentation, research, and evaluating significance, and the novel morphology-based classification would guide it. These positive findings provide new insights and strengthen our understanding of IDVP.

PS-FP-2-60

The Characteristics of Degenerative Disc Disease: Pfirrmann versus Thompson Grading Systems

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Purpose: Intervertebral disc (IVD) degeneration is considered to be one of the main pathophysiological causes of low back pain. Several grading systems have been developed for both morphological and radiological assessment. The aim of this study was to assess the morphological and radiological characteristics of IVD degeneration and validate popular radiological Pfirrmann scale against morphological Thompson grading system.

Methods: Full spinal columns (vertebrae L1–S1 and IVD between them) were harvested from cadavers through an anterior dissection. Magnetic resonance imaging scans of all samples were conducted. Then, all vertebral columns

were cut in the midsagittal plane and assessed morphologically.

Results: A total of 100 lumbar spine columns (446 IVDs) were included in the analysis of the degeneration grade. Morphologic Thompson scale graded the majority of discs as grade 2 and 3 (44.2% and 32.1%, respectively), followed by grade 4 (16.8%), grade 1 (5.8%), and grade 5 (1.1%). The radiologic Pfirrmann grading system classified 44.2% of discs as grade 2, 32.1% as grade 3, 16.8% as grade 4, 5.8% as grade 1, and 1.1% as grade 5. The analysis on the effect of age on degeneration revealed significant, although moderate, positive correlation with both scales. Analysis of the agreement between scales showed weighted Cohen's kappa equal to 0.61 ($p < 0.001$). Most of the disagreement occurred due to a 1-grade difference (91.5%), whereas only 8.5% due to a 2-grade difference.

Conclusions: With the increase of the prevalence of intervertebral disc disease in the population, reliable grading systems of IVD degeneration are crucial for spine surgeons in their clinical assessment. While overall there is agreement between both grading systems, clinicians should remain careful when using Pfirrmann scale as the grades tend to deviate from the morphological assessment.

PS-FP-2-61

Efficacy of Caudal Neuroplasty versus Transforaminal Epidural Block for Radiating Pain Caused by Lumbar Foraminal Stenosis

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Purpose: Neuroplasty and trans-foraminal epidural block (TFEB) are representative procedures performed to relieve symptoms of spinal stenosis. In both procedures, radiocontrast dye is injected in order to identify the site of medicine administration. At this time, the dye shows various distribution patterns, but there were not many studies have been conducted on how the difference in the distribution pattern makes a difference in the treatment outcome. The purpose of this study was to divide the distribution patterns of radiocontrast dyes during neuroplasty and TFEB and to find out what differences in treatment results.

Methods: The study was conducted on patients who

underwent neuroplasty or TFEB for spinal stenosis and responded to the questionnaire survey. Neuroplasty and TFEB were divided into groups 1 and 2, respectively. In neuroplasty, the dye was confined only within the spinal canal as group 1a, and the dye was contrasted to the root as group 1b. In TFEB, the dye was penetrated into the canal as group 2a, and the dye only confined to the root as group 2b. Visual analog scale (VAS), Oswestry Disability Index (ODI), and EuroQol five-dimension (EQ5D) were followed for 6 months.

Results: Both groups 1 and 2 improved VAS, ODI, and EQ5D in final result. In both groups, VAS improved on the day 3, and in group 2 maintained improvement at 1 week, 1 month, and 6 months. Group 1 maintained improvement at 1 week and 1 month, but little worsening at 6 months. In the comparison between group 1 and group 2, VAS at 1 week and 1 month was lower in group 1, but at 6 months VAS was not different from group 2. There was no difference between groups 1a and 1b. There was no difference between group 2a and group 2b, but in VAS on day 3, although not statistically significant, group 2a was low ($p = 0.74$). When group 2a and group 2b were compared with group 1 respectively, 2a showed difference only in VAS on day 3, whereas group 2b showed significant difference in VAS on day 3, week 1, and month 1.

Conclusions: Neuroplasty showed lower VAS in early period than TFEB regardless of dye pattern. However, at 6 months, there was no difference from TFEB. In TFEB, the pattern of dye penetrated into the canal showed more less difference from neuroplasty.

PS-FP-2-62

Risk Factors Associated with Low Back Pain in Patients with Osteoporosis

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Purpose: Patients with osteoporosis often experience low back pain (LBP) despite no evidence of new compression

fractures. We performed multivariate analyses to identify factors that may affect LBP.

Methods: The data of 491 patients with osteoporosis were retrospectively reviewed. Data included patient age, sex, body mass index (BMI), bone mineral density of the lumbar spine, tartrate-resistant acid phosphatase 5b level (TRACP5b), trunk muscle mass (TM), sagittal vertical axis (SVA), existing vertebral fractures, secondary osteoporosis, Controlling Nutritional Status score, pain-related disorders (PD) and gait disturbance (GD) scores from the Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ), Oswestry Disability Index (ODI) scores, and Visual Analog Scale (VAS) scores for LBP. Patients with scores of 100 for each subsection of the JOABPEQ, ODI scores <12, or a VAS score <1 cm were considered to not have LBP (LBP [-] group). Multivariate analyses were used to determine variables associated with LBP.

Results: LBP defined by PD was associated with aging, high BMI, and high SVA. Aging, high TRACP5b, high BMI, low TM, high SVA, and more vertebral fractures were associated with LBP defined by GD. LBP defined by ODI score was associated with high BMI, low TM, high SVA, and more vertebral fractures, and LBP defined by VAS score was associated with high BMI, high SVA, and more vertebral fractures.

Conclusions: Aging, high bone turnover, obesity, low TM, spinal global sagittal malalignment, and a high number of VFs were potential independent risk factors of LBP in patients with osteoporosis. Especially, all factors of LBP scores including PD and GD for JOABPEQ, ODI score, and VAS score for LBP were associated with spinal global sagittal malalignment and obesity. However, bone mineral density (BMD), secondary osteoporosis, and nutritional status were unrelated to LBP scores. Other than pharmacotherapy to increase BMD, exercise therapy to treat low muscle mass, spinal global sagittal malalignment and obesity may prove effective in improving ADL due to LBP in osteoporosis.

PS-FP-2-66

Spinopelvic Parameters and Symptomatic Lumbar Degeneration in Nepalese Patients

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Purpose: Degenerative lumbar spine disease such as spondylolisthesis, lumbar disc herniation (LDH), and lumbar spinal stenosis (LSS) may be associated with different spinopelvic parameters. The load distribution and function may play a role in different pelvic anatomy and may be susceptible to development of spinal degeneration.

Methods: Patients with symptomatic lumbar spinal degeneration who presented to KMCTH from July 2018 to June 2020 were included in this cross-sectional observational study. Degenerative pathologies were classified as LDH, LSS, and degenerative spondylolisthesis (DSPL). The anatomic pelvic parameters pelvic incidence (PI), pelvic radius (PR), and sacral table angle (STA) were assessed in lateral radiographs and compared between pathologies.

Results: Two hundred and six fulfilled all inclusion criteria and were analyzed with mean age 51.61 years (range, 23–87 years). The mean PI for women ($57.23^\circ \pm 3.24^\circ$) was significantly larger ($p=0.005$) than that for men ($56.19^\circ \pm 1.59^\circ$). No sex differences were found with regard to PR ($p=0.198$) and STA ($p=0.859$). For all three pelvic parameters, group comparisons revealed significant intergroup differences. The mean \pm standard deviation PR was the smallest in the DSPL group (127.7255 ± 1.93762), followed by LDH (136.6273 ± 2.88 mm). The mean PR was highest in the LCS group (144.3751 ± 6.33742 mm). The smallest value for the mean PI was observed in the LDH group ($56.2975^\circ \pm 2.45875^\circ$), followed by LCS ($57.1080^\circ \pm 2.56002^\circ$). The highest value for the mean PI was observed in the DSPL group ($58.9295^\circ \pm 2.14364^\circ$). The smallest STA was found in the LDH group ($93.6272^\circ \pm 2.49396^\circ$), followed by DSPL ($96.8848^\circ \pm 1.03689^\circ$). The mean STA of LCS was $103.3458^\circ \pm 3.93079^\circ$.

Conclusions: Our study showed all anatomic parameters to be specific for distinct types of degeneration, which suggest pelvis shape may be a predisposing factor for their development. This study presents the various spino-pelvic radiographic parameter values of a sample of the symptomatic Nepalese population. The role of PR and STA

defining pelvic shape as a predictor of spinal shape, load, and function may have a role in the lumbar degeneration process.

PS-FP-2-70

Is Sagittal Spinopelvic Imbalance a Critical Factor for Revision Hip Arthroplasty?

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Purpose: The spine-pelvis-hip complex has been recognized as a double-hinged system in postural changes from sitting to standing. Therefore, the orientation of total hip arthroplasty (THA) and spinopelvic alignment was closely related to each other. Previous studies demonstrated that lumbar spine fusion (LSF) prior to THA had an increased risk of dislocation and subsequent revision compared to those without prior LSF. This retrospective cohort study aims to determine if the surgical sequence of THA and LSF or the spinopelvic alignment affect the prognosis of THA in patients with both hip and lumbar spine pathology.

Methods: We included 76 patients receiving LSF, primary and revision THA in branches of Chang Gung Medical Foundation during 1995–2018. Patients lacking preoperative or postoperative images or receiving less than 2 years follow-up were excluded. The primary outcome was THA survivorship and dislocation rate. The index operations sequence and the radiographic parameters of spinopelvic alignment (pelvic incidence [PI], sacral slope, pelvic tilt [PT], lumbar lordosis [LL], spinopelvic harmony [PI–LL], THA cup inclination, and anteversion) were compared for primary outcomes. The included patients were divided into three groups based on surgical sequence, where LSF performed before, between, and after the primary and revision THA were designated as SHH, HSH, and HHS, respectively. As for the statistics, log-rank test and Cox proportional hazard model were utilized for survivals. The comparisons were analyzed via chi-square and Kruskal-Wallis according to the scale and distribution of the data.

Results: The index operations sequence showed no differences in radiographic parameters or dislocation rates, while the THA survivorship in SHH (median, 19 months) were significantly shorter than HSH ($p < 0.05$; median, 124 months) and HHS ($p < 0.005$; median, 89 months) groups. For the effect of spinopelvic alignment, patients with THA in retroverted pelvis (PT $> 20^\circ$) had a higher dislocation rate ($p < 0.01$) compared to normal pelvic version, while different pelvic morphologies showed no differences in dislocation rate. There were no differences in terms of THA survivorship in different spinopelvic alignment.

Conclusions: Different surgical sequences of THA and LSF had comparable radiographic parameters and dislocation rates. However, LSF as the index procedure prior to primary and revision THAs showed the shortest THA survivorship in this study. Spinopelvic harmony may play a role in THA stability since THAs placed in retroverted pelvis (PT $> 20^\circ$) had significantly higher dislocation rate.

PS-FP-2-72

Prevalence and Clinical Correlation of Lumbosacral Transitional Vertebra: An Ambispective Study Based on 4,027 Whole Spine Magnetic Resonance Imaging

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Purpose: Lumbosacral transitional vertebra (LSTV) even being a commonest congenital anomaly of the lumbosacral (LS) spine, its reported prevalences vary widely; because the majority of studies are based on radiographs alone. We evaluated 4,027 whole spine magnetic resonance imaging (MRI) to find a true prevalence of LSTV and its association with degenerative disc disease and back pain.

Methods: A total of 4,027 patients qualifying inclusion criteria were further subdivided into group A ($n = 2,011$, trauma) and group B (degenerative) patients. Group B subdivided into B1 ($n = 1,009$, predominant back pain) and B2 ($n = 1,007$, predominant radicular pain) patients. The sacralized and lumbarized vertebrae were classified using the Castellvi's (on plain anteroposterior LS radiographs) and O'Driscoll's (on sagittal whole spine MRI) classifications, respectively. MRI further evaluated for disc degen-

eration of last three mobile segments (Pfirmman grading), facet trophism of last most caudal well-formed facet, and total end plate (TEP) score was evaluated in last mobile segment.

Results: Total prevalence of LSTV was 11.6% and was more common in group B2 (17.3%) followed by B1 (14.8%) and A (11.6%). Castellvi's type 2A (31.35%) was the most common classification followed by 3B (25.85%). By O'Driscoll's classifications type 4 (70%) was most common followed by type 3 (23%). TEP score was significantly more in sacralized patents (4.07 ± 1.71) compared to lumbarized (3.81 ± 1.61) and non-LSTV patents (3.96 ± 1.59) of the B1 group; however, the B2 group had no significant difference. Similarly, the sacralized patients had significantly more facet trophism compared to lumbarized and non-LSTV patents in both B1 and B2 groups.

Conclusions: Total prevalence of LSTV was 13.8% and Castellvi's type 2A was the most common type. The incidence of LSTV is high in patients with radiculopathy (17.4%) than with low back pain (14.9%). The disc immediately caudal to transitional vertebra is most significantly affected by the degeneration of discs.

PS-FP-2-73

Efficacy of Analgesic Cocktail on Epidural Patch for Postoperative Pain Control in Posterior Surgery of Degenerative Lumbar Spine: Randomized Control Trial Study

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Purpose: Posterior lumbar surgery was an increase, and many patients got significant postoperative pain problems. Opioid drugs were commonly used for postoperative pain control but complications from opioid usage commonly occurred. Multimodal analgesia was the option for postoperative pain control and avoid the complication from opioid drugs used. Intraoperatively, we used absorbable gelatin mixed with analgesic drugs (Parecoxib and Bupivacaine) apply to epidural space for postoperative pain control. The aims of this study are to study the efficacy of Parecoxib and Bupivacaine combination compare with Bupivacaine alone on epidural gelatin patch in terms of

pain score reduction and to study the efficacy of Parecoxib and Bupivacaine combination compare with Bupivacaine alone on epidural gelatin patch in term of morphine use reduction.

Methods: Sixty patients who were diagnosed degenerative spinal disease from Dec 2017 to April 2020. The patients were diagnosed by physical examination, plain radiograph, and magnetic resonance imaging. The study sample was divided into two groups: (1) Bupivacaine plus Parecoxib (study group) and (2) Bupivacaine alone (control group). Study group: Absorbable gelatin patch 1 piece+0.5% Bupivacaine 0.6 mL+normal saline 0.4 mL+Parecoxib 40 mg (2 mL) apply on epidural space at laminectomy site. Control group: Absorbable gelatin patch 1 piece+0.5% Bupivacaine 0.6 mL+normal saline 0.4 mL apply on epidural space at laminectomy site. All patients were used intravenous patient-controlled analgesia morphine for morphine consumption record, Visual Analog Scale (VAS) score, and complications at 8, 24, and 48 hours postoperatively.

Results: A study group (n=30) and a control group (n=30) were included. Demographic data were not statistically significant. Postoperatively, morphine consumption in the study group was less than control group statistically significant. VAS pain score in the study group was less than control group statistically significant. Complications such as dizziness, nausea, and vomiting were similar in the two groups. No statistically significant.

Conclusions: Postoperative pain from spinal surgery was an important problem. Many complications from opioid drug usage such as dizziness, nausea, vomiting, and respiratory depression frequently occur. Multimodal analgesia was used to reduce morphine consumption, postoperative pain score, and complications from opioid drugs used. In this study, the gelatin patch nonsteroidal anti-inflammatory drugs (NSAIDs) on epidural space can reduce morphine consumption, VAS pain score statistically significant. The gelatin patch NSAIDs on epidural space was an effective optional multimodal analgesic tool to control the postoperative pain and avoid the adverse event of opioid usage for patients who underwent posterior surgery for degenerative lumbar spinal surgery.

PS-FP-2-74

Effect of 3-Months of Romosozumab Treatment on Spinal Surgery: Prospective Study Using Finite Element Analysis

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Purpose: Romosozumab is a monoclonal antibody that inhibits sclerostin and rapidly increases bone mineral density (BMD) through a dual effect on bone by increasing bone formation and decreasing bone resorption. Several studies showed the efficiency of osteoporosis treatment in patients undergoing spinal surgery. However, no studies have been performed to elucidate the effect of Romo during spinal surgery. The present study aimed to investigate the effect of Romo on spinal surgery using quantitative computed tomography (CT) based finite element analysis (FEA).

Methods: Consecutive 25 patients with postmenopausal osteoporosis, scheduled for Romo treatment, were included for the prospective study. All patients were analyzed using bone turnover markers (TRACP-5b and total-P1NP) and dual-energy X-ray absorptiometry for 6 months. To better understanding of early effects of Romo, the spinal fixation model of FEA has been developed based on CT data. The models of the implant were created separately from high resolution micro-CT and inserted in the vertebra FEA model. Screw fixation, cage subsidence stress, and compression force of vertebra were assessed following 3 months of Romo treatment.

Results: Twenty-two patients (mean±standard deviation age, 73.1±6.0 years) completed a 6-month follow-up with no fracture events. Romo treatment significantly increased the levels of total-P1NP and reduced the levels of TRACP-5b ($p<0.01$, vs. baseline: by Wilcoxon). The percent changes of spine-BMD increased significantly from baseline to 6 months (6.1%, $p<0.01$, vs. baseline: by Wilcoxon). Notably, in FEA analysis, all the biomechanical parameters improved rapidly after 3 months of Romo treatment (screw fixation: 21.5%, cage subsidence stress: 16.7%, compression force: 11.0%).

Conclusions: In summary, our prospective biomechanical study using FEA revealed 3 months of Romo treatment was effective in spinal fixation surgery. Romo may be useful for perioperative management to decrease complications.

PS-FP-3-1

Proposal of New Classification and Treatment Strategy for Transverse Fractures of the C2 Body

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Purpose: To investigate the characteristics of transverse fractures of C2 body diagnosed on sagittal computed tomography (CT) and to propose new classification and appropriate treatment strategies.

Methods: We classified 49 transverse fractures of C2 body into three types based on fracture trajectories involving superior articular facet (SAF) and lateral cortex (LC) of C2 body on coronal CT and analyzed their characteristics and treatments as follows: type 1, involvement of C2 SAF on both sides; type 2, unilateral involvement of C2 SAF on one side and LC on the other side; and type 3, involvement of LC on both sides. The characteristics, treatment methods, and results of 49 transverse fractures of the C2 body were analyzed.

Results: The mean age of the patients was 60.8 years. Twenty-six patients were male, and 23 patients were female. Twenty-six patients were type 1, 21 were type 2, and two were type 3. Correlation coefficients for intra-observer and inter-observer reliabilities for classification were 0.723 and 0.598 (both, $p<0.001$), respectively. About 40.8% (seven type 1 and 13 type 2) of the patients had fracture displacement >3 mm; Incidence of fracture displacement >3 mm was higher in type 2 than type 1 (61.9% vs. 26.9%, $p<0.05$). About 79.6% (20 type 1, 17 type 2, and two type 3) of the patients were treated conservatively, and 20.4% (six type 1 and four type 2) underwent surgery. At last follow-up, 47 out of 49 patients achieved fusion; overall fusion rate was 95.9%. All conservatively treated type 1 and type 3 patients achieved fusion. Out

of 17 conservatively treated type 2 patients, 15 achieved fusions but two developed nonunion; however, two nonunion patients opted not to undergo a surgery. Subgroup analysis showed that Philadelphia brace caused nonunion significantly in fracture displacement >3 mm compared to Minerva brace/Halovest (100% vs. 0%, $p<0.05$). All surgically treated type 1 and 2 patients achieved fusion. Neck pain Visual Analog Scale and Neck Disability Index were significantly improved (both, $p<0.01$). According to Odom's criteria, 93.9% (46/49) of the patients achieved satisfactory outcomes. No major complications occurred. Mean follow-up was 12.6 months.

Conclusions: The majority of transverse fractures of C2 body can be treated conservatively. However, surgery or rigid Minerva brace/Halovest should be considered for type 2 transverse fractures of the C2 body with fracture displacement >3 mm.

PS-FP-3-2

An Analysis of 49 Cases with Pedicle Fractures of the c2 Axis: Is Surgery Necessary?

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Purpose: C2 pedicle fractures (PFs) are not an uncommon injury but have not been focused on to the extent that dens fractures or Hangman's fractures have been. The pedicle in the lumbar and thoracic spine is an important component helping to maintain the stability of the spine, similar to the cervical spine. However, to date, little information is available about the characteristics of C2 PFs that can affect treatment and outcome. Therefore, we sought to investigate the characteristics of C2 PFs and to propose appropriate treatment strategies.

Methods: A total of 49 patients with C2 PFs were included from the database of three national trauma centers of tertiary university hospitals between January 2000 and December 2017. Radiologic data and medical records were retrospectively reviewed.

Results: Twenty-two patients (44.9%) had unilateral C2 PFs and 27 patients (55.1%) had bilateral C2 PFs. There was no case of C2 PF alone: among the cases of unilat-

eral C2 PF, 22 patients (100%) had one or more other C2 fractures and 20 patients (90.9%) had one or two C2 body fractures, while two patients (9.1%) had C2-3 anterior slip and two patients (9.1%) had other cervical injuries. Meanwhile, among the cases of bilateral C2 PF, 27 patients (100%) had two or more other C2 fractures and all patients (100%) had one or two C2 body fractures, five patients (18.5%) had C2-3 anterior slip, one patient (3.7%) had spinal cord injury (SCI) at C2-3 and six patients (22.2%) had other cervical injuries. In unilateral C2 PFs, 3 patients (13.6%) with C2-3 anterior slip or adjacent cervical spine (C1-3) injury underwent surgery and 19 patients (86.4%) were treated with conservative methods. In bilateral C2 PFs, 3 patients (11.1%) with C2-3 anterior slip or SCI at C2-3 underwent surgery and 24 patients (88.9%) were treated with conservative methods. One patient with bilateral PF, C2-3 anterior slip, and C1 posterior arch fracture developed nonunion after Philadelphia brace application.

Conclusions: Our results showed that C2 PFs do not occur alone and are always accompanied by other associated C2 injuries. In spite of the complex fracture characteristics, most C2 PFs can be managed with conservative treatment. However, surgical treatments should be considered if the C2 PFs are accompanied by the C2-3 anterior slip and adjacent cervical spine injury.

PS-FP-3-5

Direct Osteosynthesis in Hangman's Fracture Risks Vertebral Artery Injury

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Hangman's fracture, the traumatic spondylolisthesis of the axis, is the second most common fracture of this bone after odontoid fracture and is defined by the bilateral separation of the C2 vertebral body from the neural arch. The most commonly used classification of the fracture is Levine and Edwards classification. Fractures with 3 mm or less translation and no angulation, more than 3 mm of translation and angulation, 3 mm or less translation and significant angulation, and unilateral or bilateral facet joint

dislocations are classed as type I, type II, type IIa, and type III, respectively. There was a report that the union rates of conservative treatment of hangman's fractures were nearly 100% in type I, 60% in type II, 45% in type IIa, and 35% in type III. Therefore, some patients with type II, IIa, and III need surgery. Among the common surgical techniques, many authors have demonstrated good outcomes with direct C2 osteosynthesis for hangman's fractures. However, we encountered a patient whose vertebral artery (VA) had moved into the gap of the fracture. This condition creates a risk of VA injury if a patient undergoes direct C2 osteosynthesis using a pedicle screw. We report this case with a review of the literature.

PS-FP-3-6

Significance of the Neurological Level of Injury as a Prognostic Predictor for Motor Complete Cervical Spinal Cord Injury Patients

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Purpose: To investigate the usefulness of the combination of neurological findings and magnetic resonance imaging (MRI) as a prognostic predictor in patients with motor complete cervical spinal cord injury (CSCI) in the acute phase.

Methods: Forty-two patients with an initial diagnosis of motor complete CSCI (adolescent idiopathic scoliosis [AIS] A, n=29; AIS B, n=13) within 72 hours after injury were classified into the recovery group (group R) and the non-recovery group (group N), based on the presence or absence of motor recovery (conversion from AIS A/B to C/D) at three months after injury, respectively. The Neurological Level of Injury (NLI) at the initial diagnosis was investigated and the presumptive primary injured segment of the spinal cord was inferred from MRI performed at the initial diagnosis. We investigated whether or not the difference between the presumptive primary injured segment and the NLI exceeded one segment. The presence of a difference between the presumptive primary injured segment and the NLI was compared between groups R

and N.

Results: The number of cases with the differences between the presumptive primary injured segment and the NLI was significantly higher in group N than in group R.

Conclusions: The presence of differences between the presumptive primary injured segment and the NLI might be a poor improving prognostic predictor for motor complete CSCI. The NLI may be useful for predicting the recovery potential of patients with motor complete CSCI when combined with the MRI findings.

PS-FP-3-7

Clinical Features and Post-treatment Complications of C2 Odontoid Fractures: A Retrospective Analysis Using a National Inpatient Database in Japan

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Purpose: To examine the clinical features and post-treatment complications in patients with isolated C2 odontoid fractures.

Methods: We extracted data for all patients who were admitted with C2 odontoid fractures from the Japanese Diagnosis Procedure Combination database between July 2010 and March 2017. We then compared the post-treatment complications during hospitalization according to treatment types: conservative treatment (with or without use of halo-vest) and surgery (anterior or posterior spinal fixation).

Results: A total of 3,167 patients (1,533 men, 1,634 women; mean age, 70 years) with isolated C2 odontoid fractures were identified, including 1,124 patients (35%) aged ≥80 years. Among the total patients, 2,476 (78%) received conservative treatment (with halo-vest, 728; without halo-vest, 1,748). The remaining 691 patients (22%) underwent surgery (anterior surgery, 129; posterior surgery, 556; combined surgery, 6). There were no differences between

the conservative treatment and surgery groups in baseline characteristics and preexisting comorbid conditions except for age (71 vs. 69 years, $p=0.042$). In-hospital death occurred in 136 patients (4.3%). There was no significant difference in in-hospital mortality between the two groups (overall, conservative treatment 4.6% vs. surgery 3.0%, $p=0.066$; age ≥ 80 years, conservative treatment 7.2% vs. surgery 5.4%, $p=0.34$). Use of halo-vest was not associated with increased mortality (with halo-vest 3.7% vs. without halo-vest 5.0%, $p=0.15$).

Conclusions: The great majority of isolated odontoid fractures occurred in elderly patients. Conservative treatment and surgery had similarly low in-hospital mortality. Use of halo-vest was not associated with an increase in mortality.

PS-FP-3-8

Surgical Strategy as Anterior Submandibular Retropharyngeal Odontoid Osteotomy and Posterior Occipitocervical Fusion with C1 Laminoplasty for Fixed Atlantoaxial Dislocation Associated with Odontoid Fracture Malunion

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Odontoid fractures comprise 7% to 13% of all cervical spine fractures. Atlantoaxial instability often does not generally associate with spinal cord injury but only neck pain as an initially present symptom. Odontoid malunion often leads to atlantoaxial dislocation and the non-union rates of type-II odontoid fractures are 36%. This study is to report a case of complex odontoid fracture malunion accompanied by atlantoaxial dislocation which was treated with a posterior-anterior-posterior approached surgical strategy. A 37-year-old male was admitted due to progressive symptoms with a stiff limp and unsteady gait. Preoperative examination, diagnostic radiography, computed tomography, and magnetic resonance imaging were performed following admission. The examinations showed odontoid fracture malunion, an old right axial zygapophyseal fracture, atlantoaxial dislocation, and spinal cord injury. Anterior submandibular retropharyngeal odontoid osteotomy and posterior atlantoaxial fusion with

C1 laminoplasty were then performed. A good reduction of the atlantoaxial dislocation was gained. The cervical spinal cord compression was significantly relieved and neurological function was also significantly improved. Anterior submandibular retropharyngeal odontoid osteotomy and posterior atlantoaxial fusion fixation is an effective surgical strategy for treating odontoid fracture malunion associated with odontoid fracture malunion and it may avoid the adverse effects of the anterior transoral odontoid osteotomy.

PS-FP-3-9

Anterior C2–3 Fusion Surgery Alone for Highly Displaced Hangman's Fracture with Severe Angulation of C2–3 of More Than 30°

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Purpose: Highly displaced Hangman's fracture is a very rare and extremely unstable fracture of the C2 axis. Combined anteroposterior or posterior long-segment fusion surgery is typically performed for the treatment of highly displaced Hangman's fracture. However, these kinds of surgeries increase the risk of complications, loss of motion, and hospital costs. We sought to investigate the surgical outcomes of anterior C2–3 fusion surgery alone for highly displaced Hangman's fractures with severe angulation of C2–3 by more than 30° and discoligamentous injury.

Methods: A total of five patients (four men and one woman) were included in this study with a mean age of 40.4 years (range, 26–70 years). The mean follow-up period after surgery was 37.2 months (range, 12–96 months). The fracture characteristics, treatment methods, and outcomes were retrospectively analyzed.

Results: All five patients had type II Hangman's fractures (according to the Levine and Edwards classification scheme). None of the included patients had neurologic deficit or other spine injury but all patients had complete C2–3 discoligamentous injury. Before surgery, all patients successfully achieved closed reduction by skull traction, followed by C2–3 anterior decompression and fusion with

plating. For interbody grafting, three patients received a polyetheretherketone cage filled with an autogenous cancellous iliac bone graft and two received autogenous tricortical iliac bone grafts. Severe angulation (39.2° vs. 3.0° , $p < 0.001$) and severe displacement (76.1% vs. 4.0%, $p < 0.001$) of C2–3 were both significantly corrected after surgery. All patients had achieved solid fusion at last follow-up. In terms of clinical outcomes, the mean neck pain visual analog scale score was significantly improved (8.6 points vs. 1.8 points, $p < 0.001$). The mean neck disability index value was also significantly improved (45.4 points vs. 13.0 points, $p < 0.01$). According to Odom's criteria, all patients achieved satisfactory outcomes. No major complications occurred. One patient complained of dysphagia, but recovered after three months with conservative treatment.

Conclusions: Preoperative closed reduction and anterior C2–3 fusion surgery alone should be considered as a less-invasive and useful surgical option for highly displaced Hangman's fracture with severe angulation of C2–3, which is an extremely unstable fracture of the C2 axis.

PS-FP-3-10

Is Only Anterior Stabilization Enough in Three Column Injuries of Sub-axial Cervical Spine?: A Long-Term Retrospective Analysis of 78 Patients

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Study Design: Retrospective study.

Purpose: To retrospectively evaluate the long-term outcome of anterior only stabilization in three column injuries of sub axial cervical spine.

Overview of Literature: Sub-axial region of the cervical spine accounts for about 65% of all cervical spine injuries. Three column injuries (AO type C) are high energy injuries with unstable fracture patterns with need proper reduction and stable fixation. A high incidence of neurological deficits is associated with these injuries. There is no standard protocol regarding the management of such injuries. Reduction and fixation can be done by either

anterior, posterior, and combined approaches with each having its own advantages and disadvantages.

Methods: Seventy-eight patients of three column injuries operated by anterior approach with follow-up of at least 2 years were included and retrospectively analyzed. Clinical data regarding age, sex, time to surgery, diagnosis, methods of reduction, postoperative mobilization, and neurological evaluation using the American Spinal Injury Association scale (ASIA) was used. Radiological data included pre- and post-reduction X-ray, computed tomography, and magnetic resonance imaging. X-rays at 1, 3, 6 months, 1 year, and 2 years postoperative were taken. Parameters like classification of fracture (AO type), alignment, kyphosis angle, time, and grade of fusion mass were assessed.

Results: Of 78 patients, 61 bifacetal and 17 unifacetal dislocations. The most common site was C5–6 followed by C3–4 and C6–7. The mean patient age was 35.98 years with 60 male and 18 female patients. The mean operative time is 4.4 days. Forty dislocations were reduced by the closed method and 38 by the open anterior approach. Fifty-six percent of patients had traumatic disc injury on magnetic resonance imaging. All managed by single-level anterior cervical discectomy and fusion with iliac crest autograft for fusion. Mean preoperative lordosis was 4.44° (range, -13.4° to 25°), and mean postoperative lordosis was 28.57° ($p < 0.0001$). The mean loss of alignment was 2.59° by 2 years. 100% fusion was with a mean time of 22.82 weeks. Neurological recovery was in 34.6% with at least one-grade ASIA scale. No neurological worsening or need for revision surgery was required.

Conclusions: The goals of management in any cervical injury are reduction of dislocations, maintenance of alignment, cord and root decompression, bony stabilization, and fusion using an approach that is least morbid with good long-term outcome. Above study proves that just anterior stabilization after reduction of three column injuries will suffice with a very good long-term satisfactory outcome thereby obviating the need for global fusion.

PS-FP-3-11

Efficiency of Long Lateral Mass Screw

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Purpose: It is necessary for patients who have instability in the cervical spine to fix. However, the lateral mass screw is weakly fixed to the elderly with osteoporosis, and postoperative aversion is a problem. Although the pedicle screw has a good fixation, nerve damage, and puncture of the vertebral artery. In recent years, advances in implants have led to the development of screws with large swing heads. Therefore, we report the efficiency of a long lateral mass screw.

Methods: The insertion point and insertion path that lateral mass screw can hit the longest were measured from the 3rd cervical vertebra to the 6th cervical vertebra using Zed Spine manufactured by Lexi.

Results: The average screw length is 25.2 mm on the right (range, 20 to 28 mm), 24.8 mm on the left (range, 20 to 28 mm), the insertion point is 2.45 mm on the head side and 2.87 mm on the inside from interlaminar V, and the insertion angle is toward the head side. It was 49.6° and 30.6° outward.

Conclusions: The insertion point of the long lateral mass screw is 2 mm head side and 2 mm inside from interlaminar V, and the insertion angle is tilted 50° to the head side and 30° to the outside.

PS-FP-3-12

Role of Riluzole in Acute Traumatic Cervical Spinal Cord Injury with Incomplete Neurological Deficit: A Prospective, Randomized Control Study

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Purpose: Riluzole has been investigated extensively for its properties of hindering the secondary injury cascade in

spinal cord injury patients. Though experimental animal studies are satisfactory, the role of Riluzole in the clinical setting is not clear. The aim of our study was to assess the effect of Riluzole on the neurological (motor and sensory) improvement in acute cervical spinal cord trauma with incomplete neurological injury.

Methods: A prospective, randomized, single-blind, placebo-controlled study was done at our center in patients with acute cervical spinal cord injury with incomplete neurological injury. The study population included patients with SCI presenting within 72 hours of injury, level C3–C8, incomplete injury (International Standards for Neurological Classification of Spinal Cord Injury [ISNCS-CI] grade B, C, D), and age between 18–65 years. Patients with penetrating injury, significant head/chest/abdominal injury, pre-existing renal/liver disease, concomitant use of other drugs, and pregnancy are excluded. Forty-three patients were randomized into two groups (cases and controls). Patients in the case group received a loading dose (100 mg twice daily) of Riluzole started within 72 hours of injury, followed by 50 mg twice daily for the next 13 days. The control group received a placebo treatment. All patients underwent surgery for decompression and stabilization. Postoperative rehabilitation was followed. Patients were followed up at 6 weeks, 3 months, 6 months, and 1 year. Outcomes measured were changes in ISNCS-CI grade at 12 months, Spinal Cord Independence Measure (SCIM 3) at 12 months, 36-item Short Form Health Survey (health-related quality of life), and Numerical Pain Rating Scale (NPRS).

Results: Among the 43 patients, 23 were randomized in the case group and 20 in the control group. At 1 year, there were 18 and 16 patients in each group and the remaining were dead or lost to follow-up. The mean age in the case and control was 47.70±14.80 years and 51.15±14.10 years, respectively. The mean number of levels of injury was 1.43 and 1.35 in the two groups. Mean motor score at admission in case and controls were 36.05 and 43.04 which improved to 85.06 and 91.17, respectively at 1-year follow-up. However, there was no significant difference ($p=0.15$) in motor scores in both groups. Also, there was no statistically significant difference ($p=0.394$) in the sensory scores between the two groups. SCIM and NPRS at 1-year follow-up were also comparable ($p=0.684$ and $p=0.061$).

Conclusions: Riluzole did not significantly improve the neurological outcome in the acute traumatic spinal cord injury patients in our study.

PS-FP-3-13

Traumatic Cervical Spinal Cord Injury after Cervical Laminoplasty for Ossification of Posterior Longitudinal Ligament

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Study Design: A retrospective review of case series of five patients.

Purpose: To elucidate the effects of post-cervical laminoplasty on the clinical pathophysiology of traumatic cervical spinal cord injury (CSCI).

Overview of Literature: Cervical laminoplasty is widely performed with good results in patients with cervical ossification of posterior longitudinal ligament (C-OPLL) and cervical spondylotic myelopathy. However, to the best of our knowledge, no studies have thus far reported the incidence of traumatic CSCI after a previous history of cervical laminoplasty for compressive cervical myelopathy.

Methods: Five patients with traumatic CSCI following cervical laminoplasty (four men and one woman) with an average age of 66.6 years (range, 45–76 years) were included in our study. The average duration between cervical laminoplasty and CSCI was 49.4 months (range, 7–82 months). The pathology of all five patients was C-OPLL. The changes in cervical sagittal range of motion (ROM) and morphology of OPLL before cervical laminoplasty and at the time of injury were radiologically evaluated. Moreover, the mechanism of injury, level of injury, and neurological evaluations were discussed.

Results: Two patients were classified as American Spinal Injury Association Impairment Scale (AIS) grade A, one as grade B, one as grade C, and one as grade D at the time of injury. After 24 months, neurological status improved in three patients as evaluated with AIS. All the patients demonstrated ankylosed cervical spine owing to the development of the OPLL and spontaneous bony facet and laminar fusion on post-cervical laminoplasty. A significant difference in cervical sagittal ROM preoperatively and 6 months postoperatively ($p=0.0065$) was observed. Three patients had cervical spine extension injury at the ankylosed region. The other two had cervical spine flexion injuries at the motion segment, caudal and adjacent to the

ankylosed region.

Conclusions: All the five patients with traumatic CSCI had a history of previous cervical laminoplasty for C-OPLL. Cervical laminoplasty for C-OPLL may lead to cervical spine with rigidity and ankylosis owing to the development of OPLL, bony facet, and laminar fusion, and may pose a risk for traumatic CSCI with bony injury under intense external stresses on the rigid cervical spine.

PS-FP-4-5

Mesh-Hold Bone Filling Container Vertebroplasty in the Treatment of Osteoporotic Vertebral Fractures with Posterior Wall Injury: A Study of the Clinical Efficacy and Safety

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Purpose: This study aims to evaluate the clinical safety and efficacies of mesh-hold bone filling container (MHFC) vertebroplasty in the treatment of osteoporotic vertebral fractures with posterior wall injury.

Methods: From October 2017 to July 2019, 17 patients (17 vertebrae) with osteoporotic vertebral fractures with posterior wall injury were admitted in our hospital, including six men and 11 women with an average age of 69.2 years (range, 59–85 years). The injured vertebrae were distributed as follows: T8 in one case, T9 in two cases, T10 in two cases, T11 in four cases, T12 in five cases, and L1 in three cases. All patients underwent MHFC vertebroplasty using a unipedicular approach. After implanting the MHFC into a space formed by bone expander dilatation, bone cement is filled into the MHFC, a small amount of bone cement can be infiltrated into the trabecular space through the

mesh to form a microscopic twist lock and to strengthen the vertebral body. Preoperative clinical and neurologic evaluations were done. Radiological evaluations included plain X-rays, computed tomography scans, and magnetic resonance imaging. The Visual Analog Scale (VAS), Oswestry Disability Index (ODI), anterior height of the vertebral body, and Cobb's angle of the injured vertebrae were observed before operation and at 1 day, 1 month, and 6 months after the operation. Bone cement leakage and postoperative complications were also observed. The average follow-up period was 6 months.

Results: Operations were successfully completed in all 17 patients without pulmonary embolism and without spinal cord or nerve root injury. The operation time was 29.6 ± 5.1 minutes. Asymptomatic leakage into other sites was seen in 5 vertebrae (29.41%). The ODI results before operation and at 1 day, 1 month, and 6 months after the operation were 83.215 ± 8.341 , 28.125 ± 8.461 , 16.195 ± 6.543 , and 11.311 ± 5.670 , respectively. The VAS results before operation and at 1 day, 1 month, and 6 months after the operation were 7.815 ± 0.501 , 2.115 ± 0.511 , 1.726 ± 0.421 , and 1.630 ± 0.112 , respectively. There was improvement in the Cobb angle and the anterior vertebral height in all cases.

Conclusions: MHFC vertebroplasty for treating osteoporotic vertebral fractures with posterior wall injury can relieve pain effectively and effectively prevent bone cement leakage and reduce the incidence of bone cement leakage. But this technique has a "long and steep" learning curve.

PS-FP-4-7

Clinical Safety Study of Photobiomodulation Treatment of Acute Spinal Cord Injury by Scattering Fiber

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Purpose: The effectiveness of photobiomodulation (PBM) has been demonstrated mainly by percutaneous irradiation and intravascular irradiation on the treatment of spinal cord injury (SCI), but the different treatment methods, the tissue absorption of light energy, and the scattering effect all make PBM face a series of difficulties in the treatment of SCI (e.g., the light energy cannot directly

regulate the treatment of the SCI site). The study aimed to design a reliable and straightforward PBM method by implanting a medical scattering fiber above the vertebral plate. Moreover, the safety of this method was examined.

Methods: Twelve patients with acute SCI (American Spinal Injury Association [ASIA] B) requiring decompression by laminectomy were selected. The medical scattering fiber was implanted above the vertebral and was continuously irradiated at 810 nm, 300 mW, 30 min/day, once per day for 7 days. The vital signs (temperature, blood pressure, respiratory rate, heart rate, and oxygen saturation), infection indicators (white blood cell [WBC], neutrophil [NEUT], high-sensitivity C-reactive protein [hs-CRP], and procalcitonin [PCT]), photo-allergic reaction (Eosinophil and Basophil), coagulation function (prothrombin time [PT], activated partial thromboplastin time [APTT], thrombin time [TT]), and neurological stability (ASIA sensory and motor scores and somatosensory evoked potentials) were recorded to evaluate the safety of PBM. Three months after surgery, 12 patients completed follow-up.

Results: The temperature did not exceed 37.5°C during 7-day consecutive irradiation. The blood pressure of all subjects did not occur the condition requiring clinical intervention, and the blood oxygen saturation of all PBM-treated patients was not below 95%. All patients had higher WBC, NEUT, and hs-CRP at day 3 during irradiation than those before surgery, and significantly decreased at day 7. The PCT was within the normal range before irradiation and during irradiation. The changes in Eosinophil and Basophil that were closely associated with allergic reactions were within normal limits throughout the course of irradiation. The coagulation function (PT, APTT, TT) of patients were also in the normal range. The ASIA sensory and motor scores of all subjects did not decrease throughout the irradiation process, and somatosensory evoked potentials also did not show the reduced amplitude. In the follow-up, a total of seven patients had adverse events.

Conclusions: Our study concluded that direct treatment of PBM at the site of SCI would not produce adverse effects within the appropriate irradiation parameters. Our preliminary study might provide a new methodology for the clinical PBM treatment of acute SCI.

PS-FP-4-8**A Novel Steerable Percutaneous Balloon Kyphoplasty for Treatment of Thoracolumbar Osteoporotic Vertebral Compression Fractures**

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Purpose: To explore the clinical efficacy and safety of a novel steerable percutaneous balloon kyphoplasty (S-PKP) for treatment of thoracolumbar osteoporotic vertebral compression fractures (OVCFs).

Methods: From April 2018 to October 2019, a total of 29 patients (32 vertebrae) with thoracolumbar OVCFs were treated with a novel S-PKP. Including 10 men and 19 women with an average age of 73.4 years. The injured vertebrae were distributed as follows: T11 in six cases, T12 in 10 cases, L1 in eight cases, L2 in four cases, and L3 in four cases. All patients underwent the S-PKP procedure using a unipedicular approach. Introduced the novel steerable curved bone expander from the puncture side, expansion and bending to the contralateral side then inserted and inflated the curved balloon tamp. After vertebral body reduction, the bone cement was injected into the vertebral body. Clinical efficacy of S-PKP treatment was evaluated by kyphotic Cobb's angle, Oswestry Disability Index (ODI), and Visual Analog Scale (VAS) score. Bone cement leakage and postoperative complications were also observed.

Results: The anterior vertebral body height of the fractured vertebrae, Cobb's angle was a significant improvement between preoperative and postoperative values ($p < 0.05$) without a spinal cord or nerve root injury. The VAS was 8.2 ± 0.3 at preoperative, 2.1 ± 0.5 at postoperative, 1.8 ± 0.3 at final follow-up; and the ODI was 86.3 ± 2.2 at preoperative, 32.1 ± 2.9 at postoperative, 27.1 ± 2.3 at final follow-up. There was a statistically significant improvement in the VAS and ODI at the postoperative assessment compared with the preoperative assessment ($p < 0.05$). Asymptomatic leakage was seen in three vertebrae.

Conclusions: The novel S-PKP technology is a safe and efficient way for the treatment of thoracolumbar OVCFs.

PS-FP-4-9**Mid-Term Results of Anterior-Posterior Simultaneous Reconstruction for Lower Lumbar Spine Injury in the Elderly**

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In recent years, extreme lateral interbody fusion and oblique lumbar interbody fusion procedures have been introduced to Japan as a surgical procedure for lateral approach lumbar interbody fusion (LLIF). As an application of this technique, it has become possible to perform vertebral body replacement using a LLIF retractor for small skin incision. As an implant for vertebral body replacement, the expandable X-core2 System and T2 STRATO-SPHERE, which have a wide end plate covering the lateral diameter of the vertebral body, have been widely used in Japan for stable anterior column reconstruction using a huge cage. We would like to describe the short-term results, usefulness and precautions of anterior-posterior simultaneous reconstruction performed for lower lumbar spine injury (L2–4) at Miyoshino Hospital.

PS-FP-4-10**Comparison of Mini Open Wiltse Approach with Conventional Posterior Approach in Patients with Single Segment Unstable Thoracolumbar Fractures**

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Purpose: Unstable thoracolumbar fractures constitute 20% bulk of spine fractures. Road traffic accidents and accidental fall from height are the main causes of such

injuries. Fracture dislocation injury is highly unstable involving all the three columns. Most commonly It involves thoracolumbar junction. The goals of the treatments are to restore mechanical stability of spine and leading to early rehabilitation and mobilization. Choice of treatment method is still controversial. The purpose of this study is to find a superior approach for transpedicular screw fixation of unstable thoracolumbar spine fractures while using the mini-open Wiltse approach and traditional posterior approach.

Methods: The study was a randomized controlled trial. A total number of 32 patient with unstable thoracolumbar fracture were admitted, after dividing them randomly into group A and group B, In half of the cases mini-open Wiltse approach and in the rest of the half posterior traditional approach was used and transpedicular screw fixation was done at a level above and a level below the fractured vertebrae. The whole of the procedure was done under C-Arm control.

Results: The mean age of patients in group A (Wiltse approach) was 36.00 ± 9.68 years while in group B (conventional approach) was 35.56 ± 7.96 years. In both groups, male patients were more in number than females. The mean procedure time in group A was 87.19 ± 5.76 , while in group B was 120.94 ± 20.94 , respectively. The difference was statistically significant ($p < 0.05$). The mean blood loss in both the groups showed a significant difference ($p < 0.0$) of 2.34 ± 0.88 mL in group A and 12.38 ± 4.09 in group B, respectively. Results were compared in terms of operative time, blood loss, postoperative hospital stay, infection, and Visual Analog Scale for pain. All the parameters showed a statistically significant difference in both groups.

Conclusions: In thoracolumbar fractures, 20% of patients have neurological impairment. Stable fractures are treated non surgically but surgery is required for unstable fractures. Mimi-open Wiltse approach described in 1968 is considered classical approach for surgical treatment of this injury. Our study results suggest that in patients with single-segment unstable fractures at thoracolumbar junction Wiltse mini-open approach is better than the traditional approach. Wiltse approach results in less blood loss and short operative time, less pain, and a low infection rate.

PS-FP-4-12

Comparative Study to Evaluate Surgical Outcomes between Direct Lateral Corpectomy with Percutaneous Pedicle Screws and Posterior Spinal Fusion with Vertebroplasty for Osteoporotic Thoracolumbar Vertebral Fracture

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Purpose: Osteoporotic vertebral fracture (OVF) fails to bone union with conservative treatments in some cases, which results in progressive collapse and/or pseudarthrosis. Various surgical treatments have been tried to these cases, whereas complications as instrument failure and/or adjacent vertebral fracture (AVF) occur. We previously performed posterior spinal fusion (PF) with vertebroplasty (VP) but recently performed corpectomy and expandable cage replacement (X-Core Adjustable VBR System). The purpose of current study was to comparatively evaluate (1) surgical invasion, (2) mechanical complications including implant failure and AVF, and (3) radiological and clinical outcomes 2 years after surgery between two procedures.

Methods: A retrospective observational study with a cohort of consecutive patients with OVF with neurological impairment who underwent surgery was conducted. The inclusion criteria were applied: (1) initially treated conservatively with failure because of neurological deficits; (2) age > 60 years; (3) the vertebral-fracture levels selected were T11, T12, and L1. The exclusion criterion was patients who were not followed up for > 2 years after surgery. We performed radiological exams and statistical analyses and examined clinical outcomes.

Results: One hundred and two patients were enrolled. Fifty-six consecutive patients underwent PF with VP (group 1) from April 2012 to December 2015. Forty-six consecutive patients underwent corpectomy and X-core placement with posterior fixation with percutaneous pedicle screws (PPS, group 2) from January 2016 to January 2018. There was no significant difference in the mean age, bone mineral density (%YAM), number of fused levels per patient, proportion of sex, current smokers, preoperative Roland-Morris Disability Questionnaire (RDQ) score,

Oswestry Disability Index (ODI) score, or neurological score between groups. Estimated blood loss showed no significant difference between groups, whereas operating time in group 2 was significantly longer than that in group 1. RDQ, ODI, and neurological scores were improved significantly compared with preoperative scores in both groups. Kyphotic angle (LKA) in group 2 was significantly lower than that in group 1. LKA in AVF negative group was significantly lower than that in AVF positive group.

Conclusions: Anterior corpectomy and cage replacement surgery with PPS is superior procedure for OVF to PF with VP.

PS-FP-4-13

Treatment of Unstable Pelvic Ring Fractures (AO Type C) with Minimum Invasive Spino-Pelvic Fixation

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Minimally invasive spino-pelvic fixation (MIS-SP) technique is the first line treatment for unstable pelvic ring fracture patients, in our department. Twenty-eight patients of unstable pelvic fractures with posterior vertical displacement treated in our department by MIS-SP were selected for this study. The vertical pelvic posterior displacement of pre-treatment was 17.6 mm (range, 9 to 32.2 mm), reduction distance by MIS-SP was 16.5 mm (range, 8.1 to 30.1 mm) and the average of vertical reduction improvement rate was 93.5%. The axial pelvic displacement of pre-treatment was 12.9 mm (range, 5 to 25.7 mm), reduction distance was 11.3 mm (range, 3.9 to 19.6 mm) and the average of axial reduction rate was 87.3%. This study indicated MIS-SP was not only the minimum invasive rigid fixation method but also the excellent reduction method for the unstable pelvic ring fractures with posterior vertical displacement. The treatment with MIS-SP is useful for unstable pelvic fractures.

PS-FP-4-14

Surgical Treatment of Post-traumatic Kyphosis in Thoraco-Lumbar Spine: A Retrospective Analysis of Indications and Long-Term Outcome of Surgery

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Purpose: Post-traumatic kyphosis (PTK) is a challenging complication following thoraco-lumbar (TL) spinal trauma. It usually develops consequent to missed or conservatively managed AO type B2 injuries (posterior ligamentous complex disruption), injuries to the vertebral end-plates, severe osteoporosis, pseudoarthrosis, implant failure, or loosening. Progressive kyphosis can lead to recalcitrant symptoms including pain, progressive deformity, and neurological deterioration. The aim of the current study was to retrospectively analyze the long-term radiological and clinical outcomes of patients who underwent surgical correction of PTK.

Methods: A retrospective analysis of the clinical and radiological data of PTK patients who presented to our institute between January 2016 and August 2018 was performed. Only surgically treated patients with at least a 2-year follow-up were included. For deformity correction, we performed Pontes Osteotomy, Pedicle Subtraction Osteotomy (PSO), Bone Disc Bone Osteotomy (BDBO), and Closing Opening Wedge Osteotomy. Radiological evaluation of kyphosis was performed using Cobbs' angle. The functional outcome at the final follow-up was assessed using Oswestry Disability Index (ODI), Visual Analog Scale (VAS), and 12-item Short Form Health Survey score. The statistical analysis was performed using the Student t-test.

Results: A total of 28 cases (male to female ratio, 2:3; mean age, 30.3 years) with PTK treated by posterior spinal deformity correction and instrumented fusion were included for this study. The most common presenting symptom was instability-type, axial back pain (n=22, 100%). Patients (9.09%) presented with neurological deficits. The mean time of presentation from initial injury was 16.5±7 weeks. The apex of kyphosis was located between T11 and L2 in all our patients. Osteotomies performed-Pontes (n=13), PSO (n=11), BDBO (n=2), and, closing opening wedge (n=2). The mean preoperative Cobbs angle was

33.3°. Postoperatively, the mean correction, which was achieved, was 23.85° ($p < 0.05$). The mean surgical time was 275±40 minutes, and the mean intraoperative blood loss was 445±71 mL. The mean VAS score for back pain improved from 7.2 to 2, and ODI scores decreased from 58.1 to 24.1 at the last follow-up.

Conclusions: Symptomatic PTK is a rarely encountered, delayed complication following thoracolumbar trauma. It usually develops at the junctional levels of TL spine and most commonly present with axial, instability-type back pain. Some of these patients present with significant neurological deficit. Surgical deformity correction is a safe and effective method for treating this condition. Such procedures can enable the surgeons to achieve adequate correction of the kyphosis and also provide ameliorated, long-term functional outcome for the patients.

PS-FP-4-15

Preventive Effect on the Vertebral Collapse Progression and Potential in Reducing the Need for Surgery in Conservative Treatment with Initial 2-Week Bed Rest for Osteoporotic Vertebral Fracture

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Purpose: We have previously reported good results of conservative treatment protocol with hospitalized 2-week bed rest for fresh osteoporotic vertebral fractures (OVFs). However, the benefits of this approach have not been investigated yet. We aimed to elucidate the therapeutic effects of hospitalized 2-week bed rest in patients with fresh OVFs.

Methods: The subjects, aged 65 years or older, were patients with fresh OVFs who could start treatment within

2 weeks of the injury and could be observed for 6 months. Two emergency hospitals affiliated with our department were selected for this prospective study. All the enrolled patients at one facility were instructed to undergo hospitalized 2-week bed rest (rest group: 67 patients), whereas the enrolled patients at the other facility were not given this instruction (non-rest group: 51 patients). A Jewett rigid orthosis was used in all cases. The combined osteoporosis treatment was depended on the physician's choice. There was no difference between the two groups in age, bone mineral density, bone metabolism markers, and vitamin D level. In addition, the vertebral instability in X-rays, indicating the difference in vertebral collapse ratio between loaded and unloaded positions, frequency of poor prognostic findings on magnetic resonance imaging, and degree of damage to the middle column on computed tomography had no significant difference. We compared the requirement of surgical treatment and the difference in vertebral collapse ratio between the loaded positions at the start of treatment and 6 months later in the two groups as an evaluation of vertebral collapse progression (Welch's t-test, significance level $p < 0.05$). We also compared bone union and the changes of activities of daily living (ADL).

Results: One patient (1.5%) in the rest group and seven patients (13.7%) in the non-rest group did not respond to conservative treatment and required surgery. Excluding these cases, the average degree of vertebral collapse progression was 6% in the rest group and 21% in the non-rest group, indicating that vertebral collapse progressed significantly in the non-rest group. Bone union was 87% and 78% in the rest and non-rest groups, respectively. Moreover, there was no difference in the changes of ADL between the two groups.

Conclusions: The present study shows that rest group had the benefit for stabilization of the injured vertebral body. In fresh OVFs, our conservative treatment protocol with hospitalized 2-week bed rest has a preventive effect on vertebral collapse progression and has the potential in reducing the number of patients who require surgery.

PS-FP-4-16

Effect of Teriparatide in Vertebroplasty with Posterior Spinal Fusion for Osteoporotic Thoracolumbar Vertebral Fracture

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Purpose: Vertebroplasty with posterior spinal fusion (VP+PSF) is widely used for osteoporotic vertebral fracture (OVF) with neurological symptoms because it is a less invasive procedure with good neurological recovery, whereas the ability to correct kyphosis is limited. While previous studies have reported that teriparatide (TPTD) administration promotes fracture healing in OVF, the usefulness of TPTD in VP+PSF for OVF has been unclear. The purpose of this study is to investigate the surgical outcomes of VP+PSF and clarify the impact of TPTD administration during perioperative period.

Methods: Seventy-three patients (mean age, 78 years; 18 men and 55 women) with OVF affected thoracolumbar junction (T10–L2) who underwent VP+PSF with a minimum 1-year follow-up were included. Twenty-three patients who used TPTD for more than 3 months were classified in the TPTD group, and the other 50 patients in the non-TPTD group. We evaluated radiological outcomes including sagittal vertical axis (SVA), correction of local kyphotic angle (LKA), subsequent vertebral fracture, and loosening of pedicle screws. Clinical outcomes were assessed using the JOA Back Pain Evaluation Questionnaire (JOABPEQ).

Results: There were no significant differences in age, gender, follow-up period, number of fused vertebrae, preoperative bone mineral density, LKA, SVA, and scores of the JOABPEQ between the two groups. TPTD administration was started more than 3 months before surgery, within 3 months before surgery, within 1 week before or after surgery and at the first outpatient clinic after discharge in 2, 6, 10, and 5 cases, respectively. Mean postoperative SVA in the TPTD and non-TPTD groups were 107 and 101 mm ($p>0.05$), respectively, and both groups showed an increase after surgery. The TPTD group showed smaller correction loss of LKA than in the non-TPTD group (3.4° vs. 6.8° , $p<0.05$), whereas there were no significant dif-

ferences in the incidence of subsequent vertebral fracture and loosening of pedicle screws and the efficacy rates of all domains of the JOABPEQ between the two groups.

Conclusions: In the current study, perioperative use of TPTD in VP+PSF for thoracolumbar OVF decreased the loss of LKA correction, while it had little effects on global spinal alignment and clinical outcomes including the prevention of subsequent vertebral fracture. Therefore, further study is necessary to examine the appropriate timing or period for TPTD administration in order to improve clinical outcomes.

PS-FP-4-17

Comparison of Balloon Kyphoplasty and Conservative Treatment for Osteoporotic Vertebral Fractures in Patients with Dementia

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Purpose: Osteoporotic vertebral fractures (OVFs) occur in elderly people and often require hospitalization. In addition, OVFs lead to a long-term bedridden state because of severe pain and dementia in elderly patients. We actively recommend balloon kyphoplasty (BKP) for the treatment of OVF in patients with dementia to enable getting out of bed early. Therefore, we retrospectively investigated whether BKP is useful for preventing a bedridden state and promoting early discharge in OVF patients with dementia.

Methods: In this study, dementia was defined as the patients' inability to judge their own disease. All patients had a grade of 3a or more in the Japanese criteria for the degree of independence in activities of daily living (ADL). The research period was from January 2018 to June 2020. We retrospectively assessed 23 patients (eight men and 15 women) who underwent BKP and 22 patients (eight men and 14 women) with conservative treatment for more than 3 months. The average age was 86.3 years. The survey outcomes included the Visual Analog Scale (VAS) score,

ADL score, hospitalization duration, and complications. The Mann-Whitney and chi-square tests were used, and $p < 0.05$ was considered to indicate a statistically significant difference.

Results: The VAS score was significantly lower in BKP group (1.3 ± 1.7) than conservative treatment group (3.0 ± 1.1) 1 month after admission ($p < 0.01$). The BKP group tended to improve ADL score earlier than the conservative treatment group at 3 months after admission ($p = 0.07$). The hospitalization duration was 45.2 ± 23.5 days in the BKP group and 56.9 ± 26.5 days in the conservative treatment group, with no significant difference between the groups. Five patients in the BKP group had an adjacent vertebral fracture. Excluding these five patients, the hospitalization duration in the remaining 18 patients in the BKP group was 39.0 ± 17.4 days (not significant).

Conclusions: The indication and timing of BKP in elderly patients remain controversial. We investigated the advantages of BKP compared with conservative treatment. We found that BKP tended to allow patients to improve ADL early. There was no significant difference in the hospitalization duration in the conservative treatment group in the BKP group with or without AVF.

PS-FP-4-18

Is Fusion Necessary in AO Type C Injuries of the Thoracolumbar Spine?

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Purpose: Fusion surgeries are considered “gold standard” in the management of AO type B and type C injuries of the thoracolumbar spine (TLS). Over the past decade, various studies have reported comparable results of long-term stability in non-fusion surgeries with regard to AO type B injuries. The purpose of this study was to evaluate the long-term functional and radiological outcome in patients undergoing non fusion surgery for AO type C injuries of TLS.

Methods: This retrospective study included patients with AO type C injuries of TLS with normal neurology who underwent posterior instrumented stabilization without

fusion. Radiographs were assessed for wedge angle, regional angle and sagittal index. Functional outcome was assessed using Oswestry Disability Index (ODI). Statistical methodology followed was Wilcoxon test for paired samples, Pearson correlation, and analysis of variance (ANOVA) test for unpaired samples.

Results: The study included 35 patients. The mean preoperative regional kyphotic angle decreased from $19.8^\circ \pm 13.7^\circ$ to $6.6^\circ \pm 11.3^\circ$ immediately following surgery. There was a statistically significant loss of correction and the regional kyphotic angle increased to $8.7^\circ \pm 10.4^\circ$ at 6 months ($p = 0.005$) and to $9.21^\circ \pm 10.5^\circ$ at the end of 2 years ($p = 0.003$). The cumulative loss of disc space angle (2.4 ± 50) was significant at 2 years ($p = 0.002$) follow-up starting 6 months ($1.8^\circ \pm 4^\circ$, $p = 0.01$) following surgery measured using estimated marginal means and pairwise comparisons. The functional outcome was measured using the ODI, 80 % of the patients reported a score $< 20\%$ (minimal disability) while 20% had a score between 20%–40% (moderate disability). The Pearson correlation (-0.023) ruled out a significant relationship between functional outcome and loss of correction ($p = 0.898$). The Pearson correlation also ruled out any significant relationship between age and ODI ($p = 0.17$). The most frequently encountered AO type A subtype was A3 (34%) followed by A4 (31%), A1 (20%), A2 (8.5%), and A0 (6%). The ANOVA test did not reveal a relationship between the AO A subtypes and the ODI when compared between groups ($p = 0.37$).

Conclusions: “Posterior instrumented stabilization without fusion” is a successful procedure in AO type C injuries of TLS with normal neurological status.

PS-FP-4-19

Alteration of Global and Regional Sagittal Alignment after Correction Surgery for Focal Kyphosis at The Thoracolumbar Junction

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Purpose: The sagittal balance correlates with health-related quality of life. We can use surgical methods to correct local deformity. However, the reciprocal changes of the

sagittal parameters are not clear. We were interested in the alteration of global and regional sagittal alignment after correction surgery for focal kyphosis at the thoracolumbar junction.

Methods: We reviewed the medical records of our patients, who received spine surgery for thoracolumbar deformity correction with the lowest instrumented vertebra above L3. Preoperative and postoperative sagittal parameters, including local kyphotic angle, segmental Cobb angle, pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), main thoracic kyphosis (MTK), and sagittal vertical axis (SVA), were measured. We also measured correlation between sagittal parameters and functional outcome.

Results: We included thirteen patients (5 males and 8 females). There were significant changes of segmental Cobb angle ($46^\circ \pm 10^\circ$ to $18^\circ \pm 7^\circ$, $p=0.001$), LL ($-47^\circ \pm 14^\circ$ to $-35^\circ \pm 14^\circ$, $p=0.002$), MTK ($18^\circ \pm 14^\circ$ to $24^\circ \pm 13^\circ$, $p=0.025$), SVA (6.1 ± 5.1 cm to 3.9 ± 4.1 cm, $p=0.033$), Visual Analog Scale (VAS; 6 ± 2 to 3 ± 2 , $p=0.002$), Oswestry Disability Index (ODI; $48\% \pm 17\%$ to $29\% \pm 17\%$, $p=0.001$), and PI-LL ($4^\circ \pm 18^\circ$ to $16^\circ \pm 17^\circ$, $p=0.002$). There were no significant changes over PI ($51^\circ \pm 14^\circ$ to $52^\circ \pm 12^\circ$, $p=0.937$), PT ($26^\circ \pm 14^\circ$ to $23^\circ \pm 11^\circ$, $p=0.194$), and SS ($26^\circ \pm 12^\circ$ to $28^\circ \pm 11^\circ$, $p=0.141$). Segmental Cobb angle showed moderate correlation with VAS ($\rho=0.538$, $p=0.058$, preoperative; $\rho=0.637$, $p=0.019$, postoperative; $\rho=0.513$, $p=0.073$, postoperative difference) and ODI ($\rho=0.676$, $p=0.011$, postoperative). There was some sort of correlation between sagittal parameters and functional outcome, though was not statistically significant.

Conclusions: Corrective surgery significantly improved the segmental kyphosis and the functional outcome. In the meantime, the sagittal alignment got some sort of improvement. Functional outcome may correlate more with successful correction of focal kyphosis than global sagittal alignment, but global sagittal alignment still had some sort of influence.

PS-FP-4-20

The Osteoporosis-Induced Vertebral Fracture like the Traumatic Burst Fracture (AO-B2) Shows the Prolonged Instability and the Progress Local Kyphosis

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Purpose: Spinous process fractures of adjacent vertebral bodies are often overlooked in diagnostic imaging of osteoporosis-induced vertebral body fractures (OVF). The purpose of this study was to investigate that flexion-distraction type OVF with rupture of posterior elements, including spinous process fractures, was refractory to conservative treatment and had a poor prognosis.

Methods: Twenty-nine OVF (AO classification B2) cases with spinous process fractures of adjacent vertebral bodies (AO-B2 group: 12 males, 17 females; age, 79.2 ± 6.66 years) and 29 OVF patients who underwent balloon kyphoplasty due to prolonged instability of posterior vertebral wall and back pain (posterior wall injury [PWI] group: seven males, 22 females; age, 79.7 ± 6.52 years) were included. Wedging ratio (anterior wall height/posterior wall height of fractured vertebral body in sitting lateral Xp $\times 100\%$), local kyphosis angle (angle formed by end plate of upper and lower vertebral bodies of fractured vertebral body in the same image), lumbar spine young adult mean (YAM) value were compared by t-test.

Results: The wedging rate was $34.0\% \pm 10.1\%$ in the AO-B2 group and $54.1\% \pm 18.1\%$ in the PWI group, and AO-B2 group was significantly advanced ($p=0.00000268$). The local kyphosis angle was $33.0^\circ \pm 9.88^\circ$ in the AO-B2 group and $15.4^\circ \pm 10.5^\circ$ in the PWI group, and the kyphosis deformation was also significantly stronger in the AO-B2 group ($p=0.000000193$). The YAM value was not significantly different between the two groups (AO-B2 group: $80.9\% \pm 13.6\%$, PWI group: $73.0\% \pm 21.0$; $p=0.13$).

Conclusions: OVF with spinous process fractures of adjacent vertebral bodies has a higher degree of instability than OVF with posterior wall damage, which is generally considered to have a poor prognosis, resulting in crushing and destruction of the vertebral body and kyphotic deformity of the spinal column. Therefore, it should be noted that AO-B2 type OVF has a poor prognosis. It is

often difficult to point out posterior element damage from a simple roentgen image alone, and special care must be taken not to overlook it. Computed tomography and magnetic resonance imaging were considered to be useful for definitive diagnosis and treatment decision making including early surgical intervention.

PS-FP-5-1

Optimizing the Brace-Wearing Criteria in Adolescent Idiopathic Scoliosis: The Role of Utilizing the New Sanders 7b Staging

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Purpose: There is no recommended guideline for brace weaning in adolescent idiopathic scoliosis (AIS). Curve progression after weaning may reach 46%. The Sanders staging (SS) method is widely used internationally but has yet to be acknowledged as an indicator for brace weaning. The addition of the ulna physis may further refine SS for optimizing brace weaning outcomes. The study aimed to investigate whether including the stages of ulnar physal closure in SS7 aids in a more accurate assessment for brace weaning for patients with AIS.

Methods: This was a retrospective analysis of patients who weaned brace-wear and consulted from June 2016 to December 2018. Patients who weaned brace-wear at Risser stage ≥ 4 , static standing body height, and arm span for at least 6 months and ≥ 2 -years post-menarche were included. Skeletal maturity at weaning was assessed using Sanders staging with SS7 subclassified into SS7a (all phalangeal physes are fused and only distal radial physes are open, with narrowing of medial physal plate of the distal ulna) and SS7b (those with $>50\%$ fusion of the medial growth plate of distal ulna). Weaning maturity grading and any curve progression were analyzed using Fisher's exact test, with Cramer's V and Goodman and Kruskal's tau.

Results: A total of 179 AIS patients (83.2% females) were studied with a mean age of 14.8 ± 1.1 years and Cobb angle of $34.6^\circ \pm 7.7^\circ$ at weaning. The follow-up period was 3.4 ± 1.8 years. At post-weaning 6-months, curve progression rates for patients weaning at SS7a versus SS7b were 11.4% and 0%, respectively for $<40^\circ$ curves. The use of SS6, SS7a/ b,

SS8 for maturity assessment at weaning strongly associated (Cramer's V, 0.326; $p=0.016$) with whether the curve progressed at post-weaning 6-months. Weaning with SS7 subclassification allowed a 10.6% reduction of error in predicting curve progression.

Conclusions: The use of SS7a and SS7b allows accurate maturity assessment for guiding brace weaning. Weaning at SS7b is more appropriate without any curve progression cases immediately post-weaning for small curves ($<40^\circ$). This makes reaching full fusion of both distal radius and ulna physis (SS8) not necessary and brace weaning can be initiated approximately 9.0 months earlier.

PS-FP-5-2

Computed Tomography Analysis of Sacropelvic Parameters in Patients with and without L5 Spondylolysis

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Purpose: An association of increased pelvic incidence (PI) and decreased sacral table angle (STA) with spondylolysis has been reported but no study has simultaneously analyzed multiple sacropelvic variables to compare their association. Via a retrospective analysis of computed tomography scans, we aimed to determine the association of sagittal sacropelvic parameters with L5 spondylolysis.

Methods: CT scans obtained for assessment for major trauma in patients aged >16 years were analyzed. Scans were excluded if there was abnormal anatomy, previous spine or hip/pelvis surgery, or spinal pathology including deformity, infection, tumor, or trauma. Sacral anatomic orientation (SAO), PI, pelvic thickness (PTH), femoro-sacral posterior angle (FSPA), STA, and sacral kyphosis (SK) were measured.

Results: A total of 202 scans were analyzed: 25 with L5 spondylolysis and 177 normal. SAO (43.3° vs. 51.6°), PI (61.7° vs. 49.8°), STA (95.4° vs. 101.8°), and SK (31.0° vs. 23.7°) were all significantly different between groups. After logistic regression analysis, only PI (odds ratio [OR], 1.074; 95% confidence interval [CI], 1.026–1.124) and STA (OR, 0.822; 95% CI, 0.734–0.920) remained signifi-

cant predictors for the presence of spondylolysis. In the spondylolysis group PI correlated significantly with PTH ($r=-0.589$), FSPA ($r=0.880$), and SK ($r=0.576$); in the normal group PI correlated significantly with FSPA ($r=0.781$) and SK ($r=0.728$).

Conclusions: Simultaneously assessing multiple sacropevic parameters we found that increasing PI is associated with L5 spondylolysis while decreasing STA, which likely represents a chronic remodeling secondary to spondylolysis, is also associated with increased risk. Back pain in an adolescent or young adult with high PI or low STA should raise suspicion of possible occult spondylolysis.

PS-FP-5-4

Does the Segmental Flexibility Assessed by Fulcrum-bending Radiograph Correlate with Postoperative Cobb Angle in Adolescent Idiopathic Scoliosis?

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Study Design: Retrospective study.

Purpose: To clarify the correlation between the segmental flexibility using fulcrum-bending (FB) methods and postoperative correction rate at each disc level in patients with adolescent idiopathic scoliosis (AIS).

Overview of Literature: The FB method is useful to evaluate the flexibility of the scoliotic curve in patients with AIS and expect the postoperative global correction rate. We have reported there are significant differences in the segmental fulcrum flexibility (FF) at each disc level using FB methods in thoracic AIS. Assessment of segmental correlation between the preoperative flexibility and postoperative correction at each disc level has rarely been evaluated to date.

Methods: Our retrospective analysis was based on preoperative FB radiographs and postoperative computed tomography scans in 27 patients presenting with main thoracic curve scoliosis. The apex vertebra was defined as the "0" level, with the sequential cranial disc levels defined as "+1 to +5" and the sequential caudal levels as "-1 to -4". The preoperative segmental Cobb angle was measured

on both, standing and FB radiographs. The segmental FF was calculated as $([\text{the segmental Cobb angle in standing position} - \text{the segmental Cobb angle in the FB position}] / \text{the segmental Cobb angle in standing position}) \times 100$. Next, the postoperative segmental Cobb angle was measured on coronal view in computed tomography scans. The segmental correction rate (CR) was calculated as $([\text{the preoperative segmental Cobb angle in standing position} - \text{the postoperative segmental Cobb angle}] / \text{the preoperative segmental Cobb angle in standing position}) \times 100$. Furthermore, the fulcrum-bending correction index (FBCI) was calculated as: $\text{CR} / \text{FF} \times 100$. 100% of FBCI means postoperative correction was the same as preoperative correction predicted from FB. We measured from the upper-most to the lower-most end vertebra of the main curve.

Results: The correlation coefficient between FF and FBCI was -0.519 ($p < 0.01$), and it means a more rigid segment corrected greater than predicted. Furthermore, there was a significant difference in the FBCI among segments, with greater correction detected at the periapical segments (-2 , -1 , and $+1$; FBCI, 120%–160%) than predicted from the FB radiograph.

Conclusions: The curve around the apex in thoracic AIS is relatively rigid in preoperative radiography but is corrected greater than predicted. Understanding the distribution of segmental FFs and FBCIs will be important to achieve adequate correction of the curve in AIS, using the least extensive fusion mass possible.

PS-FP-5-6

Postoperative Coronal Imbalance Following Selective Thoracolumbar-Lumbar Fusion in Lenke 5C Adolescent Idiopathic Scoliosis

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Purpose: Selective thoracolumbar-lumbar fusion (SLF) for patients with Lenke 5C adolescent idiopathic scoliosis (AIS) was a generally accepted procedure. SLF has a great advantage to reduce mobile segments, but coronal imbalance

ance (CIB) or decompensation is one of the predictable complications. Several authors have proposed factors related to coronal decompensation in Lenke 5C AIS: inadequate fusion level, postoperative shoulder imbalance, bone maturity, and curve flexibility. However, coronal decompensation after SLF in Lenke 5C AIS is not yet clearly understood. The purpose of this study was (1) to evaluate the incidence and prognosis of postoperative CIB after SLF and (2) to find out the related factors with postoperative CIB in Lenke 5C AIS.

Methods: We conducted a single-center retrospective review of data from 30 AIS patients with Lenke 5C with who underwent SLF. The patient with less than minimum 2-year follow-up (FU) period was excluded. We measured the radiographic parameters before surgery (PreO), 1 week after surgery, and at the latest follow-up (FFU). We also assessed curve flexibility using side-bending films. Clinical outcomes were evaluated using the Scoliosis Research Society-22 Questionnaire. CIB was considered to have occurred if the C7PL was more than 2.0 cm lateral to the central sacral vertical line (CSVL) (C7PL–CSVL >2.0 cm) at FU. We compared the parameters between the patients with (CIB group) and without CIB (Coronal balanced: CB group).

Results: A total of 29 patients (mean age at surgery, 17.0 years; average FU period, 45.6 months) met our inclusion criteria. CIB was found in ten patients after surgery (34.5%), and decreased to 6.9% at FFU. A comparative analysis between the CB and CIB groups showed the following parameters were significantly different: age at surgery (17.5/14.7 years, $p=0.005$), PreO C7–CSVL (-6.2/-26.9 mm, $p<0.001$), LS curve in bending film ($5.9^\circ/11.2^\circ$, $p=0.02$), and L5 tilt in bending film ($-3.6^\circ/-8.1^\circ$, $p=0.02$). Clinical outcomes were comparable between the CB and CIB group.

Conclusions: Although coronal imbalance was frequently detected in the early postoperative period after SLF, it was mostly corrected spontaneously. Postoperative CIB didn't impact clinical outcomes significantly. Relatively younger age at surgery and less flexible lumbosacral curve may be related factors with postoperative CIB.

PS-FP-5-7

Preliminary Report of Surgical Outcomes of the Relatively Short Fusion (L2-Pelvis Fixation) for the Adult Spinal Deformity Patients

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Purpose: The upper thoracic area or lower thoracic area as the upper instrumented vertebra (UIV) and pelvis as the lowest instrumented vertebra (LIV) was generally accepted in corrective surgery for patients with adult spinal deformity (ASD). Longer spinopelvic fixation can provide optimal spinal alignment, but may restrict ADL because of postoperative trunk stiffness. We performed L2-pelvis fixation (L2-P PSF) for the ASD patients who had apex of kyphosis in the lower lumbar area and compensative hypokyphosis in the thoracic area. The purpose of this study is to evaluate the surgical outcomes of L2-P PSF for ASD patients.

Methods: Ninety-six consecutive ASD patients who underwent corrective surgery at our institute were retrospectively reviewed with a minimum 1-year follow-up. We performed L2-P PSF for 10 of the 96 patients. The mean age at surgery was 64.3 years, and the average follow-up period was 62.3 months. We performed interbody fusion (posterior lumbar interbody fusion or lumbar interbody fusion) at each level, and three-column osteotomies were required in three patients. We measured the several radiographic parameters before surgery (PreO), 2 weeks after surgery (PO), and at final follow-up (FFU). Clinical outcomes were evaluated using the Scoliosis Research Society-22 Questionnaire (SRS-22) PreO and FFU.

Results: Based upon the SRS-Schwab adult spinal deformity classification, three patients had an L coronal curve type, and seven patients were classified as N type. Sagittal modifier classification showed that in pelvic incidence (PI)–lumbar lordosis (LL) mismatch, all patients were classified ++, and in global alignment 2 were +, and 8 were ++, and in pelvic tilt (PT) 3 were +, and 7 were ++. Revision surgery was required for a patient who showed proximal junctional failure due to a UIV fracture. The

radiographic parameters (PreO/PO/FFU) were as follows: Cobb angles in lumbar curve: 25.9°/7.0°/9.4°, coronal vertical axis: 29.9 mm/12.7 mm/14.8 mm, thoracic kyphosis: 11.7°/23.0°/24.6°, thoracolumbar kyphosis: -4.0°/3.6°/6.6°, PI-LL: 32.8°/3.4°/3.6°, PT: 30.5°/18.2°/20.5°, and C7 sagittal vertical axis: 118.7 mm/14.7 mm/34.9 mm. All parameters significantly improved after surgery ($p < 0.005$) and didn't show any significant loss of correction at FFU ($p > 0.005$). A subtotal score of SRS-22 showed significant improvement from PreO to FFU (PreO: 2.6, FFU: 4.0, $p < 0.001$).

Conclusions: L2-PSF can provide adequate correction for ASD patients who have the apex of kyphosis in the lower lumbar area and thoracic compensatory hypokyphosis and normal thoracolumbar alignment.

PS-FP-5-10

Factors Influencing Postoperative Disc Angle in Lenke Type 5C Adolescent Idiopathic Scoliosis

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Purposes: Disc wedging after selective fusion would be increasing at the borderline between Lenke type 5C and 6C adolescent idiopathic scoliosis (AIS). The objective of this study was to evaluate the pre- and postoperative distribution of distal disc wedging and to determine the related factors influencing the disc angle below lowest instrumented vertebra (LIV) in patients with Lenke 5C AIS.

Methods: AIS patients with Lenke 5C curves underwent selective fusion and were reviewed. In this series, L3 vertebra was selected as the LIV. The difference between

pre and postoperative distribution of disc angle at L3/4 was noted. The association between disc angle and radiographic curve characteristics were also examined.

Results: There were 89 patients with a mean age of 16.2 years. Anterior approach was performed in 47 cases and posterior in 42. Preoperative disc angle below LIV was opening on the concave side ($-2.5^\circ \pm 4.0^\circ$). At final follow-up, the disc angle distribution shifted to opening on the convex side ($6.5^\circ \pm 4.3^\circ$). Twenty-five of 89 patients (28%) showed disc wedging greater than 10°. The preoperative thoracic curve, side bending of thoracic curve, lumbar curve magnitude, LIV-central sacral vertical line (CSVL) distance, and the instrumented Cobb angle revealed significant factors. The disc angle of anterior group ($8.0^\circ \pm 3.9^\circ$) was significantly greater than that of posterior group ($4.8^\circ \pm 4.3^\circ$). In multivariate logistic regression analysis, preoperative side bending of thoracic curve ($>14^\circ$; odds ratio, 5.5) and LIV-CSVL distance (>30 mm; odds ratio, 10.6) were the independent risk factors.

Conclusions: In Lenke 5C curves, disc wedging greater than 10° occurred in 28%. A preoperative side bending of thoracic curve more than 14° showed the risk of distal disc wedging after selective fusion.

PS-FP-5-11

Prevalence and Risk Factors for Subjacent Disc Wedging after Corrective Fusion Surgery in Lenke Type 5C Curve Patients

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Purpose: This study aimed to investigate the incidence and risk factors of subjacent disc wedging (SDW).

Methods: Data of 59 adolescent idiopathic scoliosis patients with Lenke type 5 curves who underwent posterior spinal fusion to L3 as the lowest instrumented vertebra (LIV) were retrospectively analyzed. The subjacent disc angle (SDA) was defined as the angle between L3 (LIV) and L4. SDW was defined as the absolute value of SDA

$\geq 10^\circ$ at 2-year postoperation. The incidence of SDW was investigated between non-selective and selective thoracolumbar/lumbar fusion group. In the selective group, patients with and without SDW were compared.

Results: Among 59 patients, 11 had nonselective and 48 had selective fusion. No patients in the non-selective group showed SDW vs 13 patients in the selective group (27%) showed SDW. In the selective group, patients with SDW showed significantly greater main thoracic (MT) curve, apical vertebral translation of the MT curve, upper instrumented vertebra tilt, LIV tilt, and SDA at 2 years postoperation, while no differences were found in the coronal balance nor clinical outcome. Multivariate analysis revealed preoperative T curve and SDA as predictors of SDW occurrence. T curve $>30^\circ$ and SDA $>0^\circ$ were calculated as cutoff values based on the receiver operating characteristic curve.

Conclusions: SDW seemed to occur as a compensation mechanism for progressing deformity of unfused segments (thoracic curve and residual lumbar curve) to maintain coronal alignment. Preoperative T curve $>30^\circ$ and SDA $>0^\circ$ (LEV as L4) were determined as risk factors for SDW occurrence.

PS-FP-5-12

Global Imbalances in the Lower Lumbar Are Risk Factors for Revision Surgeries in Postoperative Adolescent Idiopathic Scoliosis Patients: Clinical Analyses with a Median Follow-up of 17.4 Years

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Purpose: The aim of this study is to clarify the radiological risk factors for late revision surgeries in postoperative adolescent idiopathic scoliosis (AIS) patients with a long-term follow-up.

Methods: A total of 93 adult patients who underwent spinal fusion surgery for the correction of scoliosis in adolescents with a minimum follow-up of 10 years were

retrospectively evaluated and compared radiographical parameters between patients who underwent late (at least 10 years postoperation) revision surgeries and those without.

Results: Revision surgeries were performed in 10 patients with a mean time to the revision of 22.3 years after the initial operation due to disk degenerations of the lower lumbar in eight patients and adding-on in two patients. Postoperative radiological parameters before revision surgeries or at last follow-up, including pelvic tilt, lumbar lordosis, sagittal vertical axis, coronal balance, L3 and L4 tilt, and apical vertebral translation were 30.6° , 22.8° , 10.2 mm, 33.9 mm, 15.0° , 18.4° , and 42.5 mm in patients with revision surgeries, and 17.5° , 44.3° , 1.7 mm, 4.9 mm, 7.5° , 7.2° , and 23.1 mm in those without, respectively, with statistical differences.

Conclusions: We demonstrated factors significantly associated with a late revision surgery, including increases in coronal off-balance, pelvic tilt, L3 and L4 tilt, and a decrease in lumbar lordosis. Maintaining a less lumbar tilt and well-balanced sagittal and coronal alignment should be considered for better long-term postoperative clinical outcomes in patients with AIS.

PS-FP-5-13

The Role of Routine Preoperative Echocardiogram in Adolescent Idiopathic Scoliosis Patients Undergoing Deformity Corrective Surgery

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Purpose: Patients with adolescent idiopathic scoliosis (AIS) are often noted to have routine preoperative echocardiograms (ECHO). The prevalence of ECHO abnormalities and their impact on perioperative outcome is not clear, especially balancing against its costs. The study aims at identifying the significance of routine preoperative ECHO for AIS patients.

Methods: Clinical records of 295 adolescent AIS patients, >10 years age (mean age, 15.64 years), who underwent primary posterior corrective surgery in a tertiary spinal center, between 2015–2020, were reviewed. Patients with

revision surgery, anterior correction, syndromic/neuromuscular scoliosis, and/or pre-existent known cardiac comorbidities were excluded.

Results: A total of 139 patients (47%) had preoperative ECHO and complete preoperative clinical examinations. A total of 21 patients (15%) showed echocardiographic abnormalities (11 trivial valvular abnormalities, five mild root dilatation, three mild pericardial effusion, and two septal defects). None of these patients showed any clinical symptoms/signs or required cardiology assessment, and none had perioperative cardiovascular complications. Four patients (1.36%) demonstrated auscultatory murmurs on preoperative clinical assessment, of which, one had an abnormal ECHO finding (small pericardial effusion). None reported any perioperative complications. The average known cost of an echocardiogram was noted to be £363.

Conclusions: The prevalence of Echo abnormalities in asymptomatic AIS patients is 15%. Despite such findings, no patients required a cardiology workup and there were no perioperative complications as a result. Routine preoperative Echocardiogram for all AIS patients may therefore not be cost-effective.

PS-FP-5-14

The Role of Preoperative Somatosensory Evoked Potential in Patients Undergoing Adolescent Idiopathic Scoliosis Corrective Surgery

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Purpose: Patients with adolescent idiopathic scoliosis (AIS) undergoing corrective surgery have routine somatosensory evoked potential (SSEP) monitoring preoperatively. The significance of this routine investigation is not clear. The study investigates the preoperative SSEP as a predictor for perioperative abnormalities.

Methods: A total of 207 patients who underwent corrective surgery for AIS (2015–2020), and had complete clinical records were included in the study. Findings of preoperative SSEP, baseline neuromonitoring after anesthetic induction, and intraoperative neuromonitoring findings were compared.

Results: Six of 207 patients (2.9%) had abnormalities detected in the preoperative SSEP. All six of them had normal baseline neuromonitoring. Two of these six patients had intraoperative motor evoked potential (MEP) alerts. One improved with increasing mean arterial pressure. The second persisted. Both had normal postoperative neurology. 54/207 patients (26%) had intraoperative alerts. Of these, 12 had abnormal SSEPs only, 38 had abnormal MEPs only, and four had combined. Of the 12 patients with intraoperative SSEP alerts, all had normal preoperative SSEP and baselines. Eleven patients improved after limb repositioning and one persisted. Of the 38 only intraoperative MEP alerts, only two had preoperative SSEP abnormalities. Four of 54 patients (7.4%) had intraoperatively abnormal both SSEP and MEP. All of them had normal preoperative and baseline neuromonitoring.

Conclusions: Preoperative SSEP findings are not indicative of intraoperative neuromonitoring alerts. SSEP may not be required as a routine preoperative investigation for patients undergoing scoliosis correction for AIS.

PS-FP-5-15

Computed Tomography Study of the Relationship between Pelvic Incidence and Osseous Contribution to Lumbar Lordosis in Children

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Purpose: Although the relationship between pelvic incidence (PI) and segmental lordosis is well described in adults there is little data regarding the relationship in children and how it may change with aging. The aim of this study was to define the relationship between PI and segmental vertebral body lordosis through childhood.

Methods: In 150 children aged a mean of 90 months (range, 2–185 months), computed tomography scans of the lumbar spine and pelvis were analyzed measuring PI, sacral table angle (STA), sacral kyphosis (SK), and segmental lordosis (SL) individually L1–L5. Children were grouped by age: (1) 0–60 months; (2) 61–120 months; and (3) 121–185 months.

Results: The mean PI for the entire cohort was 40.4°,

mean SL for L1 -0.6, L2 0.0, L3 1.8, L4 4.7, and L5 11.4. There were 40 children in group 1, 63 in group 2, and 37 in group 3. SL differed between age groups at all levels except at L2. L1 and L2 became more kyphotic with increasing age; L3, L4, and L5 became more lordotic with increasing age. The correlation between PI and SL at each level became stronger with increasing age. Similarly, the correlation between PI and STA and between PI and SK also became stronger with increasing age.

Conclusions: As children mature the relationship between PI and segmental lordosis at each level becomes stronger and the relationship trends towards that seen in the adult. Future work should aim to define when the adult PI-LL relationship is realized and adult alignment principles can be applied.

PS-FP-5-16

Improvement of the Patient Demographics, Radiographic Index and Surgical Invasiveness for Mechanical Failure (PRISM) with Prevention Procedures of Mechanical Failures in Adult Spinal Deformity Surgery

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Study Design: Multicenter retrospective case series.

Purpose: The purpose of this study was to add on the indices of preventive procedure to improve the predictive probability of PRISM (patient demographics, radiographic index and surgical invasiveness for mechanical failure). Overview of Literature: The mechanical failure (MF) following adult spinal deformity (ASD) surgery is a serious complication and often require revision surgery. We previously described the independent risk factors for MF (age, body mass index [BMI], bone mineral density [BMD], frailty, lowest instrumented vertebra [LIV], pelvic tilt [PT]) from 321 ASDs and established the PRISM, which stratifies the risk of MF from the sum of the standardized regression coefficients of each risk. Hypothesis: Adding the indices of preventive procedure for MF on to the existing indices of the risk stratification score (PRISM) may

improve the predictive probability in ASD surgery.

Methods: A total of 136 surgically treated ASDs who reached 2-year follow-up were included (age, 49±21 years; 88% female). We analyzed the associations between three prevention procedures (upper instrumented vertebra+1 tethering [Th], teriparatide [TP], and multi-rod [MR]) and MF by multivariate logistic regression analysis (MRA) to evaluate the adjusted associations of each variable and to predict the likelihood of developing MF. The values for the procedures by rounding the β regression coefficient were added with the 6 indices of the original PRISM score (age, BMI, BMD, frailty, PT, level of LIV) to establish the PRISM2. The discriminative ability of PRISM/PRISM2 for MF were evaluated using the AUC curve. The Cuzick test were performed to analyze the trend between the PRISM/PRISM2 and MF.

Results: MF developed in 25% (34 cases). The β for Th, TP, and MR were calculated by MRA and added to the PRISM score to establish PRISM2 (β : Th, -2.48; TP, -2.98; MR, -2.06). Trend analysis showed a significant trend between the incidence of MF and PRISM/PRISM2. Diagnostic ability assessment using the receiver operating characteristic (ROC) was superior in PRISM2 when compared with PRISM (PRISM2: area under the ROC curve [AUC], 0.94 [0.90 to 0.98]; PRISM: AUC, 0.87 [0.81 to 0.93]; difference, 0.07; $p < 0.001$).

Conclusions: We refined the PRISM for predicting MF in ASD surgery by adding MF preventive procedures to the risk indices. The predictive probability of PRISM2 for the development of MF was excellent (AUC, 0.94). This model can predict a patient's risk of MF and will help surgeons adjust treatment strategies to mitigate the risk of MF.

PS-FP-5-18

The Effect of Lumbosacral Fusion on Scoliotic Curves in Young Patients with Co-existing Spondylolysis/Spondylolisthesis: A Retrospective Cross-Sectional Study of Clinical, Functional and Radiological Outcomes

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Study Design: A retrospective study.

Purpose: To analyze the clinical, functional, and radiological outcomes of lumbosacral fusion in patients affected by scoliosis with lysis or/and listhesis and prognosticate the scoliotic behavior based on them.

Overview of Literature: The association of scoliosis with spondylolisthesis is well known. However, there is no sufficient literature on the various patterns of scoliotic curves, clinical presentation, surgical consensus, and outcomes.

Methods: A retrospective analysis was performed from the year 2008–2018. All patients managed with co-existing scoliosis and listhesis/lysis were included. Clinical profile, radiographic measurements, and functional outcomes were analyzed and compared between preoperative and postoperative indices calculated at 2 years following procedure. The outcomes were analyzed amongst three groups (olisthetic-group-1, sciatic-group-2, and idiopathic-group-3).

Results: Eighteen adolescent patients were enrolled in the study (16 females, two males). The study groups included olisthetic (seven females), sciatic (four females), and idiopathic (seven patients: five females, two males). Mean age was 13.85 ± 2.41 years (group 1), 15.5 ± 2.64 years (group 2), and 22.57 ± 9.32 years (group 3) with no significant difference. Preoperative lumbar curve severity, coronal decompensation, and lumbar lordosis were significantly different between the groups. The mean preoperative lumbar curve of $51.14 \pm 15.49^\circ$ (group 1) reduced to $41.157 \pm 18.96^\circ$ following lumbosacral fusion. All except one in this group had curve regression. The mean preoperative lumbar curve of $31^\circ \pm 7.78^\circ$ (group 2) reduced to $16^\circ \pm 3.91^\circ$ and increased from $36.33^\circ \pm 10.65^\circ$ (group 3) to $44.66^\circ \pm 9.97^\circ$ following lumbosacral fusion. Though, all except one had level 1 satisfaction in North American Spine Society index, sciatic group had better functional outcomes in Scoliosis Research Society-22 scoring system. The mean preoperative Oswestry Disability Index (ODI) scores were $50.8\% \pm 6.8\%$ (olisthetic group), $27.5\% \pm 9.57\%$ (sciatic group), and $46.57\% \pm 11.42\%$ (idiopathic group), and significant difference was noted between sciatic and other groups ($p=0.016$). The mean postoperative scores were $6.57\% \pm 2.22\%$ (olisthetic group), $1.5\% \pm 1.91\%$ (sciatic), and $6\% \pm 3.26\%$ (idiopathic) with significant difference between sciatic and other groups ($p=0.027$). Within groups there was a significant improvement in ODI scores in torsional and sciatic groups but not in idiopathic group ($p=0.109$).

Conclusions: This is largest available data on outcomes of patients with scoliosis co-existing with spondylolisthesis in recent literature. Three specific patterns of scoliosis need to be identified to prognosticate progression/regression of scoliosis following lumbosacral fusion. Radiological characteristics of each pattern have been described in detail to correctly designate the patient in to one group. Not all patterns behave in the same way following lumbosacral fusion. Sciatic curves respond well compared to moderate reduction in olisthetic curves whereas idiopathic curves show progression.

PS-FP-5-20

Change of Hip and Knee Joint after Surgery for Adult Spinal Deformity and Correlation between Those and Full Body Sagittal Parameters

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Purpose: This study aimed to elucidate the change of compensation of hip and knee and correlation of spinopelvic parameters with them after deformity correction surgery in adult spinal deformity (ASD) patients with normal or only mild osteoarthritis on lower extremities.

Methods: A consecutive series of a total of 113 spinal deformity patients were included (23 men and 90 women; a mean age, 68.5 ± 14.5 years; minimum 1-year follow-up). The following variables (C7 sagittal vertical axis [C7SVA], lumbar lordosis [LL], pelvic tilt [PT], pelvic incidence–lumbar lordosis mismatch [PI–LL], and T1 pelvic angle [T1PA]), and sacrum-femur angle [SFA] and femur-tibia angle [FTA] were collected for evaluation of the regional compensatory response of the hip and knee, respectively. The Pearson correlation test was used to evaluate the correlation of postoperative changes of SFA and FTA with the other parameters.

Results: Both the preoperative SFA and FTA increased significantly after the surgery (preoperative SFA, $149.6^\circ \pm 11.9^\circ$; 2 months postoperative SFA, $152.9^\circ \pm 11.3^\circ$; and preoperative FTA, $155.9^\circ \pm 10.9^\circ$; 2 months postoperative FTA, $168.9^\circ \pm 8.4^\circ$; $p < 0.001$). In addition, these

regional changes were maintained at 1-year postoperatively. After deformity correction, the preoperative C7SVA (15.5 ± 5.5 cm), PT ($37.1^\circ \pm 8.7^\circ$), and PI-LL ($66.2^\circ \pm 29.0^\circ$) significantly decreased to 3.6 ± 5.1 cm, $20.3^\circ \pm 7.3^\circ$, and $4.4^\circ \pm 15.5^\circ$ ($p < 0.001$), respectively. Except PT and C7SVA, all measured parameters showed moderate correlation with 2-month and 1-year postoperative changes in SFA, (LL: $r = 0.351$, $r = 0.325$; PI-LL: $r = -0.323$, $r = -0.325$; T1PA: $r = -0.374$, $r = -0.364$; the first r indicated the 2-month postoperative values and the latter, 1-year postoperative values). PT showed strong correlation with postoperative change of SFA ($r = -0.620$, $r = -0.555$). However, C7SVA did not show statistically significant correlations with SFA ($p = 0.621/0.584$; 2-month postoperative/1-year postoperative).

Conclusions: For patients who underwent deformity correction surgery with ASD and normal lower extremity or only mild osteoarthritis, surgeons could expect improvement of compensatory change of the knee along with correction of spinopelvic parameters. However, the degree of hip compensation improvement was relatively difficult to predict than that of the knee.

PS-FP-5-21

Comparison of 5-Year Surgical Results between Anterior Surgery and Posterior Surgery in Type 5 Adolescent Idiopathic Scoliosis: Stratification with Level of Upper and Lower End Vertebra

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Purpose: For adolescent idiopathic scoliosis (AIS) type5 patients, anterior surgery (ASF) and posterior surgery (PSF) have been indicated, and the superiority between these two methods is still controversial. Radiographical and clinical results of both surgical methods were compared in type 5 AIS patients with identical upper end vertebra (UEV) and lower end vertebra (LEV) to decrease selection bias.

Methods: Eighty-five type5 AIS patients who underwent

correction surgery with a minimum follow-up of more than 5 years were included. Patients with UEV at T10 or T11 and LEV at L3 were selected. The radiographic parameters and clinical results (Scoliosis Research Society-22 Questionnaire [SRS-22]) were compared between ASF and PSF groups.

Results: All preoperative radiographic parameters were similar between ASF and PSF groups. The mean intraoperative blood loss of the PSF group (168 mL) was significantly smaller than the ASF group (367 mL), and the mean intraoperative time was shorter in the PSF group (131 minutes) than the ASF group (262 minutes). However, the mean fused vertebrae in the ASF group was 0.6 vertebrae shorter than that of the PSF group. All radiographic parameters at 5 years were similar between ASF and PSF groups. The postoperative SRS-22 scores were also similar between ASF and PSF groups.

Conclusions: In patients with UEV at T10 or T11 and LEV at L3, all postoperative radiographic parameters were similar between the PSF and ASF groups. And the mean difference in fused vertebrae was 0.6 shorter in the ASF group. The present study results will help in considering surgical options in the treatment of AIS Lenke type 5 curve.

PS-FP-5-25

Do Different Upper Instrumented Vertebra Anchors Impact the Incidence of Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery?

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Purpose: The purpose of this study was to retrospectively compare the incidence of proximal junctional kyphosis (PJK) among the three types of the upper instrumented vertebra (UIV) instruments: pedicle screw (PS), hooks, and hooks combined with short-PS at UIV-1 in adult spinal deformity (ASD) surgery.

Methods: Fifty-three consecutive patients who underwent ASD surgery were retrospectively reviewed with a

minimum 1-year follow-up (FU). We divided the patients into three groups according to the UIV instruments: PS group (15 patients; 69.4 years; 78 months), hook group (25 patients; 71.5 years; 59.0 months), and hook-sPS group (13 patients; 71 years; 17 months). PJK was defined as the presence of a UIV or $UIV \pm 1$ fracture in this study. We measured several radiographic parameters (preoperative, postoperative, and final follow-up [FU]). We compared the parameters among the three groups.

Results: The incidence of PJK was calculated to 30% (6/15) in the PS group, 24% (6/25) in the hook group, and 7% (1/13) in the hook-sPS group, respectively. There are some tendency of significant differences between the three groups ($p=0.09$). Comparative analysis of the radiographic parameters among the three groups demonstrated that preoperative pelvic incidence–lumbar kyphosis, pelvic tilt, and thoracolumbar kyphosis at final FU were significantly different ($p<0.05$). The changes of proximal junctional angle was not significantly different among the three groups ($p=0.11$).

Conclusions: Our study shows that the construct consisting of hooks at UIV and short PSs at UIV-1 may prevent UIV fractures. This construct may match the concept of soft-landing for thoraco-pelvic fixation in the ASD patients. Further biomechanical study should be necessary to clarify our results.

PS-FP-5-26

Short-Segmental Spinal Fusion for Chronic Low Back Pain with Bone Marrow Edema Adjacent to the Vertebral Endplate

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Purpose: Corrective long spinal fusion is a widely accepted surgical method for the management of patients with adult spinal deformity. However, instrumented long-fusion for the treatment for elderly patients has been associated with a significant risk of complications and high cost of medical care. The purpose of this study was to assess

the results of short-segmental spinal fusion specifically for bone marrow edema (BME) adjacent to the vertebral endplate in patients with chronic low back pain (LBP) with spinal deformity.

Methods: A prospective study was performed at our hospitals, whereby we analyzed patients with spinal deformity and accompanying chronic LBP. For inclusion in this study, the required patient age was at least 50 years old, with a minimum LBP severity score of 40 mm on the Visual Analog Scale (VAS). Standard conservative medical treatment was performed. We included patients with lumbar BME on magnetic resonance imaging (MRI) and a lumbar tenderness point on the BME lesion. We defined BME as an area of high signal intensity on T2-weighted fat-saturated MRI. Short spinal fusion was performed on segments of BME. Clinical evaluations of VAS for LBP, the Oswestry Disability Index (ODI), the radiological parameter for sagittal vertical axis (SVA), pelvic incidence (PI), lumbar lordosis (LL), and pelvic tilt (PT) were carried out. To analyze the clinical and radiological data, we used the paired t-test, and statistical significance was defined as $p<0.05$.

Results: There were 27 patients (19 men and 8 woman), with a mean age of 64.6 years (range, 51 to 78 years). The mean VAS and ODI scores were 70.2 ± 2.5 mm and $48.4\% \pm 3.3\%$ before surgery, 20.4 ± 2.5 mm and $31.2\% \pm 3.1\%$ 1 month after surgery, and 33.4 ± 4.8 mm and $29.3\% \pm 3.5\%$ 12 months after surgery, respectively. The mean VAS and ODI scores significantly improved after surgery. The mean spinal fusion ranges were 1.3 segments. The SVA, PI–LL, and PT scores were 60.7 ± 10.6 mm, $20.5^\circ \pm 3.9^\circ$, and $23.8^\circ \pm 2.0^\circ$ before surgery, respectively. These spinal alignment parameters did not change significantly after surgery. MRI showed the BME to decrease after surgery.

Conclusions: Short-segmental spinal fusion is an effective procedure for chronic LBP with BME and spinal deformity.

PS-FP-5-28

Evaluation of Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis Lenke Type 5 Using EOS Radiography

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Purpose: To evaluate the outcomes of adolescent idiopathic scoliosis (AIS) Lenke type 5 patients treated with cantilever and direct vertebral derotation maneuvers via EOS three-dimensional reconstruction.

Methods: A retrospective study was conducted focusing on AIS Lenke type 5 patients from March 2018 to February 2019. The cantilever combined with direct vertebral derotation maneuvers were used for deformity correction. Various clinical and radiographic parameters preoperatively and at follow-up were compared, including angle of trunk rotation (ATR), Scoliosis Research Society-22r score (SRS-22r), Cobb angle of lumbar curve, apical vertebral translation (AVT), thoracic kyphosis, lumbar lordosis, and apical vertebral rotation (AVR).

Results: Totally 16 consecutive cases were enrolled in the study, with one male and 15 females. The average age was 15.25 ± 1.67 years old. The average follow-up period was 15.67 ± 3.01 months. The statistical significance was found in ATR ($15.75^\circ \pm 5.92^\circ$ vs. $5.13^\circ \pm 1.46^\circ$, $p=0.002$), Cobb angle ($41.25^\circ \pm 7.00^\circ$ vs. $12.45^\circ \pm 5.85^\circ$, $p<0.001$), AVT (4.49 ± 1.30 cm vs. 1.15 ± 0.65 cm, $p<0.001$), and AVR ($20.44^\circ \pm 4.42^\circ$ vs. $7.75^\circ \pm 4.62^\circ$, $p<0.001$) preoperatively and at follow-up. The statistical correlations were found between Cobb angle correction rate and AVT correction rate ($r=0.729$, $p=0.040$), Cobb angle correction rate and AVR correction rate ($r=0.706$, $p=0.050$), respectively. For SRS-22r score, the statistical improvement was found in self-image domain (3.53 ± 0.72 vs. 4.40 ± 0.37 , $p=0.025$).

Conclusions: The vertebral rotation of AIS could be evaluated effectively by EOS Imaging. EOS Imaging could be applied to rate the correction of AIS Lenke type 5 patients treated with cantilever and direct vertebral derotation maneuvers. Besides, truncal incline improvement positively correlated with Cobb angle correction in Lenke type 5C curves.

PS-FP-5-29

Can Anatomic Reduction with Monosegmental Fusion in High-Grade L5 Spondylolisthesis Restore Global Spinopelvic Alignment?

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Purpose: In high-grade spondylolisthesis (HGS), it has been demonstrated that the presence of a local lumbosacral deformity, L5 slippage, and lumbosacral kyphosis, results in an abnormal sacro-pelvic orientation as well as global sagittal imbalance of the spine. Recently, various studies have reported the importance of distinguishing between balanced and unbalanced pelvis in HGS, sustaining the importance of anatomic reduction in unbalanced cases. In our institute, we conducted spondylolisthesis reduction and monosegmental fusion for HGS. The aim of this study was to assess the improvement in the sagittal spinopelvic alignment after surgical reduction.

Methods: Fifteen consecutive patients with HGS (female, 11; male, 4) underwent corrective surgery. Following radiographic parameters were measured: slip angle (SA), %slip, sacral slope (SS), pelvic tilt (PT), thoracic kyphosis (TK), lordosis L1–L5 (lumbar lordosis [LL]1–5), and the sagittal vertical axis (SVA). Pelvic balance was assessed from PT and SS, to identify patients with a balanced pelvis or unbalanced pelvis.

Results: A mean follow-up period was 4.6 years (range, 2–10 years). An average age at surgery was 33 years. A mean SA and %slip improved from 12.7° to -6.9° and from 66.5% to 11.1%, respectively. Mean preoperative SS, PT, TK, LL1–5, and SVA were 42.9° , 28.0° , 13.7° , 66.1° , and 34.1 mm, respectively. Mean final SS, PT, TK, LL1–5, and SVA were 49.6° , 23.5° , 19.9° , 54.4° , and 22.5 mm, respectively. At baseline, nine patients had an unbalanced pelvis, with six patients remaining unbalanced and three becoming balanced postoperatively. On the other hand, six patients with a preoperative balanced pelvis remained balanced at the final. Three patients had signs of a L5 root lesion after surgery. In one of these patients, a revision was performed with decompression of the L5 roots. These nerve root lesions resolved completely at the final.

Conclusions: SVA in the patients with HGS was generally maintained by following compensatory mechanisms: retroversion of the pelvis, increased LL, and decreased TK. Such non-physiological postures and unbalanced pelvis worsened patient's quality of life. Surgical reduction in HGS allowed to restore spinopelvic alignment that means decrease PT, LL1–5, and increase TK. Moreover, anatomic reduction is effective in maintaining and restoring a normal pelvic balance postoperatively. We believe that nearly complete reduction is essential for normalization of global spinopelvic alignment for HGS.

PS-FP-5-31

Fat Infiltration in Back Muscles and Gluteus Maximus Muscle Is Significantly Related to Deterioration of Spino-Pelvic Sagittal Balance During Gait

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Purpose: Adult spinal deformity (ASD) patients often present with deteriorating posture during walking, suggesting that the pathology of ASD includes dynamic factor. Although full-spine lateral standing radiograph is widely used, it may be insufficient to evaluate ASD when used alone. We evaluated change in dynamic spino-pelvic balance in ASD by using three-dimensional motion analysis system (3DMAS). Additionally, we hypothesized that fatty degeneration of trunk and hip muscles might affect change in spino-pelvic sagittal balance during gait. We aimed to clarify the relationship between change in spino-pelvic sagittal balance during gait and fat degeneration in trunk and hip muscles in ASD.

Methods: We analyzed dynamic spino-pelvic balance during gait in 27 ASD patients by using 3DMAS (VICON). The mean radiologic parameters were as follows: C7 sagittal vertical axis, 118 mm; thoracic kyphosis, 20°; lumbar lordosis, 8.4°; pelvic tilt, 33°; and pelvic incidence, 48°. We

calculated dynamic thoracic, lumbar, and pelvic sagittal balance parameters (thoracosacral angle [TSA], lumbosacral angle [LSA], and pelvic sacral angle [PSA]). The patients were asked to continue walking for as long as possible, and dynamic parameters were evaluated using data from initial and final lap. We also analyzed fat infiltration rate (FI) of psoas major muscle (PM), back muscles (BM), and gluteus maximus muscles (GM) using computed tomography scan at L3 level of each patient. The correlation between the FI of each muscle and the change in dynamic spino-pelvic sagittal balance was investigated by the Spearman rank correlation test.

Results: The mean of the dynamic spino-pelvic sagittal balance (initial/final) were as follows: TSA, 27.3°/31.1°; LSA, 6.72°/8.85°; and PSA, 2.81°/4.37°. As a result, spinal kyphosis and pelvic anteversion significantly increased during gait. The mean FI was as follows: PM, 5.6%; BM, 11.8%; and GM, 8.3%. The deterioration of lumbar sagittal balance positively correlated with fatty degeneration of BM ($r=0.39$), and the deterioration of pelvic sagittal balance positively correlated with fatty degeneration of BM ($r=0.67$) and GM ($r=0.49$).

Conclusions: Full-spine lateral standing radiograph is influenced by transient compensation for spinal deformity and has the possibility to underestimate spinal balance during gait. The 3D gait analysis demonstrated that spinal kyphosis and pelvic anteversion significantly increased while walking and could detect failure of compensation of ASD. Although 3D gait analysis could be optimal for quantitatively evaluating spino-pelvic balance, the 3D motion analysis system has a high initial cost. The current analysis revealed evaluation of the fatty degeneration in BM and GM has the potential to reflect the dynamic change in spino-pelvic sagittal balance in ASD.

PS-FP-5-32

Single Level Posterior Lumbar Interbody Fusion Can Improve Global Sagittal Alignment in a Patient with Severe Dysplastic Spondylolisthesis

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Purpose: We investigated the impact of the correction of % slip and lumbosacral kyphosis by single-level posterior lumbar interbody fusion (PLIF) on global sagittal alignment in the patients with L5–S1 severe dysplastic spondylolisthesis (DS).

Methods: A total of 22 consecutive patients (mean age, 17±11 years; mean follow-up period, 5±3 years) who underwent single-level PLIF for L5–S1 severe DS were retrospectively reviewed. The preoperative and final follow-up % slip, lumbosacral angle (LSA), dysplastic LSA (D-LSA), sacral slope, lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI), PI–LL, sagittal vertical axis, and thoracic kyphosis were evaluated based on standing whole spine radiographs.

Results: Although asymptomatic implant failure and motor weakness of L5 nerve root were found in 23% (pedicle screw/rod breakage, 3 cases; pedicle screw loosening, 2 cases) and 9%, bone union was achieved, and motor weakness was full recovered in all patients at final follow-up. The mean preoperative % slip (59%±13%) was significantly improved to 25%±14% ($p=4.8\times 10^{-7}$), preoperative LSA (12°±9°) was improved to 1°±5° ($p=9.5\times 10^{-7}$), and preoperative D-LSA (-1°±12°) was improved to -10°±8° ($p=6.4\times 10^{-5}$). Moreover, the mean preoperative LL (53°±15°), PT (28°±11°), and PI–LL (23°±20°) were significantly improved to 60°±8°, 25°±6°, and 13°±10° at final follow-up ($p=0.01, 0.03, 0.003$). Especially, the mean preoperative LL, PT, and PI–LL were improved remarkably by single-level PLIF in 11 patients who had severe sagittal imbalance (PT >30°) ($p=0.002, 1.6\times 10^{-5}, 6.9\times 10^{-4}$).

Conclusions: Single-level PLIF for L5–S1 DS showed preferable correction of slippage and lumbosacral kyphosis. The correction of slippage and lumbosacral kyphosis improved the global sagittal alignment, particularly lumbar lordosis, and retroverted pelvis. The maximum reduction may lead to better local and global alignment in patients with DS.

PS-FP-5-38

Comparison of Radiographic Outcomes between Traditional Growing Rod and Shilla Graduates by a Single Surgeon

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Purpose: There is no study comparing the traditional growing rod (TGR) graduates to Shilla growth guidance system (SGGS) graduates who were operated by a single surgeon. This is a retrospective comparative cohort study.

Methods: Since 1993, a total of 96 consecutive patients who had TGR or SGGS procedure by a single surgeon were analyzed. There were 29 TGR graduates excluding congenital scoliosis with rib anomalies, neurofibromatosis, and 28 patients who were SGGS graduates. There was no significant difference between the two groups in terms of average age at initial surgery (TGR 8.8±3.0 vs. SGGS 8.2±2.7, $p=0.92$) and the duration of fusionless treatment (TGR 5.3±2.9 years vs. SGGS 5.3±1.8 years, $p=0.46$). Because of the consecutive series, the duration of latest follow-up after initial TGR is longer than that of SGGS (TGR 11.6±3.0 years vs. SGGS 7.9±2.2 years, $p<0.01$). Radiographic evaluation over treatment. Analysis included number and frequency of complications.

Results: There was no significant difference in terms of initial correction rate (TGR 38%±13% vs. SGGS 47%±18%, $p=0.62$) and initial gain of T1–S1 length (TGR 40±22 mm vs. SGGS 47±15 mm, $p=0.32$). The greater correction loss at pre-definitive fusion (TGR 10%±17% vs. SGGS 35%±31%, $p<0.01$) and shorter elongation of T1–S1 length during fusionless period were shown in SGGS group (TGR 43±12 mm vs. SGGS -7±28 mm, $p<0.01$). In

contrast during fusionless period, the greater gain of T1–S1 length at the definitive fusion were shown in SGGs group (TGR 9 ± 31 mm vs. SGGs 47 ± 31 mm, $p<0.01$). Instrumentation related complications and other complications such as infection or malalignment during fusionless treatment were observed in 24 out of 29 TGR patients (83%), and in all SGGs patients. However, in SGGs patients, there was significant decrease in number of repetitive surgeries including unplanned additional surgeries, compared with TGR patients (TGR 1.5 ± 0.4 vs. SGGs 0.3 ± 0.4 , $p<0.01$).

Conclusions: To our knowledge, this is the first study directly comparing between TGR and SGGs graduates operated by a single surgeon. The SGGs allowed repetitive scheduled surgeries and the comparable correction rate and spinal growth to those of TGR.

PS-FP-5-42

Surgical Outcome of Spinal Fusion for Osteogenesis Imperfecta with Scoliosis

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Purpose: Surgery for spinal deformity in osteogenesis imperfecta (OI) is a challenge due to severe and rigid deformity with extreme bone fragility. However, surgical outcome and complications still remain unclear. In addition, an application of the pedicle screws to the tiny and fragile vertebrae in OI is poorly understood. The purpose of this study is to evaluate the result of surgical outcome, and the accuracy and safety of pedicle screw placement for OI.

Methods: Twenty-five patients (female 14) of OI were included in this study. Mean age was 21 ± 9.3 years (range, 10–49 years). Mean follow-up was 5.8 ± 2.0 years. According to Sillence classification, the mildest form ‘type I’ was 16 patients, moderate form ‘type IV’ was one patient, and the most severe form ‘type III’ was eight patients. Fifteen patients were performed anterior release followed by posterior fusion; the others were performed posterior only. Two patients couldn’t be placed any implants due to extreme bone fragility. The accuracy of pedicle screw placement was evaluated by postoperative computed tomography scan. Placed screws were divided into five groups as

follows: inside the pedicle as ‘complete’, medial or lateral perforation under 2 mm as ‘med or lat <2 mm’, and over 2 mm as ‘med or lat >2 mm’. Radiographical findings and clinical data were also examined.

Results: Scoliosis was corrected from 95.6° to 65.8° after operation (correction rate 32.5%) and 68.1° at final follow-up. Space available for the lung was improved 76.3% to 84.9% at final follow-up. Fusion was obtained in all patients. Of the 290 screws placed, 213 screws (73%) were placed precisely. Although, 30 screws (10%) were penetrated from the pedicle cortex more than 2 mm. In particular, over 2 mm penetration rates of type III were much higher than that of type I and IV (27.8% vs. 3.0%). Complications related to spinal surgery included two transient neurological disturbances, and one of the two patients required screw removal. Surgical site infections were observed in two patients.

Conclusions: Pedicle screws were applicable to spinal fusion surgery in OI. Excellent bony union and no implant dislodgement were observed. However, special care should be taken in placing pedicle screws because of the weakness of the pedicle cortex, which could be easily penetrated especially in Sillence type III.

PS-FP-5-44

Development of a Prediction Model for Postoperative Lumbar Cobb Angle Following Selective Thoracic Fusion in Patients with Adolescent Idiopathic Scoliosis

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Purpose: Selective thoracic fusion (STF) for adolescent idiopathic scoliosis (AIS) aims to limit spinal fusion in main thoracic (MT) curves while achieving spontaneous correction and sparing more mobile segments in minor lumbar curves (LC). Although several guidelines have been proposed as criteria for STF, factors related to residual Cobb angle and potential progression of unfused LC are yet to delineate. The purpose of this study is to reveal

radiographic parameters related to magnitude of residual LC after STF and to establish a model to predict postoperative lumbar Cobb angle.

Methods: A multi-center observational retrospective analysis was performed in AIS patients who underwent STF for MT curves (Lenke type 1, 2, 3, or 4). STF was defined as a lowest level of fusion cephalic to or at L1. Multivariate linear regression analysis was performed to study the relationship between postoperative lumbar Cobb angle and selected radiographic variables to develop the prediction model.

Results: Ninety patients were included in this study. Mean age at AIS surgery was 14.7 ± 2.8 years and mean follow-up duration was 36.7 months. The patients were female predominant (87.5%). Preoperative Cobb angles of MT and thoracolumbar/lumbar curves were $51.1^\circ \pm 9.7^\circ$ and $36.8^\circ \pm 8.4^\circ$, respectively. The MT and TL/L Cobb angle ratio was 1.4 ± 0.3 and the MT:TL/L apical vertebral translation ratio was 2.9 ± 2.4 . After STF, the correction rate of MT curve was $62.6\% \pm 13.2\%$ and the spontaneous correction rate of LC was $57.3\% \pm 13.5\%$. Residual LC were less than 35° in all patients after STF. And there was no revision surgery was needed during the study period. Multivariate linear regression model was established as following: postoperative lumbar Cobb angle = $-3.813 + 0.1536$ (preoperative thoracolumbar/lumbar Cobb) + 0.0914 (preoperative LC-bending) + 0.543 (preoperative lumbosacral takeoff angle) + 0.669 (postoperative lowest instrumented vertebra [LIV] tilt) ($R^2=0.77$, $R=0.88$, $p<0.0001$). This formula showed high correlation and good prediction of postoperative lumbar Cobb angle.

Conclusions: The selected variables including preoperative TL/L Cobb angle, preoperative LC-bending angle, preoperative lumbosacral takeoff angle and postoperative LIV tilt angle yielded a formula with high accuracy for prediction of postoperative residual Cobb angle of LC after STF. In order to achieve an acceptable curve magnitude of unfused LC, this study disclosed the LIV tilt as a manipulatable factor and the formula as a guideline for selecting proper candidates of STF.

PS-FP-5-45

Does Osteoporosis Affect the Postoperative Course of Adult Spinal Deformity Surgery?

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Purpose: The purpose of this study was to examine the effect of osteoporosis on adult spinal deformity surgery.

Methods: Among the adult spinal deformity surgeries from March 2010 to October 2018, 209 patients with preoperative femoral neck T scores were included in the study. Inclusion criteria were a 2-year follow-up, surgical age >60 years, and upper instrumented vertebra fixed with an iliac screw. Exclusion criteria were that Parkinson's disease and steroid use. T score ≤ -2.5 was defined as group P, and T score > -2.5 was defined as group N. Finally, 113 patients were included in this study. Patient background (age, sex, body mass index [BMI], American Society of Anesthesiologists grade, smoking history, alcohol history, osteoporosis treatment history), X-ray parameters (preoperative, first standing, 1 year postoperative, 2 years postoperative), quality of life (QOL) scores (Oswestry Disability Index [ODI], Japanese Orthopaedic Association [JOA], Scoliosis Research Society-22 Questionnaire [SRS22]), and mechanical complications (MC: proximal junctional failure, rod fracture, fracture) were compared among two groups.

Results: There were 26 patients in the P group and 87 patients in the N group. There was a significant difference in BMI (P/N = $20.8/22.8$ kg/m², $p=0.000$) and alcohol history (4%/25%, $p=0.036$) between the two groups. There was no significant difference in the preoperative use of bisphosphonate and teriparatide, but the percentage of postoperative teriparatide use was higher in group P (65.4%/35.6%, $p=0.014$). There was no significant difference in spinal sagittal alignment parameters between the two groups. There was a significant difference in ODI (36.0/26.4, $p=0.037$), JOA walk (45.9/59.3, $p=0.043$), JOA mental (40.0/51.9, $p=0.010$), SRS-22 function (2.85/3.29, $p=0.010$), SRS-22 self-image (3.06/3.58, $p=0.004$), SRS-22

subtotal (3.20/3.57, $p=0.034$), and SRS-22 total (3.21/3.57, $p=0.020$). Mechanical complications tended to be more frequent in the P group both at 1 and 2 years postoperatively. The percentage of MC requiring reoperation at 2 years postoperatively was significantly higher in the P group (23.1%/7.9%, $p=0.047$).

Conclusions: Osteoporosis can cause poor postoperative course in elderly adult spinal deformity surgery. It is necessary to pay attention to measures such as preoperative osteoporosis therapeutic agents, postoperative health-related QOL and mechanical complications.

PS-FP-5-47

Predicting the Natural Course of Hemivertebra in Early Childhood: Clinical Significance of Anteroposterior Discordance Based on Three-Dimensional Analysis

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Purpose: Previous studies have utilized the three-dimensional computed tomography (3D-CT) for the classification of congenital spinal deformities and have introduced the concept of two types of deformity: unison and discordant anomalies. However, there have been no further studies on the clinical significance of these discordant deformities, especially in the identification of deformities that will progress and require an operation. Therefore, we conducted this retrospective study to compare the progression of scoliosis due to single hemivertebra (HV) during early childhood, according to the anteroposterior discordance obtained from the 3D-CT studies.

Methods: We analyzed 97 cases of single HV with thoracolumbar scoliosis, diagnosed in children before the age of 3 years and followed up past the age of 6 years. The segmentation of the anterior and posterior components and anteroposterior discordance of the HV were evaluated using 3D-CT images. Coronal segmental curve angle (SCA) and balance were measured using whole spine plain radiographs.

Results: Using 3D-CT, 41 (42.3%) cases of unison HV and

56 (57.7%) discordant HV were identified. Unison HV comprised 21 (21.6%) cases of fully segmented (FS) unison HV and 20 (20.6%) cases of semi-segmented unison HV with corresponding anterior and posterior segmentation. The 56 cases of discordant HV were further classified into 4 different types. In the 86 patients who were followed without operation between the ages of 3 and 6 years, the average progression of SCA was significantly larger in FS unison HV than that in the other deformities (one-way analysis of variance, $p<0.001$). Ten of 86 (11.6%) patients showed a coronal imbalance at the age of 6 years, but the proportion of patients with coronal imbalance was not significantly different among the deformity types.

Conclusions: Anteroposterior discordance on 3D analysis is a useful indicator for the progression of congenital scoliosis in early childhood.

PS-FP-5-51

Which Is More Predictive Value for Mechanical Complications: Fixed Thoracolumbar Alignment versus Dynamic Global Balance Parameter

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Purpose: In this study, we investigate about relationship between postoperative global sagittal imbalance and occurrence of mechanical complications after adult spinal deformity (ASD) surgery. In global sagittal balance parameters, C2-hip axis (C2HA) and T1 pelvic angle (TPA) were analyzed.

Methods: Between January 2009 and December 2016, 199 consecutive patients with ASD underwent corrective fusion of more than 4 levels and were followed up for more than 2 years. Immediate postoperative and postoperative 2-year whole spine X-rays were checked for evaluating immediate postoperative C2HA, TPA, and other parameters. In clinical outcomes, back and leg pain Visual Analog

Scale (VAS), Scoliosis Research Society-22 Questionnaire (SRS-22), Oswestry Disability Index (ODI), 36-item Short Form Health Survey (SF-36) were evaluated.

Results: Total of 199 patients (26 males and 173 females) were reviewed, the average age was 66.8 ± 12.28 years, and they were followed for an average of 30.54 ± 10.25 months. Based on the occurrence of mechanical complications, a comparative analysis was performed for each parameter. In univariable analysis, mechanical complications were significantly much more occurred in C2HA abnormal group (odds ratio [OR], 3.296; $p < 0.001$; area under the curve [AUC]=0.645). In multivariable analysis, the result was much more related (OR, 2.924; $p = 0.001$; AUC=0.727). In contrast, there was no significant difference between normal and the occurrence of mechanical complications in TPA. In clinical outcomes, the differences of SRS-22, ODI, SF-36 physical component summary (PCS) were significantly improved in C2HA normal group (normal vs. abnormal; SRS-22: 0.88 ± 0.73 vs. 0.68 ± 0.64 , $p = 0.042$; ODI: -24.72 ± 20.16 vs. -19.01 ± 19.95 , $p = 0.046$; SF-36 PCS: 19.33 ± 18.55 vs. 12.90 ± 16.73 , $p = 0.011$).

Conclusions: To maintain the global balance through the cervical compensation even if the thoracolumbar global balance is not correct. It could make reduce the prevalence of mechanical complications. The C2HA could be useful postoperative predictable factor for occurrence of mechanical complications.

PS-FP-5-52

Mid-Term Health-Related Quality of Life and Its Related Factors Following Adult Spinal Deformity Surgery: A Minimum 5-Year Follow-up Case Series

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Purpose: Several reports indicated that adult spinal deformity (ASD) surgery showed significant improvement in

health-related quality of life (HRQOL) with short-term follow-up (FU) period. However, there are still unknown that HRQOL can be maintained with mid-term FU. The aim of this study was to evaluate the mid-term HRQOL in ASD surgery and to identify the factors related to HRQOL in mid-term FU.

Methods: Study design was retrospective cohort study. Sixty-one consecutive ASD patients who underwent spinopelvic fixation (mean fused level: 9.9 segments) at our institute from 2010 to 2015. Four patients with additional surgeries and two patients who could not be followed for more than 5 years were excluded in this study. We identified 55 ASD patients (mean age, 66.8 years; average FU period, 83.0 months), and evaluated HRQOL with Scoliosis Research Society-22 Questionnaire (SRS-22) and physical component summary (PCS) and mental component summary (MCS) of SF-36 before surgery (Preop), 2 years after surgery (PO2Y), and at final FU. We also evaluated the trunk stiffness using lumber stiffness disability index (LSDI) at FU.

Results: HRQOL significantly improved PO2Y and maintained at FU ($p < 0.0001$, $p > 0.5$). Each domain (Preop/PO2Y/FU) were as follows: subtotal score of SRS-22, 2.6/3.9/3.8; PCS, 21.4/35.4/34.4; and MCS, 42.1/53.2/52.2. Key radiographic parameters (Preop/PO2W/PO2Y/FU) were thoracic kyphosis (TK: $13.0^\circ/26.4^\circ/34.1^\circ/34.3^\circ$), pelvic incidence–lumbar lordosis ($40.5^\circ/3.2^\circ/6.5^\circ/6.4^\circ$), pelvic tilt ($32.5^\circ/21.0^\circ/23.9^\circ/23.7^\circ$), and sagittal vertical axis ($94.9/27.1/46.3/47.5$ mm). Mean LSDI was calculated to 19.1 points. Univariate analysis indicated that PCS was significantly correlated with age at surgery ($r = -0.62$, $p = 0.002$), LSDI ($r = -0.61$, $p = 0.003$), TK ($r = -0.49$, $p = 0.005$), and TLK ($r = -0.59$, $p = 0.004$). MCS didn't show any significant correlation. SRS-22 showed significant correlation with age at surgery ($r = -0.36$, $p = 0.04$), LSDI ($r = -0.57$, $p = 0.007$), TK ($r = -0.46$, $p = 0.01$), and TLK ($r = -0.53$, $p = 0.002$). Multivariate logistic analysis indicated that significant related factors for PCS was age ($p = 0.04$; 95% CI, -0.78 to -0.028) and LSDI ($p = 0.02$; 95% CI, -1.6 to -0.14), and for SRS-22 was LSDI ($p = 0.005$; 95% CI, -0.08 to -0.02).

Conclusions: HRQOL after ASD surgery significantly improved and maintained in mid-term FU. Age and trunk stiffness may be possible risk factors for HRQOL in ASD surgery. Improving the trunk flexibility may be important for postoperative HRQOL in the ASD patients.

PS-FP-5-53

Predicting the Progression of Thoracolumbar Kyphosis in Achondroplasia Patients after Walking Age: Generalized Estimating Equation Analysis

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Purpose: The purpose of this study is to identify the trend of changes in radiologic parameters over age and to predict the factors that ultimately affect the progression of thoracolumbar kyphosis (TLK).

Methods: In this study, we retrospectively reviewed all achondroplasia patient who visited our institution from July 2001 to December 2020. Among these patients, 81 patients who have TLK confirmed in simple radiograph before age of 10 were included. Radiographic parameters were measured on D-L spine lateral or whole spine lateral view. We divided and analyzed two groups based on the TLK angle for patients (n=49) who had standing x-rays after 36 months of age: the progression group (P group) versus the resolution group (R group). The R group was defined as a group of patients who had TLK angle less than 20° at the last follow-up, whereas P group had TLK of more than 20°. The two groups used the Student t-test to compare mean value. And, for each parameter, different changes in age were predicted with a scatter plot, and generalized estimating equation was performed.

Results: The results of this study also showed the tendency of TLK angle to increase until the sitting age and then decrease as patients start standing. According to age, T10–L2 angle, Cobb's angle, apical wedge vertebral translation, percentage of wedge vertebral height, and the number of anterior heights less than 30% of posterior wall differ significantly between the two groups. Parameters without significant interactions for age, percentage of wedge vertebral width (both superior and inferior) did not differ according to age, but the P group was 6.135% and 6.375% higher than the R group, respectively. The ratio of wedge vertebra that anterior wall is less than 30% of posterior was also higher in the P group by about 0.207, regardless of age.

Conclusions: In this study, we described the natural courses of patients with or without the progression of TLK in

achondroplasia. Among various radiological parameters, apical vertebral translation and wedge vertebral height are considered as the driving factors in the TLK progression, which can be explained by the Hueter-Volkman rule. In addition, the presence of severely deformed vertebra rather than the number of deformed vertebrae seems to be more critical in the progression of TLK in achondroplasia patients.

PS-FP-5-54

Oblique Lumbar Interbody Fusion Combined with Anterior Screws Fixation for Surgical Treatment of Lumbar Degenerative Scoliosis

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Purpose: We designed oblique lumbar interbody fusion (OLIF) combined with anterior screws fixation in the same approach for the treatment of lumbar degenerative scoliosis in order to reduce the invasiveness and the duration of operation. The purpose of study is to evaluate the feasibility, efficacy, and safety of this surgical method.

Methods: Eight cases of lumbar degenerative scoliosis (coronal Cobb angle >10°) underwent OLIF (using cage and allograft bone) combined with anterior screws fixation for L2–5 through the mini approach in a right lateral position without real-time monitoring by electromyography in this study. We assessed statistical differences between preoperative and postoperative (12 months) coronal and sagittal parameters. Visual Analog Scale (VAS) score and Oswestry Disability Index (ODI) were evaluated before and 12 months after surgery. The fusion rate at OLIF cage, total blood loss, incision length, operation time, hospital stay, and surgical complications were also evaluated.

Results: The duration of operation was 217.5±22.7 minutes. There was a mean blood loss of 110 mL (range, 50–600 mL). The incision length was 4.6±0.4 cm. The mean stay at the hospital was 6 days (range, 5–8 days). The average follow-up duration was 13.5 months (range, 12–18 months). At 1-year follow-up, all patients who underwent combined OLIF and anterior screws fixation achieved statistically significant improvement in coronal Cobb angle

(range, $22.7^{\circ}\pm 4.8^{\circ}$ to $9.8^{\circ}\pm 3.7^{\circ}$), apical vertebra translation (range, 2.5 ± 0.8 to 1.5 ± 1.0 cm), coronal vertical axis (range, 2.2 ± 1.6 to 0.6 ± 0.4 cm), sagittal vertebral axis (range, 6.3 [0.2–23.4] to 2.3 [0.1–9.6] cm), thoracic kyphosis (range, $25.2^{\circ}\pm 4.0^{\circ}$ to $28.7^{\circ}\pm 4.8^{\circ}$), lumbar lordosis (LL) (range, $29.4^{\circ}\pm 9.5^{\circ}$ to $37.9^{\circ}\pm 8.5^{\circ}$), pelvic incidence (PI) (range, $52.4^{\circ}\pm 13.1^{\circ}$ to $49.0^{\circ}\pm 11.3^{\circ}$), pelvic tilt (range, $28.4^{\circ}\pm 6.9^{\circ}$ to $22.4^{\circ}\pm 5.7^{\circ}$), and PI–LL mismatch (range, $23.0^{\circ}\pm 11.4^{\circ}$ to $11.1^{\circ}\pm 8.9^{\circ}$). For the clinical evaluation, VAS for back pain (range, 8 [6–10] to 1 [0–2]) and ODI (range, 55.6 ± 8.7 to 21.1 ± 3.4) improved significantly after surgery. Fusion grades based on the Bridwell grading system at 1-year follow-up were grade I in 17 segments (70.8%) and grade II in seven segments (29.2%). No patients had any form of permanent iatrogenic nerve damage and a major complication. No failure of instruments was observed.

Conclusions: OLIF combined with anterior screws fixation is a good choice of minimally invasive surgery for lumbar degenerative scoliosis.

PS-FP-5-55

Propensity Score-Matched Analysis to Assess the Risk Factor of Postoperative Proximal Junctional Fracture in Adult Spinal Deformity Surgery

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Purpose: Increasing numbers of older adults with spinal deformity have recently been undergoing corrective surgery to improve their quality of life. Such surgery has a high incidence of complications, proximal junctional kyphosis reportedly occurring in 20%–40% of cases. We therefore aimed to determine the incidences of postoperative proximal junctional fracture (PJFr) and proximal junctional kyphosis/failure according to pre-existing vertebral fracture status (used as a surrogate for bone mass density) and identify whether pre-existing vertebral fracture (VF) is a risk factor for complications after surgery for adulthood spinal deformity.

Methods: The cohort of this retrospective single institu-

tion study comprised 78 women aged 70.7 ± 7.5 years who had undergone long spinal fusion (\geq six segments) for spinal deformity in our institution from 2014 to 2017 and been followed up for ≥ 2 years. We excluded patients due to acute VFs, adult idiopathic scoliosis and Parkinson's disease. Pre-existing VFs were identified on preoperative whole spine radiographs and patients grouped according to their presence and severity by Genant classification. We used propensity score analysis to reduce patient selection bias of this cohort. The postoperative incidences of PJFr and proximal junctional kyphosis/failure were assessed in the whole cohort and after propensity score matching and compared according to pre-existing VF status using Student t-test and Mann-Whitney tests.

Results: In the whole cohort, the incidences of PJFr and proximal junctional kyphosis/failure were significantly greater in patients with pre-existing severe VF than non-VFs. The latter were younger, less likely to have received teriparatide, and had smaller pelvic tilts and pelvic incidence minus lumbar lordosis than those with pre-existing VFs. After propensity matching to minimize the effects of these differences, we identified the incidence of PJFr was significantly higher in the severe VF than non-VF group (adjusted odds ratio, 8.8; PJFr 15.4% vs. 61.5%; $p < 0.05$; 95% confidence interval, 1.3–57.4).

Conclusions: Pre-existing VFs are as important osteoporosis surrogate markers as dual energy X-ray absorptiometry, while pre-existing VFs are a risk factor for postoperative PJFr in older patients undergoing long spinal fusion for spinal deformity.

PS-FP-5-56

Clinical Outcomes of Extensive Corrective Fusion Surgery from Thoracic Spine to Pelvis for Adult Spinal Deformity at 5 Years Postoperatively

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Purpose: Patient-reported outcomes (PROs) up to 2 years

after corrective surgeries for adult spinal deformity (ASD) have been well-studied, but there are few reports of medium- to long-term results. The purpose of this study was to investigate whether PROs were consistent from 2 to 5 years after extensive corrective fusion surgery from the thoracic spine to the pelvis for ASD, and to analyze whether revision surgery affected long-term outcomes.

Methods: We retrospectively analyzed patients who underwent extensive corrective fusion surgery from the thoracic spine to the pelvis for ASD between 2010 and 2015 and who were followed up for more than 5 years. Patients with neuromuscular disease, infection, and metastatic tumors were excluded. Radiographic parameters and PROs (revised Scoliosis Research Society-22 [SRS-22r], Oswestry Disability Index [ODI]) preoperatively and at 2 and 5 years postoperatively were investigated, and the correlations between PROs at these time points were investigated. We compared the change in PROs at 2 years (Δ PRO2 years) and 5 years (Δ PRO5 years) after surgery. We also compared Δ PRO2 years and Δ PRO5 years of patients who did and did not undergo revision surgery after the index surgery.

Results: Of 168 patients who underwent extensive corrective fusion surgery from the thoracic spine to the pelvis, 96 (mean age, 66.7 years) were analyzed. The PROs at 2 and 5 years after surgery showed significant correlations in all domains (SRS-22r function [$r=0.752$], pain [$r=0.644$], self-image [$r=0.668$], mental health [$r=0.719$], subtotal [$r=0.757$], and ODI [$r=0.789$]). No significant differences were found between Δ PRO2 years and Δ PRO5 years in the other domains, except for self-image (1.4 ± 1.0 vs. 1.0 ± 1.0 , $p=0.002$) and ODI (-14 ± 18 vs. -17 ± 18 , $p=0.018$). There were no significant differences between the Δ PRO2 years and Δ PRO5 years in the presence of revision surgery in any domain ($p>0.05$).

Conclusions: PROs at 2 years after corrective surgery for ASD were strongly correlated with PROs at 5 years after surgery. PROs were maintained or improved at 5 years after surgery, except for the self-image domain. The presence or absence of revision surgery was not an aggravating factor in the mid- to long-term clinical outcomes of extensive corrective fusion surgery for ASD.

PS-FP-5-59

Upper End Vertebra of Proximal Thoracic Curve at T1 is a Novel Risk Factor of Postoperative Shoulder Imbalance in Type 2 Adolescent Idiopathic Scoliosis

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Purpose: Several risk factors for the postoperative shoulder imbalance (PSI) in type 2 adolescent idiopathic scoliosis (AIS) were reported. We have noticed that the position of upper end vertebra (UEV) in proximal thoracic curve might have influenced the postoperative shoulder balance. We investigated the risk factors of PSI in patients with type 2 AIS including the position of preoperative UEV.

Methods: A total of 126 type 2 AIS patients who underwent posterior correction and fusion surgeries from 2008 to 2018 were included. We included only patients whose upper instrumented vertebra were selected at T2. The patients were divided into two groups based on radiologic shoulder height (RSH) 2 years after surgery. The patients with RSH more than 10 mm were included in the PSI group, and the others were included in the non-PSI group. UEV, RSH, Cobb angle, curve flexibility, T1 and T2 tilt, correction rate, Risser grade, Scoliosis Research Society-22 scores, and demographic data were compared between the two groups using independent t-tests or chi-square tests. The variables with p -value <0.20 in univariate analysis were assessed in logistic regression analysis.

Results: Seventy-one patients were included in this study (mean age, 14.1 ± 2.0 years; range, 10–19 years). Thirty-four patients in the PSI group and 37 patients in the non-PSI group were analyzed. UEV was T1 in 49 patients and T2 in 22 patients. Univariate analysis showed that there were more patients with UEV at T1 (PSI: 85%, non-PSI: 54%; $p<0.01$) and Risser grade ≥ 3 (PSI: 88%, non-PSI: 62%; $p<0.05$) in the PSI group than in the non-PSI group.

Regarding preoperative radiographic parameters, the mean Cobb angle of the main thoracic curve and RSH tended to be larger and the mean T2 tilt tended to be smaller in the PSI group than in the non-PSI group. Logistic regression analysis revealed that UEV at T1 (odds ratio [OR], 4.1; 95% confidence interval [CI], 1.2–14.4; $p < 0.05$) and Risser grade ≥ 3 (OR, 3.9; 95% CI, 1.1–14.5; $p < 0.05$) are significantly associated with PSI. There were no differences in the preoperative and final Scoliosis Research Society-22 scores, in total or in any domain, between the two groups

Conclusions: UEV at T1 and Risser grade ≥ 3 at the time of surgery are significant risk factors of PSI. The level of UEV in proximal thoracic curve should be considered in planning for posterior correction surgery as for avoiding PSI in patients with type 2 AIS.

PS-FP-5-60

A Novel Intraoperative Spino-Pelvic Parameter “Thoracic 10 Pelvic Angle” Can Predict Proximal Junctional Kyphosis after Adult Spinal Deformity Surgery

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Purpose: Previous studies reported several risk factors for proximal junctional kyphosis (PJK) after adult spinal deformity surgery. However, there was no report describing the correlation between the pelvic tilt (PT) and T10 vertebral body. Here we proposed a novel intraoperative spino-pelvic parameter “thoracic 10 pelvic (T10P) angle”, and investigated the risk factors for PJK.

Methods: Forty-seven patients who underwent adult spinal deformity surgery were enrolled. All patients were fused to the pelvis. We excluded the patients whose upper instrumented vertebra was above T9. The patients were divided into two groups based on the development of PJK at 2 years after surgery. T10P angle was defined as the angle between the line connecting the midpoint of sacral plate to the femoral head axis and the line connecting the

center of T10 vertebral body to the midpoint of sacral plate. Preoperative and postoperative spino-pelvic parameters (pelvic incidence [PI], lumbar lordosis [LL], PT, PI–LL, T10P angle), age, gender, and T-score were measured, and statistical analyses were performed using independent t-tests, chi-square test, and correlation coefficient.

Results: PJK was observed in 19% (9/47 patients), and they were divided into the PJK group. Thirty-eight patients were divided into the control group. There were no differences between the two groups in PI (PJK group: 51.8°/control group: 51.2°), preoperative LL (7.6°/12.7°), postoperative LL (35.9°/40.3°), preoperative PT (35.8°/31.8°), postoperative PT (22.9°/21.4°), preoperative PI–LL (44.2°/37.8°), postoperative PI–LL (15.9°/9.9°), preoperative T10P angle (38.2°/33.3°), postoperative T10P angle (15.8°/15.3°), age, gender, and T-score. Although there were 13/38 patients (34%) with postoperative T10P angle over 20° or under 0° in the control group, there were 7/9 patients (78%) with postoperative T10P angle over 20° or under 0° in the PJK group ($p < 0.05$). The linear correlation coefficient revealed that the postoperative PT were strongly correlated with the intraoperative T10P ($r = 0.80$, $p < 0.05$), and were calculated by the equation ‘the postoperative PT = 0.77 × intraoperative T10P angle + 9.2°.

Conclusions: T10P angle should be corrected between 0 to 20°. T10P angle enable us to predict postoperative PT and the development of PJK, surgical correction would be adjusted intraoperatively.

PS-FP-5-62

Differences in Natural Walking for Elderlies by the Degree of the Low Back Pain: Gait Analysis with KINECT

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Purpose: The objective of this research is to reveal the

characteristics of trunk inclination while walking differed by the degree of low back pain.

Methods: Elderlies who interested and voluntary-gathered dwellers for this study were researched at Toei town in Japan, between May and October 2019. A total of 88 subjects (31 men, 57 women) who answered the Oswestry Disability Index (ODI) questionnaire survey and joined the gait evaluation were included. Each subject was categorized into two groups (threshold of ODI 20%): the low back pain group (LBPG: ODI 20% or more) and the healthy group (HG: ODI 0% to 19%). Each gait was evaluated with a portable gait analyzer AKIRA (System Friend Co. Ltd.) which equips KINECT (Microsoft Co. Ltd.). Each natural walking was analyzed, and evaluated factors are as follows: stride length and width, velocity, and trunk inclination angle (from mid-pelvis to cervical crest) during walking.

Results: The total of 88 subjects were categorized into LBPG for 25 participants (average age, 81.8 years; ODI, 33.5%; height, 149.7 cm; weight, 57.4 kg; body mass index [BMI], 25.5 kg/m²) and HG for 63 participants (average age, 76.5 years; ODI, 8.0%; height, 154.4 cm; weight, 55.0 kg; BMI, 22.2 kg/m²). On average, the LBPG has stride length 0.491 m, width 0.149 m, velocity 60.8 m/min, trunk forward inclination 20.1°, and trunk backward inclination -4.6°. On the other hand, the HG has stride length 0.578 m, width 0.133 m, velocity 74.2 m/min, trunk forward maximum inclination of 7.4°, and trunk backward maximum inclination -0.4° on average. The stride length in the LBPG (0.491 m) was smaller than that in the HG (0.578 m) ($p=0.004$). The width in the LBPG (0.149 m) was larger than that in the HG (0.133 m) ($p=0.041$). The velocity in the LBPG (60.8 m/min) was slower than that in the HG (74.2 m/min) ($p=0.004$). The trunk leaning forward during walking in the LBPG (20.1°) was larger than that in the HG (7.4°) ($p=0.048$). The difference in trunk inclination suggested that the necessary muscle activity pattern to stabilize the spinal-column during walking may be different by the degree of low back pain.

Conclusions: The elderlies with high ODI have wide steps, short strides, and big trunk inclination ranges while they walk.

PS-FP-5-63

Clinical Relationships between Spinopelvic Parameters and Lumbar Disc Degeneration in Different Disc Regions

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Purpose: The pathology of lumbar disc degeneration (LDD) remains unknown, although it is associated with genetic, mechanical, and lifestyle factors. The purpose of this study was to clarify the clinical relationship spinopelvic parameters and the LDD.

Methods: A total of 58 patients (37 males and 21 females; mean age, 69.1 years old) who underwent surgery for lumbar spinal canal stenosis were retrospectively reviewed. Using magnetic resonance imaging, the grade of LDD was assessed according to the Pfirrmann classification at the L1/2 to L5/S1 levels. Spinopelvic parameters on whole-spine standing radiography were analyzed, including the coronal Cobb angle, sagittal vertical axis, thoracic kyphosis, lumbar lordosis (LL), sacral slope (SS), pelvic tilt, pelvic incidence (PI), and L1–L5 range of motion (ROM). The age, sex, smoking history, alcohol consumption, and comorbidity (diabetes mellitus [DM]) were also recorded.

Results: There was a positive correlation between the age and LDD grade at all disc levels, while no correlation was found between the coronal Cobb angle, sex, smoking history, alcohol consumption, and DM and the LDD. The correlation and multivariate regression analyses (adjusted for age and sex) showed that decreasing ROM and loss of LL and SS were correlated with the LDD at the L1/2 and L2/3 levels and the L5/S1 disc level, respectively; a low PI was correlated with the LDD at the L4/5 and L5/S1 disc levels.

Conclusions: This study showed that the pathology of LDD may differ depending on the disc level. Disc degeneration in the upper lumbar region was associated with decreasing in ROM. In contrast, disc degeneration in the lower lumbar region was associated with spinopelvic sagittal alignment but not with coronal alignment.

PS-FP-5-64

Three-Rod Correction Technique for Severe Neuromuscular Scoliosis

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Purpose: In severe neuromuscular scoliosis surgery, simple rodding to multiple pedicle screws is often difficult. To improve this issue, we have developed three-rod correction technique. In this technique, two rods are placed at the cephalad and caudal anchors on the concave side and connected by the cantilever technique, then followed by distraction between the two rods, and the translation with sublaminar tapes at the apex. After that, the single rod is placed on the convex side. Objective of this study is to evaluate the efficacy and safety of three-rod correction technique for severe neuromuscular scoliosis.

Methods: Twenty-four patients (male 8, female 16) with neuromuscular scoliosis over 90° were investigated. Mean age at operation was 14.2±3.5 years. Patients were divided into two groups: one is treated by posterior spinal fusion (PSF) with multi-segmental pedicle screws (group M: GM, n=11); the other is by PSF with three-rod correction technique (group T: GT, n=13). We retrospectively investigated operation time (OT), estimated blood loss (EBL), range of fixation, peri- and postoperative complications on medical record and Cobb angle (CA), pelvic obliquity (PO), thoracic kyphosis (TK, T2–12), and lumbosacral lordosis (LS, L1S1) on plain X-ray film at preoperation and final follow-up.

Results: Mean OT (min) was 388±76.5 (GM) and 444.4±78.3 (GT) ($p=0.09$), respectively. EBL (g) was GM 2,389±1,273 and GT 2,414±1,485 ($p=0.9$). Upper instrumented vertebra were upper thoracic (T1-4) and lower instrumented vertebra were L4 (4), L5 (5), and S1(15). Complications are seven excessive bleeding (GM, 4; GT, 3), three pulmonary related (GM), two proximal junctional kyphosis (GM, 1; GT, 1), one late surgical site infection (GM), and urinary tract infection (GM). CA (GM, 105°±16.4°; GT, 122°±15.5°; $p=0.001$) were corrected to 41.4°±15.5° (GM), 54.1°±15.8° (GT) ($p=0.059$) and correction rate (%) were 60.7±14.6 (GM) and 55.9±11 (GT) ($p=0.36$). PO 21.8°±15.3° (GM) and 25.1°±10.5° (GT)

($p=0.57$) were corrected to 8.6°±6.7° (GM) and 10.6°±6.6° (GT) ($p=0.51$). TK 20.6°±30.1° (GM) and 49.8°±32.5° (GT) ($p=0.03$) were corrected to 27.5°±21.9° (GM), 37.1°±18.4° (GT) ($p=0.09$). LS -27.5°±39.7° (GM) and -46.5°±37.7° (GT) ($p=0.24$) were corrected to -44.7°±14.1° (GM) and -47.3°±12.9° (GT) ($p=0.65$).

Conclusions: Three-rod correction technique could correct severe neuromuscular scoliosis with less complications.

PS-FP-5-66

Influence of Pelvic Obliquity on Postoperative Coronal Radiographic Parameters in Patients with Lenke Type 5 Adolescent Idiopathic Scoliosis at Minimum 5-Year Follow-up

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Purpose: Preoperative pelvic obliquity in patients with adolescent idiopathic scoliosis (AIS) may have an impact on postoperative radiographic alignment on non-fused segments, but there is very little information about it. We analyzed the influence of preoperative pelvic obliquity on postoperative coronal radiographic parameter in patients with AIS Lenke type 5.

Methods: Thirty cases of Lenke type 5 with a mean age of 14.6±1.8 years were investigated retrospectively. They were classified into two groups (≥5° group, <5° group) according to the angle (sacral takeoff angle–iliac takeoff angle). We compared the reviewed the coronal radiographic parameters at postoperative 2 and 5 years between the both groups.

Results: The ≥5° group had significantly larger wedging angle of the lower adjacent intervertebral disc ($p<0.05$, 9.1°±3.2° [≥5° group] vs. 5.9°±3.2° [<5° group]) at postoperative 2 years and ($p<0.01$, 9.0°±2.8° [≥5° group] vs. 4.9°±3.1° [<5° group]) at postoperative 5 years. No significant difference of wedging angle between 2 and 5 years postoperatively was observed in the both groups. The ≥5° group had significantly lower correction of lumbar Cobb angle ($p<0.05$, 51.1°±19.3° [≥5° group] vs. 67.2°±17.5° [<5°

group]) at postoperative 5 years. No significant differences were observed between the two groups for age, Risser-grade, correction rate of T-cobb angle, lowest instrumented vertebra-central sacral vertical line (CSVL), and C7-CSVL.

Conclusions: The $\geq 5^\circ$ group had larger wedging angle and less correction rate of lumbar Cobb angle than those of $< 5^\circ$ group postoperatively, and the values were continued until postoperative 5 years. Preoperative pelvic obliquity may be a critical consideration in selecting distal and proximal fusion level when planning corrective surgery in patient with AIS.

PS-FP-5-67

Can Bone Improvement after 2-Year Calcium+ Vitamin-D Supplementation Be Maintained in Idiopathic Scoliosis after 4-Year of Treatment Discontinuation: A Prospective Randomized Double-Blinded Placebo-Controlled Trial

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Purpose: Adolescent idiopathic scoliosis (AIS) is associated with low bone mass which could persist into adulthood. Given that AIS girls have low dietary calcium intake and high prevalence of vitamin-D (Vit-D) insufficiency, our group has previously reported the first 2-year randomized double-blinded placebo-controlled trial with calcium (Ca) and Vit-D supplementation to AIS girls with low bone mass (the Cal study) showing strong evidences of bone accretion with Ca+Vit-D supplementation. This study was an extension of the Cal study to address the important issue whether bone density and quality improvement from the initial 2-year Ca+Vit-D supplementation could persist as subjects approached peak bone mass at 6-year, i.e., after 4-year of supplement discontinuation.

Methods: This was a randomized double-blinded placebo-controlled trial on AIS girls (range, 11–14 years old; mean age, 12.9 years; Tanner stage $< IV$) with femoral neck areal bone mineral density (aBMD) Z-score < 0 and Cobb angle

$\geq 15^\circ$. A total of 330 subjects were randomized to group 1 (placebo), group 2 (600 mg Ca+400 IU Vit-D 3/day), or group 3 (600 mg Ca+800 IU Vit-D 3/day) for 2-year treatment. Investigations were done at baseline, 2-year and 6-year including high-resolution peripheral quantitative computed tomography at distal radius and dual-energy X-ray absorptiometry at proximal hips. Analysis of covariance was used for analysis. A *p*-value < 0.05 was considered statistically significant.

Results: A total of 270 subjects (81.8%) completed the treatment. At 2-year time-point, the increases in serum 25(OH)Vit-D, left femoral neck aBMD (group 3), trabecular volumetric BMD, trabecular bone volume to tissue volume ratio, and trabecular number were significantly greater in group 2 and 3 than in group 1 ($p < 0.05$). At 6-year follow-up after 4-year discontinuation of supplementation at a mean age of 19.2 years during the early phase of peak bone mass, no difference was noted except increase in cortical thickness being greater only in group 3 than in group 1.

Conclusions: This study provided strong evidences that 2-year supplementation with Ca+Vit-D improved bone health for low bone mass in AIS. At 6-year follow-up with 4-year discontinuation of treatment, the treatment effect mostly regressed towards the null hypothesis indicating the need to continue supplementation in order to maintain the therapeutic effect on bone health up to the stage of peak bone mass. This study is supported by Research Grants Council of the Hong Kong S.A.R., China (project no., 14130216 and 14174517).

PS-FP-5-72

The Impact of Growing Rod Surgery for Early Onset Scoliosis on the Cervical Spine Sagittal Alignment

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Purpose: The sagittal plane alignment of the cervical spine

is thought to be correlated with the patient's quality of life. The postoperative sagittal alignment of the cervical spine correlates with thoracic spine alignment in adolescent and adult scoliosis patients. Therefore, the cervical spine alignment of early onset scoliosis (EOS) patients who undergo surgery is thought to be affected by the instrumented thoracolumbar spine; however, there is no reports about EOS patients. In this study, we evaluated the effect of growing rod (GR) surgery on cervical sagittal alignment in patients with EOS.

Methods: This study includes 21 EOS patients (four males and 17 females; mean age, 8.6 years at first surgery) who underwent GR surgery at single institution between 2004 and 2017 and were followed up until final fusion (FF) surgery. Cobb angle in main thoracic curve, C2–7 angle, T1 slope, thoracic kyphosis (TK, T2–12), and sagittal vertical axis (SVA) were evaluated retrospectively at pre-surgery, post-index surgery, pre-FF, and post-FF (final follow-up). The patients were divided into a good cervical lordosis group (C2–7 angle after FF $< -10^\circ$) and a poor cervical lordosis group (C2–7 angle $\geq -10^\circ$). The radiographic parameters were compared between the two groups and the correlation analyses were performed.

Results: The Cobb angle and TK decreased significantly after the first operation and were well maintained until FF (preoperative vs. post-FF; Cobb 76.9° vs. 30.4° , TK 35.9° vs. 21.3°). The C2–7 angle and T1 slope tended to decrease after FF but without significant difference. SVA showed no significant changes. Patients in the poor group showed a significantly smaller preoperative C2–7 angle and postoperative T1 slope than those in the good group (good: $n=14$, poor: $n=7$). There was a strong positive correlation between postoperative C2–7 angle and postoperative T1 slope (0.829 , $p=0.00$). Furthermore, there was a positive correlation between postoperative C2–7 angle and preoperative C2–7 angle (0.443 , $p=0.023$) or postoperative TK (0.449 , $p=0.021$).

Conclusions: Thirty-three percent of patients who underwent GR surgery had poor cervical sagittal alignment after FF. These patients had a significantly smaller T1 slope after FF, and C2–7 angle positively correlated with T1 slope and TK. Therefore, cervical sagittal alignment could be adversely affected by distraction force in GR surgery.

PS-FP-5-73

Scoliosis in Osteogenesis Imperfecta: Quality of Life and Surgical Impact

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Purpose: Spinal deformity is prevalent among patients with osteogenesis imperfecta (OI), but little is known about its impact on quality of life. We hypothesize that scoliosis in OI patients is associated with lower quality of life; scoliosis surgery improves treatment satisfaction.

Methods: OI patients were recruited through the University of Hong Kong Shenzhen Hospital, one of the largest tertiary OI referral centers in China in this cross-sectional epidemiological study. Patients with a confirmed clinical or genetic diagnosis of OI were invited to complete an electronic questionnaire where patient demographics, health seeking behavior, treatment received, radiographs, and quality of life measures (in validated Chinese versions of Scoliosis Research Society-22 Questionnaire [SRS-22] and EuroQol 5-dimensional-5 levels) were assessed. OI patients were divided into the following groups: no scoliosis with Cobb angle $< 10^\circ$, scoliosis of Cobb angle between 10° and 50° without receiving treatment, scoliosis of Cobb angle over 50° without receiving treatment, scoliosis treated with bracing only, and scoliosis treated with surgery. Patients without a confirmed diagnosis of OI, or without radiographs for assessment of spinal deformities were excluded.

Results: A total of 148 OI patients (101 with scoliosis [male, 60; female, 41; mean age, 16.5 years] and 47 without scoliosis) were analyzed. The scoliosis group had lower self-image (3.31 vs. 3.70 , $p=0.003$) and mobility (3.13 vs. 3.66 , $p=0.015$). Within the scoliosis groups, the median Cobb angle for the primary curve was 34.5 (interquartile range, 16.8 – 58.4), with elder patients having greater curves ($\rho=0.544$, $p<0.001$). Curve magnitude was associated with pain ($\rho=-0.355$, $p<0.001$) and anxiety ($\rho=-0.352$, $p<0.001$), but inversely correlated with function ($\rho=-0.225$, $p=0.024$), self-image ($\rho=-0.379$, $p<0.001$), and total SRS score ($\rho=-0.283$, $p=0.004$). Eleven point nine percent

underwent scoliosis surgery, 13.9% underwent bracing, and 41.6% underwent physiotherapy. Fourteen point nine percent reported that they did not receive any treatment for scoliosis because they did not have the means, while 23.8% were not aware or uncertain whether they had scoliosis. Brace compliance was poor with only 18.2% reporting brace wear >20 hours per day. Patients treated operatively reported higher treatment satisfaction scores (4.41 vs. 3.43, $p=0.002$) than patients with scoliosis of Cobb angle over 50° without receiving treatment, despite similar curve magnitudes ($p=0.354$).

Conclusions: This is the largest quality of life study of scoliosis among OI patients to date. OI patients with scoliosis reported lower self-image and mobility. Curve magnitude was associated with older age, pain, and anxiety and was inversely correlated with function, self-image, and total SRS score. Patients who received surgery reported higher treatment satisfaction than those managed nonoperatively.

PS-FP-5-74

Machine Learning for Predicting Mechanical Complication after Adult Spinal Deformity Surgery

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Purpose: There have been many methods to prevent mechanical complication after adult spinal deformity (ASD) surgery, but mechanical complication cannot be avoided in ASD surgery. A modified Global Alignment and Proportion (GAP) scoring system equipped with a body mass index (BMI) and bone mineral density (BMD) (GAPB) system developed predictive values of mechanical complications after ASD surgery. Further, the purpose of this study is to create an ideal model through machine learning to predict mechanical complication in ASD surgery.

Methods: Between January 2009 and December 2018, 238 consecutive patients with ASD received at least 4 level fusions and were followed for at least 2 years. Data collec-

tion included demographic and radiologic examinations. The sample was stratified into groups: 167 cases (70%) for training, 71 cases (30%) for performance testing. The data were used as input to some machine learning algorithms, including logistic regression (LR), random forest (RF) gradient boosting system (GBS), and deep neural networks (DNN). The performance of algorithm was evaluated by the area under the curve (AUC) and accuracy using test data.

Results: The patients' average age and follow-up period were 67.1 ± 6.17 years and 28.54 ± 4.25 months, respectively. Statistical differences between complication and non-complication groups were as follows: BMI, BMD, relative pelvic version score, relative lumbar lordosis score, relative sagittal alignment score of GAP score were statistically significant in the training set and the test set ($p < 0.05$). The AUC in the training set of LR, GBS, RF, and DNN model were 0.871 (0.817–0.925), 0.942 (0.911–0.974), 1.000 (1.000–1.000), and 0.947 (0.915–0.980). The accuracy in the training set of LR, GBS, RF, and DNN were 0.784 (0.722–0.847), 0.868 (0.817–0.920), 1.000 (1.000–1.000), and 0.856 (0.803–0.909). The AUC in the testing set of LR, GBS, RF, and DNN model were 0.785 (0.678–0.893), 0.808 (0.702–0.914), 0.810 (0.710–0.910), and 0.730 (0.610–0.850). The accuracy in the testing set of LR, GBS, RF, and DNN were 0.732 (0.629–0.835), 0.718 (0.614–0.823), 0.732 (0.629–0.835), and 0.620 (0.507–0.733). RF achieved the best prediction performance on testing dataset and independent testing dataset.

Conclusions: This study created a comprehensive model to predict mechanical complications after ASD surgery. It was found that RF is the most appropriate model to reduce mechanical complications after ASD surgery. This information can be used to preventing mechanical complications to the surgeon and patient in ASD surgery.

PS-FP-5-75

Defining Spino-Pelvic Alignment in Adult Population Over 60 Years Old: Prospective Analysis of 214 Volunteers

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Purpose: The values of the surgical target angle and ideal sagittal balance that have been published so far are the results of a study targeting patients over 18 years of age. However, most patients in adult spinal deformity surgery are currently in their 60s or older, and it is unreasonable to apply these values to patients in their 60s or older. The purpose of this study is to prospectively analyze adult patients to obtain the ideal sagittal balance value at age 60 or older.

Methods: A total of 214 people over the age of 60 participated in the study. Questionnaires related to health-related quality of life (HRQOL) were administered. Spino-pelvic parameters were measured by whole spine X-rays. Radiographical evaluation was conducted on the lateral planes and HRQOL questionnaires (Oswestry Disability Index [ODI]) were completed. Multivariate logistic regression analysis was conducted to analyze radiologic parameters related with ODI. Radiographical parameters demonstrating highest correlation with HRQOL values were evaluated to determine thresholds predictive of ODI more than 20.

Results: Two hundred fourteen consecutive patients (mean age, 71.3 years) were enrolled. There were 131 people with an ODI value of less than 20 (minimal-ODI group) and 83 people with an ODI value of 20 or more (moderate-ODI group). Moderate-ODI group had greater pelvic tilt (PT) ($28^\circ \pm 13.7^\circ$ vs. $19.9^\circ \pm 13.9^\circ$, $p < 0.05$), greater T1 pelvic angle (T1PA) ($33.6^\circ \pm 15^\circ$ vs. $23.7^\circ \pm 14.6^\circ$, $p < 0.05$), and greater pelvic incidence/lumbar lordosis PI/LL mismatch (PI-LL) (45.2 ± 30.7 vs. 31.7 ± 36.1 , $p < 0.05$) than minimal-ODI group. Moderate-ODI group demonstrated greater disability on ODI measures compared with minimal-ODI (ODI 25.3 ± 4.3 vs. 11.8 ± 5.4 , $p < 0.05$). Pearson analysis demonstrated that among all parameters, PT, T1PA, and

PILL correlated most strongly with disability for both minimal-ODI and moderate-ODI groups ($p < 0.001$). Logistic regression models demonstrated threshold radiographical spinopelvic parameters for ODI more than 20 to be: PT 15° or more (area under curve [AUC]=0.820), T1PA 17° or more (AUC=0.888), and PI-LL 16° or more (AUC=0.842).

Conclusions: As you age, degenerative changes progress. Prospective analysis of consecutively enrolled age 60 or older patients proved that PT, T1PA, and PI-LL can predict patient disability and provide evaluation guides for appropriate treatment decisions. Threshold values for moderate disability (ODI >20) included: PT 15° or more, T1PA 17° or more, and PI-LL 16° or more.

PS-FP-5-76

Which Domain or Factors Of 36-Item Short Form Health Survey Impact on Patient Satisfaction after Adult Spinal Deformity Correction Surgery?

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Purpose: Increasing patient satisfaction is one of the key goals in adult spinal deformity (ASD) surgery. The 36-item Short Form Health Survey (SF-36) consists of eight domains and is very widely used, but the study of the association between each domain and satisfaction is limited. Our objective was to evaluate the relationship between patient satisfaction, Oswestry Disability Index, SF-36 domains, and radiographic measures at 2 years after surgery.

Method: A single center prospective database of ASD surgery was retrospectively reviewed. The correlation coefficients between demographics, radiographic parameters, health-related quality of life (HRQOL) including SF-36 8 domains and Scoliosis Research Society-22 questionnaire satisfaction scores at 2 years (Sat-2y). The patients were divided into highly satisfied and less satisfied group according to Sat-2y and compared each factor.

Results: A total of 41 patients who underwent thoracolumbar fusion for ASD and had a minimum of 2-year

follow-up was collected. All HRQOL subdomains and several sagittal radiographic parameters had significantly improved 2 years after surgery. In SF-36, Sat-2y was moderately correlated with general health (GH) ($r=0.51$), role emotional (RE) ($r=0.51$) domain at 2 years after surgery, not correlated with role physical, weakly correlated with the remaining domains. There were no differences in demographics and radiologic outcomes between the highly satisfied and less satisfied groups, and there were better scores in SF-36 GH, RE, and bodily pain in highly satisfied group.

Conclusions: GH and RE may be useful goal in improving patient satisfaction with management at 2 years after ASD surgery. Surgeon should pay attention to these domains for patient satisfaction.

PS-FP-5-80

Preoperative Distraction of Severe Caries Kyphotic Spine Deformities with Modified Halo-Pelvic Distraction Assembly

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Purpose: Halo-traction device has been seen with favorable outcome in preoperative management of with severe kyphotic deformities; however, associated complications are inevitable. Modifications in assembly can improve the outcome and clinical efficacy. Objective of the present study was to evaluate the clinical efficacy of our modified halo-pelvic distraction device for managing severe kyphotic deformity before definitive surgery.

Methods: Three cases of caries spine presented with severe kyphotic deformity (OMGEA spine deformity) were males of 14, 10, 36 years of age. The 1st had kyphotic angle of 141° from T1 to T10 vertebrae and complete loss of power of both lower limbs, and the other two had kyphotic angle of 162° from T7 to T12 and 159° from T7 to L2 vertebra, respectively. The third also had complete loss of power at both lower limbs. A modified halo-pelvic distraction device comprised of halo and pelvic assembly was applied before definitive surgery. The halo-ring was connected to head with 06 pins, while pelvic assembly had Ilizarov half pins connected to two arches allowing patients

to lie supine in bed. Two Ilizarov half pins were placed in the supra-acetabular region for sturdy anchorage, two were 10 cm posterior to the anterior superior iliac spine, and muscles were not pierced for placement of wires or pins that minimized the risk of infection and pain. The assembly had four rods, and set of two were placed anterolateral and posterolateral each, to provide balanced distraction forces. Distraction at the rate of 3 mm/day was started from first postoperative day for 35 days in first and 45 days each for 2nd and 3rd patients.

Results: The neurology in 1st patient improved in both lower limbs to grade 2 on 5th post-distraction day and after 35 days kyphotic angle reduced to 56° . The neurology remained intact in 2nd patient while in third patient, neurology improved to 3/5 in both lower limbs after 7 days of distraction, kyphotic angle reduced to 76° and 70° respectively after 45 days of distraction. At the end of distraction, definitive surgery was done and a stand-alone titanium cage was placed at the affected levels after debridement through an anterior approach. No peri- or postoperative complications were observed.

Conclusions: Gradual correction through preoperative halo-pelvic distraction can be safe and effective in severe caries spine kyphotic deformities. Our modified assembly will be useful for spine surgeon in these cases as no neurological and other complications were observed during peri or postoperative period.

PS-FP-5-82

Which Health-Related Quality of Life Assessment Tool, Patient-Reported Outcomes Measurement Information System, Revised Scoliosis Research Society-22, or Oswestry Disability Index, Is More Sensitive in Assessing Outcomes of Primary versus Revision Adult Spinal Deformity Surgery?

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Purpose: The Patient-Reported Outcomes Measurement Information System (PROMIS) has been recognized to be essential in assessment of the effectiveness of our clini-

cal interventions. However, there is a paucity of literature using the PROMIS instruments in assessing the health-related quality of life (HRQoL) of primary and revision surgery in adult spinal deformity (ASD).

Methods: All patients were enrolled with different PROs evaluation from preoperative to minimum 2 years postoperative time point. PROMIS, revised Scoliosis Research Society-22 (SRS-22r), Oswestry Disability Index (ODI), patient demographic data, and X-ray parameters were obtained at 3-time points: preoperatively, 1- and 2 years postoperative.

Results: A total of 86 ASD patients undergoing posterior spinal fusion of ≥ 5 vertebral levels to the sacrum, performed from 2016 to 2017, at a single institution. A total of 42 cases (48%) were primary surgery (P) and 44 (52%) were revision surgery (R). Both groups had significant HRQoL improvement from preoperative to 1- and 2 years postoperative. Patients in the R group had worse baseline HRQoL as compared with the P group. However, only PROMIS could detect differences in outcomes between primary surgery and revision surgery at 1 year postoperative, whereas SRS-22r and ODI showed no difference at 1 year postoperative between the two groups.

Conclusions: The majority of HRQoL improvement occurs within the 1 year postoperative in ASD patients. PROMIS domains are not only more efficient in administration, they are also more sensitive in assessing outcome differences between primary and revision surgery at preoperative, 1- and 2 years postoperative compared to other legacy instruments (SRS-22r and ODI).

PS-FP-5-83

Experiences of Early Air Travel with Pneumothorax after Anterior Spinal Surgery: A Report of Three Cases

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Anterior thoracic or thoracolumbar spinal surgery by retropleural approach always carries a risk of pneumo-

thorax as its consequence. Conventionally the Aerospace Medicine Association (AsMA) and the British Thoracic Society (BTS) recommend 2 weeks delay of air travel for patient with resolved postoperative pneumothorax. They also label active pneumothorax as an absolute contraindication for commercial air travel. Such a delay always causes psychological and financial stress to patients and family who are far from home. Here we report three patients with postoperative pneumothorax and insisted on early air travel despite being informed of the possible consequences. We report the cases of three female patients with adolescent idiopathic scoliosis (Lenke 5) treated at Hospital Umum Sarawak. They each developed postoperative pneumothorax which remained stable and slowly resolving on repeated chest radiographs at day 3. All three patients flew home on the same day of their discharge, and each retrospectively reported to be asymptomatic throughout their journey home. We have observed three postoperative pneumothorax patients travel home safely by flight earlier than stipulated recommended guidelines. However, the possibility of pneumothorax progressing into tension pneumothorax during air travel cannot be ignored. Until more evidences emerge, we still adhere to AsMA and BTS guidelines.

PS-FP-5-84

Radiological Assessment of Pre- and Postoperative Shoulder Balance Following Posterior Spinal Fusion for Lenke 2 Adolescent Idiopathic Scoliosis

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Purpose: To elucidate useful coronal parameters to control shoulder balance in posterior spinal fusion surgery for Lenke 2 adolescent idiopathic scoliosis (AIS).

Methods: A total of 33 patients were reviewed. Proximal thoracic, main thoracic Cobb angle (pelvic tilt [PT] and main thoracic [MT]), % correction of both curve (PT curve [PTC] and MT curve [MTC]), T1 tilt, and shoulder asymmetry by the radiographic soft tissue shadow (RSH)

were measured from preoperative, immediately postoperative and latest follow-up radiographs. PTC:MTC ratio was defined as an index of PTC and MTC matching. The amount changes in RSH (Δ RSH), T1 tilt (Δ T1 tilt), PTC (Δ PTC), MTC (Δ MTC), and PTC:MTC (Δ PTC:MTC) from pre- to post-surgery was calculated. The relationship between Δ RSH and other amount changes in other parameters was examined.

Results: A mean preoperative RSH of -12 mm was changed to +9 mm immediately after surgery and improved to +6 mm at the latest follow-up. A mean PT and MT were 44° and 64° before surgery, 18° (56%) and 12° (79%) immediately after surgery, and 17° (55%) and 17° (74%) at the latest follow-up, respectively. Δ RSH was significantly correlated with Δ T1 tilt, Δ PTC and Δ PTC:MTC.

Conclusions: Unlike RSH, T1 tilt is a parameter which can be checked easily by intraoperative X-ray examination. The results suggested that controlling and checking T1 tilt intraoperatively can be useful to avoid postoperative shoulder imbalance. Sufficient PT curve correction what is matched to MT curve correction would be necessary not only to levelling T1 tilt but also to prevent postoperative shoulder imbalance.

PS-FP-5-85

Surgical Outcomes in Syndromic Scoliosis with Neurofibromatosis

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Purpose: Spinal deformity surgery with neurofibromatosis (NF) is challenging. This study included 36 consecutive patients with NF who underwent scoliosis surgery. We evaluated the surgical outcome of spinal fusion for NF.

Methods: Fifteen cases were males and 21 cases were females, ranging in age from 2 to 49 years (mean age, 14.3±9.7 years) at the initial surgery. The surgical procedures were growth friendly in eight cases, anterior and posterior fusion in 24 cases, and only posterior fusion in 12 cases. We evaluated complications, number of surgeries, radiographic data, and health-related quality of life (HRQOL) (Scoliosis Research Society-30 [SRS-30], Oswestry Disability Index [ODI]) at final follow-up. Mean

follow-up was 10.2±7.1 years postoperatively.

Results: Scoliosis was corrected from 68° to 43° at final follow-up (correction rate=37.0%). Complications were observed in five cases (62.5%) of growth friendly surgery and nine cases (32.1%) of spinal fusion surgery, including four cases of adding-on, three cases of proximal junctional kyphosis, three cases of infection, three cases of rod fracture, three cases of hook dislocation, and one case of lowest instrumented vertebra dislocation. Two patients died during follow-up: one due to malignant transformation of neurofibroma and the other due to sudden death during bathing. The total number of surgeries was 3.8±4.1, and unplanned additional surgery was 0.4±1.0. HRQOL was SRS-30 (function 3.9±0.5, pain 4.6±0.4, self-image 3.7±0.5, mental-health 4.4±0.5, satisfaction 4.1±0.5) and ODI (6.1%±8.0%). There were no significant correlations between HRQOL and complications. Spearman's correlation analysis was performed for each of the HRQOL domains and scoliosis correction rate, but no correlation was found for all of them. There was a significant correlation between satisfaction and Cobb angle at final follow-up ($R=-0.41$, $p<0.05$).

Conclusions: SRS-30 function, self-image, and satisfaction domain scores in NF patients tended to be lower than those of AIS patients after surgery. These results are related to various factors such as severe scoliosis curve, skin lesions, multiple surgeries, and so on. On the other hand, the complications didn't affect the HRQOL at the final follow-up. Therefore, it may be important to provide appropriate additional treatment for complications even if the number of surgeries increases. We evaluated the surgical outcomes of NF with scoliosis. There was no significant correlation between correction rate and HRQOL or complications and HRQOL. Good outcomes were obtained for pain and mental-health.

PS-FP-5-86

Risk Factors for Lateral Translation in Adult Idiopathic Adolescent Scoliosis with Thoracolumbar/Lumbar Curves

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Purpose: Although lateral vertebral translation is associated with inducing curve progression, no study has analyzed risk factors for lateral slip in residual idiopathic scoliosis patients. We investigated risk factors for lateral slip in residual adolescent idiopathic scoliosis.

Methods: Forty-two preoperative patients with residual adolescent idiopathic scoliosis with thoracolumbar/lumbar (TL/L) curves were included (three males, 39 females; age, 41.9±18.2 years; TL/L Cobb angle, 55.5°±10.0°). All patients were older than 20 years and had been diagnosed with AIS during their adolescence. Lateral slip was defined as more than a 6 mm slip on coronal computed tomography images.

Results: Patients were divided into slip (n=22) and non-slip (n=20) groups. There were significant differences in age, TL/L Cobb angle, apical vertebral rotation, apical vertebral translation, and L3 and L4 tilt between slip and non-slip groups. Multivariate analyses and receiver-operating characteristic curves demonstrated that only older age was a significant risk factor for lateral slip (odds ratio, 1.203; 95% confidence interval, 1.067–1.357; $p=0.003$), with a cutoff value of 37 years old.

Conclusions: This study demonstrated that older age, especially age >37 years, is a risk factor for lateral slip in residual adolescent idiopathic patients. These findings suggest that residual adolescent idiopathic scoliosis patients who need surgery should have surgery by age 37 to prevent lateral slip causing progression.

PS-FP-5-87

Predictive Factors for Nighttime Bracing Treatment Outcome in Adolescent Idiopathic Scoliosis

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Purpose: To assess the effectiveness and predictive factors for nighttime bracing treatment in adolescent idiopathic scoliosis (AIS).

Methods: We retrospectively analyzed consecutive patients with AIS treated with the nighttime bracing between February 2006 to December 2018. A cohort of 172 AIS girls 10 years or more who have completed the nighttime bracing treatment with a minimum of 2-year follow-up were included in this study. Patients were instructed to wear the brace only in the nighttime. Curve progression of $\leq 5^\circ$ was used to define the success of the treatment while curve progression of $\geq 6^\circ$ and patients underwent surgery were defined the failure. The success group and the failure group were compared in terms of initial age, age of menstruation, initial Risser sign, status of the triradiate cartilage, degree of rotation of the apical vertebra (Nash-Moe classification), curve pattern, initial curve magnitude, and initial correction rate (ICR). We used multiple logistic regression analysis to determine the independent predictors of the treatment outcome.

Results: The mean follow-up period was 55.2±25.6 months. Of 172 patients, 23 patients (13.3%) underwent surgery due to progression of the curve and the rate of treatment success was 52.9% among all patients. At the beginning of this brace treatment, the mean age of the cohort was 12.5±1.4 years, and the mean curve magnitude was 29.4°±7.8°. Compared with the success group, the failure group was found to have significantly younger initial age (odds ratio [OR], 0.37; 95% confidence interval [CI], 0.25 to 0.54), older age of menstruation (OR, 1.65; 95% CI, 1.16 to 2.34), higher apex of the curve (OR, 0.52; 95% CI, 0.29 to 0.96), greater initial curve magnitude (OR, 1.06; 95% CI, 1.01 to 1.12), and lower ICR (OR, 0.95; 95% CI, 0.90 to 0.99), whereas initial Risser sign, status of the triradiate cartilage, and Nash-Moe classification were not associated with success or failure.

Conclusions: In this study, nighttime bracing was effective

for more than half of AIS patients. Initial age, age of menstruation, curve pattern, initial curve magnitude, and ICR were considered to be significantly associated with this bracing treatment outcome.

PS-FP-5-89

Predictors for Total Blood Loss During Posterior Spinal Fusion Surgery for Idiopathic Scoliosis

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Purpose: Some previous studies have reported predictive factors and formulas for perioperative risk factors associated with intraoperative blood loss during correction surgery for idiopathic scoliosis. However, previously reported formulas are relatively complicated and have limitations. The purpose of this study was to determine preoperative and surgical factors associated with intraoperative blood loss in patients and build a simple predictive formula for total blood loss.

Methods: Idiopathic scoliosis patients who underwent posterior spinal fusion from 2017 to 2019 were included. Preoperative patients' general data, radiographic parameters, and intraoperative data were collected retrospectively from medical records. Multiple regression analysis was performed to generate a predictive formula for blood loss using preoperative and intraoperative factors as explanatory variables.

Results: Thirty-five patients (average age, 17.2 years) were evaluated. Average values for operation time and total blood loss were 280.6 minutes and 738.5 mL, respectively. The average postoperative Cobb angle and correction rate were 16.0° and 73.2%, respectively. Using multiple regression analysis, preoperative Cobb angle, number of fixed vertebrae, and blood loss during exposure were identified as significant contributing factors. A predictive formula to estimate total blood loss was calculated: total blood loss (mL) = $-960.3 + 12.1 \times \text{activated partial thromboplastin time} + 10.5 \times \text{preoperative Cobb angle (°)} + 54.6 \times \text{number of fixed vertebrae} + 1.7 \times \text{blood loss during exposure (mL)}$

($p < 0.05$, adjusted $R^2 = 0.59$).

Conclusions: Preoperative Cobb angle, number of fixed vertebrae, and blood loss during exposure were the key factors to estimate total blood loss during posterior spinal fusion.

PS-FP-5-91

Analgesic and Opioid Medication Profile of European Adult Spinal Deformity Patients: Minimum 5 Years Follow-up Study

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Purpose: There remains significant variability in the use of opioids. On one end, it is proven that appropriate pain control is a critical aspect of patient management; on the other end, past few decades have been associated with major increases in overdoses and addiction treatment. Several studies further noted that preoperative opioid use resulted in increased hospital length of stay, delayed return to work, greater surgical complications, and adverse functional outcomes. Nonetheless, patients considering surgery often expect to discontinue opioids after surgery. Moreover, most studies have focused on the opioid use for chronic back pain and degenerative conditions and information regarding long-term opioid use following adult spinal deformity surgery is limited.

Methods: Retrospective analysis of a prospective multicentric data. Adult spinal deformity patients with ≥ 4 -level fusion and ≥ 5 years follow-up were included. Analgesic use was divided into four groups: (1) no analgesics, (2)

non-opioid analgesics (groups 1 and 2 referred as opioid naive), (3) weak opioids, and (4) strong opioids (groups 3 and 4 referred as opioids). Clinically-relevant six scenarios were investigated: (1) opioid use preoperatively, (2) opioid use at 6 weeks, (3) continued opioid use at 6 months onwards, (4) opioid cessation, 5) restart on opioids, and (6) persistent opioid use at 5 years onwards.

Results: A total of 265 patients (215 females, 50 males; mean age, 52±19 years) with a mean follow-up of 67 months (range, 60–102 months) were included. A total of 202 patients (76%) were opioid naive while 63 reported preoperative opioid use. At 6 weeks, 22.8% of opioid naive patients were using opioids, which dropped to 13.4% at 6 months onwards. Patients (25%) of who used opioids at 6 weeks eventually discontinued opioids. Follow-up restart rate on opioids for all opioid naive patients were 42%. At the final follow-up, 15.4% of opioid-naive patients were still using opioids. On the other hand, for the 63 patients with reported preoperative use, opioid usage rate at 6 weeks and at 6 months onwards were 67% and 43%, respectively. An overall cessation rate of 36.5% followed by a restart rate of 44% resulted in a 44.4% of final follow-up use where >50% of the patients were using stronger opioids.

Conclusions: Approximately 15% of patients who used no preoperative opioids ended up using long-term opioids. Plus, another 17% was still using non-opioid analgesics at a minimum of 5 years postoperative. Of the preoperative opioid users, only 55% could quit opioids, and 57% of the long-term continued users used stronger opioids compared to preoperative. Patients should be informed to have realistic expectations regarding opioid use when considering surgery.

PS-FP-5-92

Relationship between Adult Spinal Deformity Surgery and Employment, Sick Leaves, Return to Work and Early Retirement: Minimum 5-Year Follow-up Study

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Purpose: Adult spinal deformity is a common cause of disability and sick leave. It is unclear whether patients who undergo surgery can keep an active employment life as the general population. Although this presents an economic burden to the individual and the society, predictors of permanent disability and early retirement among individuals with spinal deformity are not well established. Information regarding long-term work status following adult spinal deformity surgery is limited.

Methods: Retrospective analysis of a prospective multicentric data. Adult spinal deformity patients with ≥4-level fusion and ≥5-year follow-up were included. Work status was divided into four groups: (1) employed, 2) employed but at sick leave (groups 1 and 2 referred to as active work life), (3) unemployed, and (4) retired due to back pain (groups 3 and 4 referred to as inactive work life). Clinically-relevant six scenarios were investigated: (1) preoperative work status, (2) time it took active ones to return to work, (3) active ones that kept being on sick leave or had to quit their jobs, (4) active ones that had an early retirement, (5) inactive ones that could make it back to work or became employed, and (6) inactive ones that couldn't make it back to work.

Results: A total of 120 patients (92 females, 28 males; mean age, 44.6±14.1 years) with a mean follow-up of 68

months (range, 60–102 months) were included. A total of 74 patients (62%) were active while 46 reported being unemployed or retired early. Of the 46 that were employed, 39 (85%) returned to work within 6 months. At the final follow-up, 7% became unemployed and 26% had an early retirement (mean age at surgery, 49.5 years). Of the 28 that were at sick leave preoperatively, 17 (61%) never made it back to work; and it took longer for the ones that did. Patients (39%) had an early retirement (mean age at surgery, 53.2 years). Of the 17 (mean age, 42.5 years) that were unemployed and 29 (mean age, 50.5 years) that were retired due to back pain, respectively, 29% and 24% made it back to work.

Conclusions: Approximately 30% of patients that were involved in active work life ended up having an early retirement due to back pain within 5 years after surgery. Another 15% had long-lasting sick leaves or became unemployed. Only 25% of patients who were not involved in active work life were able to make it back to work. Patients should be informed to have realistic expectations regarding future work life when considering surgery.

PS-FP-5-93

Complications and Analysis of Risk Factors of Spinal Surgery in Ankylosing Spondylitis: Single Center Case Series of 50 Patients

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Purpose: This Retrospective study (level 3) hypothesized that ankylosing spondylitis (AS) patients have increased perioperative morbidity and mortality. AS is an inflammatory disorder which frequently affects spine and known to have a high percentage of complications including mortality.

Methods: A total of 50 patients of AS (40 males, 10 females; mean age, 54.6 years [range, 22–73 years]; mean follow-up, 36 months [range, 9–122 months]) presenting from 2007 to 2020, requiring surgery were included. The demographic data, body mass index (BMI), comorbidities, neurological and ambulatory status, surgical details, and complications were analyzed. A multivariate regression analysis of all predisposing risk factors was done. A total of 40 patients had fractures/pseudoarthrosis (21/19)

and 10 patients, cervical and/or thoracolumbar kyphotic deformity (3/10). Total of 45 fractures were seen with five patients having fractures at two non-contiguous levels. Patients underwent spinal fusion for stabilization or deformity correction either with an anterior (ASF), posterior (PSF), or combined approach (APSF).

Results: Most common intraoperative complications were excessive blood loss (EBL>1,500 mL; 55%), incidental durotomies (17.5%), and screw pullout (15%). In postoperative period, superficial wound infection (2/40), deep wound infection (1/40), paralytic ileus (10%), pulmonary complications (27.5%), cardiac complications (17.5%), and neurodeficit (12.5%) were also seen. Mortality was seen in 10% of operated patients in early postoperative period. Late complications were seen in the form of implant prominence (7.5%), junctional kyphosis (7.5%), implant failure (15%), and pseudoarthrosis (10%). The length of intensive care unit stay, overall hospital stays, and rate of blood transfusion were significantly higher in patients undergoing APSF and PSF as compared to ASF ($p<0.05$). Patients' age more than 60 years ($p=0.0349$), higher BMI ($p=0.0459$), paraparesis ($p=0.0193$), quadriplegia ($p=0.0138$), and non ambulatory status ($p=0.0014$) had more complications. Patients with diabetes and hypertension showed a trend towards more complications. Ambulatory patients had significantly less complications ($p=0.0145$). Also increasing fusion segments (>9) ($p=0.0175$), operating time ($p=0.0329$), and EBL ($p=0.0017$) were associated with more complications.

Conclusions: AS has high complications during preoperative, intraoperative, and postoperative periods. This single center retrospective study was done to assess the rates of complications of spinal surgery and the risk factors in AS. AS has high complications during preoperative, intraoperative, and postoperative periods with 10% mortality rate. Patients' age more than 60 years, higher BMI, osteoporosis, presence of major neurodeficit and non ambulatory status, increasing fusion segments (>9), operating time and EBL were associated with more complications. Although AS has high rate of perioperative and delayed complications, a thorough preoperative evaluation with extreme caution during positioning, surgery and postoperative period leads to optimal outcome

PS-FP-5-94**Impact of Endplate Injury during Corrective Surgery Using Oblique Lumbar Interbody Fusion in Adult Spinal Deformity**

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Purpose: These reported oblique lumbar interbody fusion (OLIF) is common as the minimum invasive method for adult spinal deformity (ASD) surgery, but endplate injury is induced during the procedure of cage insertion and corrective maneuver. Still, the site of endplate fracture and their relationship with subsequent cage subsidence, fusion status or sustained alignment remain unclear. The purpose of this study is to determine the prevalence and location of endplate fracture after inserting a cage for to treat ASD and their association with cage subsidence, fusion status and global alignment.

Methods: We analyzed data obtained by multiplanar computed tomography (CT) of 75 spinal levels in 27 patients (25 females; mean age, 70.3 years old), which was used to detect endplate fracture immediately after surgery and subsidence and fusion status at 1 year postoperatively. OLIF was performed for 2.8 ± 0.4 spinal levels combined with posterior spinal fusion for 8.3 ± 0.5 levels. More than 2 mm displacement between CTs was determined as endplate fracture. Additionally, global and local alignment including spinopelvic parameters was evaluated by plain X-ray, and postoperative complication was also investigated until mean final follow-up of postoperative 3.8 years.

Results: Endplate fracture was observed in 64 levels (85.3%) of 27 patients, with significantly higher prevalence in the posterior area of affected vertebra than in the anterior area (85.3% vs. 68.0%, $p=0.02$) in the sagittal plane. In the coronal plane, there was no significant difference in prevalence between the left (approach) and right (non-approach) sides (77.3% and 81.3%, respectively), or concave and convex sides (69.4% and 79.6%). Compared with preoperative alignment, lumbar lordosis (LL), pelvic incidence-LL, pelvic tilt, sagittal vertical axis, and Cobb angle were improved significantly after surgery. No

parameters changed significantly from just after surgery to the final follow-up. Segmental lordotic and wedging angles before and after surgery and their changes were not significantly different in OLIF segments with or without endplate fracture. Also, endplate fracture was not significantly associated with neither of cage subsidence, fusion status, and postoperative complications.

Conclusions: Endplate fracture during an OLIF procedure is difficult to avoid in ASD corrective surgery. The fracture is possibly induced by the corrective maneuver, even with an ideal rod counter and cantilever compressive force. However, fracture is not significantly associated with subsequent cage subsidence, fusion status, or sustained corrected alignment, even in elderly patients with osteopenia or osteoporosis.

PS-FP-5-95**Single-Stage Posterior Surgical Treatment for Grade V Spondylolisthesis of L5 in a Patient with Neurofibromatosis Type 1 and Dural Meningocele: A Case Report**

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Purpose: To report the radiological and clinical outcomes of a case treated by single-stage posterior operation with neurofibromatosis type 1 (NF1) and meningocele, while the surgical treatment for L5/S1 spondylolisthesis of Meyerding grade V remains challenging.

Methods: We present the case of 18-year-old female who was admitted in our department due to low back pain and radicular pain of both lower limbs 4 months ago. Multiple cafe-au-lait spots were seen on her back, signifying the neurofibromatosis. The straight leg raising test was negative and there were no dysesthesias of the legs. Both the muscle force of lower limbs were normal. X-ray showed the Meyerding grade V spondylolisthesis of L5 (modified Newman grading 10+10). On the magnetic resonance imaging, dural meningocele could be seen extend through the intervertebral foramen of L4/5, and extend through the first anterior and dorsal sacral foramen on the left. Considering it was too risky to perform one stage surgery immediately, this patient was managed with halo traction for 3 months.

X-ray was rechecked and found there was seldom improvement of the spondylolisthesis comparing to that before tracking. After a multidisciplinary discussion, we decided to perform single stage posterior L5 vertebrectomy with L4/5 and L5/S1 discectomy, sacral dome osteotomy, L2–S1 pedicle screw fixation, and bone graft fusion.

Results: All procedure were performed under the intra-operative neuromonitoring and no signal changes were seen neither on the motor evoked potentials nor somatosensory evoked potentials. This patient appeared temporary disability of raising legs but recovered 3 days later. Four days after the surgery, she was able to walk without radicular pain while wearing the lumbosacral orthosis. Radiography showed the reduction of L4 and the cage placed well in the position between L4 and S1. We had to perform debridement of the right iliac side incision because of the complication of poor healing. Before the discharge, she was able to walk without low back pain and no neurological complication were found. At 1.5-year follow-up, computed tomography scanning showed good bone fusion. All the pedicle screws are in good position and the cage were not dislocated.

Conclusions: Base on the relative literature, we discuss about the different choices for treatment of high-grade spondylolisthesis of L5 with NF1 and dural meningocele.

PS-FP-5-96

Handgrip Strength Potentially Predicts Curve Progression in Adolescent Idiopathic Scoliosis Girls

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Purpose: Adolescent idiopathic scoliosis (AIS) girls are

known to have low bone mass, deranged bone qualities, low bone mechanical properties, low lean mass, and muscle imbalance. Previous findings from our group showed a unique correlation pattern of handgrip strength and bone qualities in AIS girls as compared to controls. This longitudinal cohort study aimed to investigate whether baseline muscle and bone parameters in AIS could predict curve progression.

Methods: A total of 126 AIS girls aged 12–14 years old were recruited and followed up until reaching skeletal maturity. They were divided into progressive and stable groups according to Scoliosis Research Society criteria. Maximum handgrip strength at both hands were measured with a standard dynamometer; lean mass at arm, leg, and trunk were measured by bioelectrical impedance analysis; and bone qualities and bone mechanical properties of non-dominant distal radius were measured by high-resolution peripheral quantitative computed tomography. The predictors for curve progression were determined using logistic regression model.

Results: Forty-four AIS (34.9%) had curve progression with increased Cobb angle $\geq 6^\circ$ before skeletal maturity. Progressive AIS had similar age, curve severity and lifestyle but lower weight, Thumb Ossification Composite Index, lower trunk (5.7%) and arm lean mass (8.9%), weaker handgrip strength at dominant side (8.8%), deranged cortical compartment (29.1% smaller area and 6.5% lower volumetric bone mineral density), and lower bone mechanical properties (13.2% lower stiffness and 12.5% lower estimated failure load) when compared with controls. A cut-off of 19.75 kg in maximum dominant handgrip strength was identified for distinguishing between progressive AIS and stable AIS (75% sensitivity and 52.4% specificity; positive likelihood ratio, 1.577; $p=0.011$) by receiver operating characteristic analysis.

Conclusions: Progressive AIS showed poorer muscle and bone parameters than stable AIS. A cut-off value of 19.75 kg in the dominant handgrip strength in distinguishing progressive and stable AIS might potentially be useful for predicting curve progression in AIS. (This study was supported by RGC of HKSAR [468809 & 468411].)

PS-FP-5-97**Outcome of Posterior Vertebral Column Resection in Neglected Rigid Congenital Scoliosis and Kyphoscoliosis: Our Experience and Review of Literature**

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Study Design: Consecutive, retrospective review.

Purpose: Aim of this study is to assess the functional outcome of posterior vertebral column in patients with neglected congenital kyphosis or kyphoscoliosis.

Overview of Literature: Congenital kyphosis or kyphoscoliosis is rare and progressive deformity which results in serious neurological compromise because of serious spinal cord compression usually at the apex of deformity. In neglected cases, the patients present with shoulder-trunk imbalance, coronal and sagittal plane deformity, a rib hump, pelvic tilt, presence of intramedullary anomalies, neurological deficit, and VACTERL.

Methods: This single-center retrospective study reviews the management and outcomes of 37 consecutive patients with neglected congenital kyphosis and kyphoscoliosis, a rigid three-dimensional deformity of the spine treated by posterior column resection by a single posterior approach over a 7-year period (2012–2018). There were 24 males and 13 females with a mean age of 22 years (range, 12–60 years). Visual Analog Scale score, Oswestry Disability Index, and revised Scoliosis Research Society-22 were used for assessment of clinical parameter, i.e., pain, function, and self-image evaluation subsequently. Radiological parameters assessment, classification of vertebral anomaly, pattern and region of curve, preoperative surgical planning, cord compression, and intraspinal anomaly was evaluated by radiographs, computed tomography scan, and magnetic resonance imaging. Pre- and postoperative neurology was assessed by the American Spinal Cord Injury Association Scoring. Intraoperative neuromonitoring was used to assess neurological complications perioperatively. Complications were monitored intraoperatively, immediate postoperative, and at follow-up.

Results: The average follow-up was 4 years (range, 2–7 years). The preoperative coronal plane deformity was 68°

(range, 35°–120°) and corrected to 28° (range, 9°–45°), showing 64% curve correction. Average preoperative segmental kyphotic angle was 86° (range 3°–110°). Correction rate for kyphosis was 62%. All patients after surgery showed their baseline neurological status except one with permanent neurological deficit and other complications were encountered in five patients. The mean estimated blood loss was 1,235 mL (range, 800–1,800 mL). The resection was performed at the involved level and apex of deformity. Fusion was achieved in average 9 segments (range, 4–13 segments). Anterior reconstruction was with titanium mesh cage in eight and with anterior strut graft in one patient. Bony fusion achieved in all patients, and there was no correction loss.

Conclusions: Posterior vertebral column resection provides direct circumferential visualization and decompression of the spinal cord through a single posterior approach. Although a difficult procedure it provides better correction of the deformity in both sagittal and coronal planes.

PS-FP-5-98**Clinical and Radiological Outcomes in the Patients of Parkinson's Disease Undergoing Instrumented Lumbar Spine Surgery for Spinal Disorders**

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Purpose: Parkinson's disease (PD) patients often develop stereotypical postural changes. Surgical treatment of spinal disorders is high risk in patients with PD. The aim of this study was to describe the clinical and radiological outcome in the PD patients operated for spinal disorders.

Methods: A retrospective study included instrumented surgeries for spinal disorders in patients with PD. Clinical and surgical data including revision surgeries were collected. Assessment of functional outcomes at last follow-up was done with modified Oswestry Disability Index (ODI) scores and radiological parameters was assessed on anteroposterior and lateral plain X-rays of the spine. Sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), lumbar lordosis (LL), and PI-LL mismatch were measured.

Results: Fourteen PD patients (seven females and seven males) with mean age of 64.14 years (range, 47–77 years) was recruited. Median follow-up was 13.63 months (range, 1–60 months). Nine patients (64.28%) had at least one associated medical comorbidity along with PD. One patient (7.14%) presented with the sequelae of failed previous surgery. Eleven patients (78.57%) underwent open fixation, and three patients (21.43%) underwent percutaneous fixation. At a mean follow-up of 13.63 months, we noted surgical complications in four patients (28.57%): two in the form of adjacent segment degeneration and two proximal junctional kyphosis. The mean PI–LL mismatch was 19.78° (range, 4°–34°) preoperatively, which marginally improved to 16.41° (range, 5°–35°) postoperatively, and 15.32° (range, 4°–27°) at final follow-up. The PI–LL mismatch was within normal limits (0–100) in four patients (28.57%), moderate (100–200) in five patients (35.71%), and marked (200–300) in five patients (35.71%). All the four patients who have postoperative complications during follow up had marked PI–LL mismatch. The rate of surgical revision was 14.29% (two patients)—both had adjacent segment degeneration. Two patients are under observation with proximal junctional kyphosis. Modified ODI score was minimal disability (0–20) in 4 (28.57%) patients, moderate disability (21–40) in 8 (57.14%) patients, and severe disability (41–60) in 1 (7.14%) patient; crippled (61–80) in 1 (7.14%) patient and no patient was bed bound.

Conclusions: Patients with PD undergoing lumbar decompression and fusion have higher complication rates. Preoperative PI–LL mismatch long segment fusion might lead to poorer outcomes.

PS-FP-5-99

Evaluating Biomechanics of the Novel Active Apex Correction Technique Using a Patient-Specific Finite Element Approach with 6-Month Follow-up

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the shortcomings of both SHILLA & growing rods techniques; the SHILLA suffer a loss of correction or reappearance of deformity through crank-shafting or adding-on and growing rods require multiple re-operation. Newer techniques like the active apex correction (APC) provide an excellent surgical alternate; designed to avoid apical fusion amongst having other benefits. The objective is to simulate and explore the effect of apical remodulation using the APC technique over a 6-month follow-up period for two patient-specific finite element models.

Methods: Four representative scoliotic models were developed to match patient anteroposterior and lateral radiographs provided by the surgeon. To simulate the APC technique; the apex was pushed medially followed by compression of the convex side of apex (using two screws implanted proximal and distal to the most wedged vertebrae). The rest of construct was then completed to simulate the APC. The models then simulated the effect of gravity followed by epiphyseal spinal growth. Relevant clinical output parameters such as primary Cobb, apical vertebra translation (AVT), vertebral wedging, and so forth were recorded and compared with the clinical data.

Results: All patients showed a significant reduction in the Cobb angle (26%, 59%, respectively) for the primary curve following the APC surgery. The AVT was significantly reduced with the surgical correction. Additionally, the vertebral wedging in the apical region was significantly reduced due to the APC technique for all patients. Kyphotic angles (T4–T12) were also reduced in all cases. Furthermore, at the gravity loading and 6-month spinal growth time points, the output parameters showed a consistent maintenance of the correction achieved by the APC technique (reduction in the Cobb angle, vertebral wedging and translation) for all patients.

Conclusions: The output parameters indicate excellent preliminary clinical outcomes. While this study is limited in terms of follow-up time as well as sample size, it paves the way for additional research expanding the preliminary results to get a broader biomechanical understanding of the APC. The results also indicate the potential of this novel technique as a legitimate alternative; it can be employed as-is or in hybrid with incumbent techniques for effective, innovative patient management.

Purpose: Multiple studies have previously highlighted

PS-FP-5-100

Usefulness of Percutaneous Pedicle Screws for Minimizing the Risk of Proximal Junctional Kyphosis after Adult Spinal Deformity Correction Surgery

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Purpose: The high incidence of postoperative proximal junctional kyphosis (PJK) is a problem in corrective fusion for adult spinal deformity (ASD). We examined PJK incidence in two operative procedures and the usefulness of percutaneous pedicle screws (PPS).

Methods: Corrective fusion was performed on 70 ASD patients, with follow-up of over 2 years. The basic procedure was lumbar spine lateral interbody fusion, followed by posterior fusion from the lower thoracic spine to the pelvis using PPS. Patients were divided into two groups: a Hybrid group (thoracic spine: open, lumbar spine: PPS; 30 cases; four males, 26 females; mean age, 76 years), and an All-PPS group (40 cases; one male, 39 females; mean age, 72 years). Fusion levels, operative time, surgical blood loss, pre- and postoperative radiographic parameters, and PJK incidence were examined in both groups.

Results: In the Hybrid group, a mean of 10.0 levels was fused. Mean operative time was 432 minutes, with mean surgical blood loss of 394 mL. Pre- and postoperative coronal Cobb angles in degenerative lumbar scoliosis were 29° and 8°, respectively, lumbar lordosis (LL) angle was corrected from 2° to 44°, pelvic incidence (PI)–LL mismatch decreased from 51° to 7°, sagittal vertical axis (SVA) decreased from 123 to 18 mm, and pelvic tilt (PT) was corrected from 38° to 24°. In the All-PPS group, a mean of 8.1 levels were fused. Mean operative time was 401 minutes, with mean surgical blood loss of 502 mL. Pre- and postoperative coronal Cobb angles in degenerative lumbar scoliosis were 48° and 12°, respectively, LL angle was corrected from 7° to 50°, PI–LL mismatch decreased from

44° to 0°, SVA decreased from 144 to 11 mm, and PT was corrected from 34° to 18°. PJK incidence was 40% (12 cases/30 cases) in the Hybrid group and 10% (four cases/40 cases) in the All-PPS group, which was significantly lower ($p < 0.05$; by Fisher's exact test).

Conclusions: In recent years, corrective fixation with PPS has been used for ASD. One advantage of PPS is low invasiveness, which minimizes intraoperative blood loss, but this study suggests that using PPS also effectively prevents postoperative PJK. This is because using PPS preserves muscle attachments and thus minimizes muscle degeneration, does not interfere with blood flow to posterior supporting tissues, and completely preserves the facet joints adjacent to the fixed end. In ASD corrective surgery, PPS was considered to be effective in preventing PJK.

PS-FP-5-103

Optimal Position to Insert the Sacral-Alar-Iliac Screw with the Analysis of Computed Tomography View and the Torque of Inserting It

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The purpose of this study was to evaluate the fixing strength of the modified sacral-alar-iliac (SAI) screw compared with the SAI screw and the iliac screw. We examined 71 cases of the pelvic computed tomography image. The cases include 31 male and 40 female patients. The average age was 66.8 years old. The average length of the modified SAI screw was 112.6 mm. The average distance between the lamina of the sacrum and the most stenosis point on the quadrilateral surface was 66.8 mm. The average valgus angle when inserting the modified SAI screw was 28.8°. Our modified SAI screw is gotten the inserting torque of 7.8 Nm when its screw is set on the quadrilateral surface, stronger than the SAI screw's inserting torque of 3.5 Nm when penetrating the ilio-sacral joint. We can connect directly the Modified SAI screw with the rod of pedicle screw without a connector, but cannot connect directly the SAI screw or the iliac screw with it. The most stenosis inserting point of the modified SAI screw is on the quadrilateral surface. And maximum inserting torque is when penetrating here. The modified SAI screw is useful for spinopelvic fusion.

PS-FP-5-106

Is It Really Less Invasive?: Systemic Effects of Anterior-Posterior Lumbar Surgery with Oblique Lateral Interbody Fusion by Nutrition Support Team Perspective

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Purpose: Recently, lateral lumbar interbody fusion (LIF) using oblique lateral interbody fusion (OLIF) is increasing new procedure, due to its minimal invasiveness. We examined the systemic effects of anterior-posterior lumbar surgery with OLIF from the perspective of the nutrition support team.

Methods: The subjects were patients with anterior-posterior lumbar spine surgery with OLIF, which was performed at our institute from 2016. Out of all 18 cases, in principle, in addition to anterior fixation of two or more vertebral bodies, nine cases with one-stage or two-stage posterior surgery were extracted, and perioperative serum albumin, total cholesterol, and total lymphocyte count were extracted. The fluctuation of hemoglobin value was examined. As a method for evaluating nutritional status, a Controlling Nutritional Status (CONUT) score was calculated using the former three items. As a control group, the same evaluation was performed on nine patients who underwent interbody fusion (transforaminal lumbar interbody fusion [TLIF]) between two or more vertebral bodies by posterior single surgery at the same time, and a statistical study was conducted between these two groups.

Results: Average serum albumin was 4.3 mg/dL before surgery for in both armies, 3.4 mg/dL in the OLIF post-surgery, 3.1 mg/dL in the TLIF, and total cholesterol in OLIF-preoperative (pre) 205, TLIF-pre 203, OLIF-postoperative (post) 165, TLIF-post 160, total lymphocyte counts in OLIF-pre 1,666, TLIF-pre 2,360, OLIF-post 1,325, TLIF-post 1,801, the hemoglobin (Hb) in OLIF-pre 13.3, TLIF-pre 13.8, OLIF-post 11.3, TLIF-post 9.7, the CONUT scores OLIF-pre 0.67, TLIF-pre 0.33, OLIF-post 3.8, and TLIF-post 3.6. No statistically significant difference was found between the two groups in all items.

Conclusions: OLIF combined surgery is considered to be a minimally invasive surgical method from the viewpoint of reducing the amount of bleeding and soft-tissue damage. In

fact, in this study as well, the postoperative Hb level tended to decrease less in the OLIF group. On the other hand, from the nutritional point of view, both OLIF and TLIF showed the same degree of deterioration in nutritional status after surgery, and it was considered that there was no significant difference in systemic effects between the two groups. We investigated the systemic effects of anterior-posterior lumbar surgery with OLIF from a nutritional point of view. It was considered that the same systemic effects as the conventional procedure were occurring.

PS-FP-5-108

Distribution of Spinal Sagittal Alignment Based on Hierarchical Clustering

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Purpose: Spinal sagittal alignment depends on the individual. Although several classifications have been proposed, the validity remains unclear. The purpose of this study is to classify and characterize the spinal sagittal alignment by cluster analysis.

Methods: A total of 1,378 patients (70.4±10.9 years; 680 males, 698 females) who visited a spinal outpatient clinic were included. Cluster analysis was performed using five radiographic parameters (thoracic kyphosis [TK], thoracolumbar kyphosis [TLK], lumbar lordosis [LL], pelvic incidence [PI], and pelvic tilt [PT]) to investigate the characteristics of each cluster.

Results: Patients were classified into eight clusters (A to H). Cluster A (10%) had low PI and large TK (TK41, TLK26, LL44, PI43, PT6°), cluster B (23%) had low PI and LL (TK25, TLK19, LL34, PI39, PT14°), cluster C (24%)

had middle PI and LL (TK22, TLK5, LL44, PI48, PT16°), cluster D (13%) had high PI and LL (TK35, TLK7, LL58, PI58, PT18°), and none of them had PI–LL mismatch. The other four clusters had PI–LL mismatches, cluster E (12%) had a high PI and retroverted PT (TK19, TLK-0.5, LL37, PI60, PT29°), cluster F (5%) had a low PI and flat back (TK9, TLK5, LL18, PI42, PT22°), cluster G (4%) had a lumbar acute kyphosis (TK10, TLK30, LL-2, PI46, PT34°), and cluster H (10%) had global kyphosis (TK41, TLK47, LL24, PI48, PT31°).

Conclusions: The spinal sagittal alignment of 1,378 patients were classified into eight clusters. The four clusters without PI–LL mismatch were similar to Roussouly's classification. The four clusters with PI–LL mismatch included retroverted type, flat back, lumbar acute kyphosis, and global kyphosis.

PS-FP-5-109

The Analysis of Progression of the Pfirmann's Grade in Distal Unfused Segments in Postoperative Adolescent Idiopathic Scoliosis: A Long-Term Follow-up Magnetic Resonance Imaging Based Study

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Purpose: The impact of the long-segment fusions on the distal mobile segments is of major concern. There is currently a paucity of literature on the progression of Pfirmann's grading in distal unfused segments in patients with strategic pedicle screw instrumentation. In our institute, we conducted a retrospective study to analyze the progression of the Pfirmann's grade in the distal unfused lumbar segments in postoperative adolescent idiopathic scoliosis (AIS).

Methods: A total of 58 patients who underwent surgery for AIS with minimum 6.5-year follow-up (6.5–15) were included. Coronal Cobb's angle (CCA), apical translation, lower instrumented vertebra tilt (LIV tilt), lower instrumented vertebra-sacral angle (LIV-sacral angle), sagittal spinal parameters (thoracic kyphosis and lumbar

lordosis), and pelvic parameters were measured. Disc health was assessed in magnetic resonance imaging (MRI) by Pfirmann's grading, total endplate score (TEPS), and facet degeneration were measured by Fujiwara's grading. Functional evaluation was performed using the Scoliosis Research Society-22 score.

Results: A total of 58 patients were included in the study. The mean follow-up was 9.1 years. Based on MRI scan, 43 were included in Pfirmann's grade static (PGS) group and 15 in Pfirmann's grade progressed (PGP) group. Of the 15 in PGP group, LIV was L4 in eight, L3 in three, L1 in three, and L2 in one. Fifteen patients in our cohort had a progression of Pfirmann's grade. Of these, 11 patients (73.3%) progressed from grade 1 to grade 2, but in four patients (26.6%), Pfirmann's grade progressed to more than 3. The progression of the degeneration did not correlate to the preoperative and postoperative TEPS score, coronal, or sagittal parameters.

Conclusions: The analysis of progression of the Pfirmann's grade in distal unfused segments did not correlate with preoperative and postoperative coronal or sagittal parameters and the number of unfused segments.

PS-FP-5-110

Characteristics of Pedicle Screw Misplacement Using Freehand Technique in Degenerative Scoliosis Surgery

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Purpose: Clinical evidence demonstrating the characteristics of pedicle screw (PS) misplacement with a freehand technique in degenerative scoliosis (DS) surgery is limited because previous studies on PS accuracy included several etiologies. This study aimed to estimate the accuracy of PS placement in the thoracic to lumbar spine in DS surgery, characterize a patient population with PS misplacement, and analyze the association between misplaced PS vector and lumbar coronal curve.

Methods: We retrospectively identified 122 patients (average age, 68.6 years) who underwent corrective and decompression surgery at a single institution from 2016 to 2019. We extracted patient demographic data, including lumbar coronal curve, a vertebral rotation that could affect PS misplacement, and evaluated PS accuracy in the thoracic to lumbar spine. We also identified characteristics of misplacement for each patient. Screw positions were categorized into grade A, entirely in the pedicle; grade B, <2 mm breach; grade C, 2–4 mm breach; and grade D, >4 mm breach using postoperative computed tomography.

Results: The mean preoperative lumbar coronal curve was $32.3^\circ \pm 18.4^\circ$, and the number of fused vertebrae was 8.9 ± 2.8 . A total of 2,032 PS were categorized as follows: grade A, 1,897 PS (93.3%); grade B, 67 PS (3.3%); grade C, 26 PS (1.3%); and grade D, 43 (2.1%). One PS (grade D) inserted at T5 needed removal surgery due to neurological deficit. The misplacement group (grades C and D) had a significantly stronger lumbar coronal curve and apical vertebral rotation compared with the accuracy group (grades A and B). Misplaced PS vector (direction and degree) was significantly correlated with inserted vertebra rotation. Grade D misplacement was distributed mainly around the transitional vertebra of the lumbar curve.

Conclusions: The obtained findings could help identify the vertebra location at higher risk of PS misplacement using the freehand technique. The accuracy of PS insertion in the thoracic to lumbar spine was high in DS surgery, but the need for care was highlighted in the transitional vertebra.

PS-FP-5-113

Increased C7 Tilt Is Associated with Higher Risk of Shoulder Imbalance in Adolescent Idiopathic Scoliosis Patients Receiving Posterior Spinal Fusion

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Purpose: Shoulder balance plays a vital role in correction surgery for adolescent idiopathic scoliosis (AIS). Even with detailed preoperative evaluation of the patient, shoul-

der imbalance may occur. However, there is a scarcity of sufficient evidence comparing the various factors in current literatures and there is also a lack of linear prediction models. This study examines the correlation between the individual vertebral tilt and shoulder balance, specifically aims to identify parameters that may serve as an intraoperative proxy in surgical correction of AIS.

Methods: AIS patients with (1) single posterior spinal correction and fusion and (2) all pedicle screws instrumentation with derotation in two tertiary medical centers from 2015 to 2018 were recruited for analysis. We excluded patients who underwent correction over lumbar segments only (Lenke classification type 5) and patients with scoliosis other than AIS, such as neuromuscular scoliosis and congenital scoliosis. All patients had a minimum follow-up of 2 years with a complete set of standing anteroposterior radiographs for whole spine. Both inner and outer shoulder balance parameters were included for detailed analysis, including clavicular angle (CA), coracoid height difference, clavicular tilt angle difference, clavicle-rib cage intersection difference, and 1st rib tilt. Individual vertebral tilt from C5 to T4, as well as the upper instrumented vertebra tilt on coronal plane were also recorded for further analysis.

Results: A total of 107 patients of AIS were recruited in the final analysis. The mean follow-up length was 2.5 years. Mean preoperative Cobb angle for main thoracic curve was $52.6^\circ \pm 9.8^\circ$ (range, 36.6° – 91.5°), and the postoperative Cobb angle was $20.6^\circ \pm 6.9^\circ$ (range, 7.2° – 39.2°). In Pearson correlation analysis, C7 tilt demonstrates significantly moderate to high correlation with both inner and outer shoulder balance parameters (coefficient, 0.36–0.72; $p < 0.05$). In subgroup analysis, postoperative C7 tilt on coronal plane was identified as an independent risk factor for developing shoulder imbalance (odds ratio, 1.19; 95% confidence interval, 1.066–1.329; $p = 0.0019$) in multivariate logistic regression model. In addition, quantification for change of shoulder balance is established as follows: $\Delta CA = 0.21 \times [(\Delta C7 \text{ tilt} + \Delta T1 \text{ tilt})/2]$ (standard error = 0.04, $p < 0.001$).

Conclusions: C7 tilt on coronal plane is highly correlated to shoulder balance parameters in AIS surgical correction. Furthermore, increased C7 tilt poses a higher risk of developing shoulder imbalance. More meticulous strategy to improve shoulder balance is warranting, and quantification of shoulder balance change by individual vertebral tilt may be adopted in the surgical correction of AIS.

PS-FP-6-1**Computed Tomography Based Intraoperative Navigation for Spine Tumors: Perspectives in Surgical Margin**

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Study Design: A retrospective study.

Purpose: To evaluate efficacy of intraoperative navigation for spine tumors on effective surgical margin.

Overview of Literature: Computed tomography (CT) based intraoperative navigation is gradually popular in orthopedic surgery. Especially, the use of this system may be more useful for spinal tumors, not only in the point of view of reconstruction, but of safe surgical margin.

Methods: A retrospective review was performed in consecutive six patients who underwent CT based navigation assisted surgery for spinal tumors between 2017 to 2019. The cases included osteosarcoma (n=3), chondroma (n=1), chordoma (n=1), and solitary breast cancer metastasis (n=1). For surgical margin for tumor excision, thorough review of preoperative radiographic studies including diffusion weighted magnetic resonance images and positron emission tomography-CT was done with musculoskeletal radiologists. Based on these findings, surgical margin was made using intraoperative navigation system. Clinical data such as general demographics, intraoperative efficacy of this system for reconstruction, perioperative complications, oncologic outcomes and pathological review of surgical margin were collected.

Results: Mean age of the patients was 47 years (range, 16–77 years), and mean duration of follow-up was 12.8 months (range, 5–32 months). There were no intraoperative complications related to intraoperative navigation system. And in terms of reconstruction, there was no mal positioned screw or early mechanical failure. In terms of oncological outcomes, all patients survived with five of no evidence of disease and one of alive with disease state. On resection margin, tumor free margin was obtained in five patients and margin involvement of tumor was noted in patient with solitary metastasis. Adjuvant radiotherapy was done for local control in the patient with margin involvement. In one patient with sacrum osteosarcoma,

local recurrence leads to revisional wide excision and reconstruction.

Conclusions: CT based navigation-assisted surgery for spinal tumors could be useful not only for accurate reconstruction, but for determination of surgical margin. Even limited number of cases, both thorough preoperative radiological review and intraoperative navigation could provide us more benefits for safe resection margin.

PS-FP-6-2**Spinal Extra-Osseous Chordoma Mimicking as Herniated Intervertebral Disc in the Lumbar Spine**

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Most lumbar disc herniation occur between the age of 30 and 50 years old, with a reported average age of 40.8 years. Age-related changes within the extracellular matrix of the intervertebral disc leads to weakening of the annulus fibrosus, causing susceptibility to annular fissuring and tearing. These changes in the composition of disc matrix often lead to loss of intervertebral disc height, which in turn predispose the apophyseal joints to osteoarthritis. Loss of disc height also allow ligamentum flavum to thicken, leading to narrowing of the spinal canal and the constellation of signs and symptoms of degenerative lumbar spondylosis. We report a case of an 81-year-old male with clinical presentation of low back pain and gradual leg weakness. Physical examination and magnetic resonance imaging findings suggested radiculopathy caused by herniated L3/L4 lumbar intervertebral disc. Preoperative Visual Analog Scale (VAS) was 8/10 and Medical Research Council (MRC) Scale 3/5 of both lower limbs. Despite significant right paracentral disc extrusion, there was no reduction in disc height and no marked hypointense signal in T2-weighted images to suggest a degenerated disc. A suspicion of soft tissue tumor was made and we proceeded with laminectomy, biopsy and L3–L4 short segment instrumentation. Intra-operatively we found a whitish mass

appearing to originate from L3/L4 intervertebral disc space exerting mass effect and causing dural indentation at this level. There was adherence of this mass to the dura. Postoperative VAS reduced to 4/10 and improvement of MRC 4/5 of both lower limbs. Histopathology and immunohistochemistry showed neoplastic cells with focal nuclear positivity for brachyury, consistent with chordoma.

PS-FP-6-4

Perioperative Complications of Total En Bloc Spondylectomy for Spinal Tumors

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Purpose: We evaluated the perioperative complications associated with total en bloc spondylectomy (TES) for spinal tumors depending on the extent and level of tumor resection.

Methods: We retrospectively reviewed 307 patients who underwent TES in a single center. The subjects comprised 164 men and 143 women with a mean age of 52.9 years at the time of surgery. The surgery was performed in 225 patients with spinal metastases, 34 with a primary malignant, 41 with an aggressive benign, and seven with a primary unknown tumor. The main lesion was located in the thoracic spine in 213, and lumbar spine in 94 patients. There were 97 patients who underwent TES for more than two consecutive vertebrae.

Results: Major and minor perioperative complications were observed in 122 (39.7%) and 84 (27.4%) patients, respectively. The breakdown of complications was as follows: bleeding more than 2,000 mL in 60 patients (19.5%), hardware failure 82 (26.7%), neurologic 46 (15.0%), surgical site infection 23 (7.5%), wound dehiscence 16 (5.2%), cerebrospinal fluid leakage 45 (14.7%), respiratory 52 (16.9%), cardiovascular 11 (3.6%), digestive 19 (6.2%), and mortality within 2 months 4 (1.3%). The total number of complications per surgery were 1.01±1.0 in single

group and 1.56±1.2 in more than two resection group. Cardiovascular, respiratory complication, and hardware failure were statistically higher in more than two resection group. The amount of bleeding in lumbar lesion and respiratory complication in the thoracic lesion were statistically higher. Multivariate analysis showed combined approach and more than 2 vertebral resections were significant independent factors.

Conclusions: The characteristics of perioperative complications after TES were different depending on the extent and level of the tumor resection. In addition to preoperative clinical and pathological factors, it is also important to consider these factors in cases of en bloc resection for spinal tumors.

PS-FP-6-6

Long-Term Outcomes of Spinal Meningioma Resection with Outer Layer of Dura Preservation Technique

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Purpose: Spinal meningioma is a common benign intradural spinal tumor. It has been reported that the local recurrence rate after surgical resection increases with longer follow-up duration. Simpson grade 1 resection could reduce the risk of recurrence, but this procedure needs

dural reconstruction, which would cause cerebrospinal fluid (CSF) leakage or iatrogenic spinal cord injury. There has been one report that the dura preservation technique reduces the risk of CSF leakage, in which the meningioma together with the inner layer of the dura is removed and the outer layer is preserved for simple dural closure. The long-term outcomes with this technique have never been investigated.

Methods: In this study, we retrospectively analyzed the data of 38 surgically treated patients (dura preservation technique, 12 patients; Simpson grade 2 resection, 26 patients) to assess the long-term recurrence rate (mean, 121.5 months; range, 60–228 months).

Results: The local recurrence rate in the dura preservation group was 8.3% (one of 12 cases), which was similar to that in Simpson grade 2 resection group (two of 26 cases [7.7%]).

Conclusions: Although this case series did not indicate the significant difference in the recurrence rates between the dura preservation group and Simpson grade 2 group, we consider that this technique still has advantages for surgically less invasiveness in terms of dural reconstruction which is necessary for Simpson grade 1 and higher possibility of complete resection of tumors compared with Simpson grade 2 resection.

PS-FP-6-7

Prognostic Factors for Short-Term versus Long-Term Readmission-Free Survival after Metastatic Spine Tumor Surgery

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Purpose: Unplanned hospital readmissions (UHR) after metastatic spine tumor surgery (MSTS) are important indicators of poor general condition of the patient, aggressive disease, and inappropriateness of treatment approach. Increase in UHR reduces quality of life (QoL) of the patient and increases resource utilization. Hence, re-admission-free survival (ReAFS) defined as 'time duration between discharge after index-operation and first UHR/death', may serve as a new outcome indicator in MSTS-pa-

tients. The aim of our study was to identify the prognostic factors for short-term (up to 3-months) and long-term (up to 1-year) ReAFS after index-MSTS.

Methods: We retrospectively reviewed the medical records of 266 consecutive adult patients who underwent MSTS between 2005–2016 with follow-up until 2 years or demise, whichever was earlier. Institutional Review Board approval was obtained prior to study initiation. Demographic, oncological, procedural, and postoperative details were collected. Factors predictive of short and long-term ReAFS were evaluated using multivariate analysis.

Results: Final analysis included 209 patients. Mean age was 60±12 years. Majority had lung primaries (25.8%). A total of 110 and 57 patients were alive without UHR up to 3 months and 1 year of index-MSTS, respectively. Both univariate and multivariate analysis revealed that patients with Eastern Cooperative Oncology Group performance status (ECOG-PS) 0–2 (multivariate adjusted odds ratio [OR], 0.286; 95% confidence interval [CI], 0.110–0.747; $p=0.011$), preoperative hemoglobin >12 g/dL (OR, 0.444; 95% CI, 0.244–0.807; $p=0.008$), number of comorbidities <4 (OR, 0.474; 95% CI, 0.223–1.008; $p=0.052$), index length-of-stay ≤10 days (OR, 0.359; 95% CI, 0.170–0.760; $p=0.007$), and no neurological/hematologic complications during index-stay (OR, 0.145; 95% CI, 0.031–0.688; $p=0.015$) had higher probability of ReAFS up to 3 months after MSTS. On univariate analysis, patients with a higher probability of ReAFS up to 1 year included those with ECOG 0–2 ($p=0.017$), preoperative hemoglobin >12 ($p=0.003$), and prostate primaries ($p=0.014$). Multivariate analysis revealed preoperative hemoglobin and primary tumor type to be significant factors influencing long-term ReAFS. Lung primaries had highest UHR/death, while breast had the least at 1 year after MSTS.

Conclusions: Our study revealed that general condition of the patient at the time of index surgery (ECOG and preoperative hemoglobin status) may significantly influence both short and long-term ReAFS after MSTS. Short-term ReAFS may also be influenced by the number of comorbidities and quality of postoperative recovery (length of index stay and postoperative complications during index stay), while long-term ReAFS may be influenced by the primary tumor type. Knowledge of factors influencing short-term ReAFS can allow oncologists and surgeons to optimize treatment approach, quality of cancer care, and patient counselling/surveillance to prolong the ReAFS, set expectations and improve the long-term QoL of MSTS-patients.

PS-FP-6-8**Clinical Results of Carbon-Ion Radiotherapy with Separation Surgery for Primary Spine/Paraspinal Sarcoma**

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Purpose: To evaluate the clinical outcome of combination carbon-ion radiotherapy with separation surgery (CIRT-SS) in patients with primary spinal/paraspinal sarcoma (PSPS) and epidural spinal cord compression (ESCC).

Methods: CIRT-SS was performed in 11 consecutive patients. Patients treated in the primary and salvage settings were categorized into group A (n=8) and group B (n=3), respectively. Clinical results and imaging findings were collected, with a particular focus on ESCC grade, treatment-associated adverse events (AEs), and the locoregional control (LRC) rate and overall survival (OS).

Results: The median follow-up period from the start of CIRT-SS was 25 months (range, 7–57 months). ESCC was improved by SS in all cases. No patients exhibited radiation-induced myelopathy (RIM), but three developed grade 3 vertebral compression fracture (VCF) during follow-up. Locoregional recurrences were observed in four patients (group A: 1 [12.5%], group B: 3 [100%]). Over the entire follow-up period, three patients developed distant metastases and two patients died. The 2-year LRC rate and OS were 70% and 80%, respectively.

Conclusions: CIRT-SS in the primary setting achieved acceptable LRC and OS without RIM in patients with PSPS with ESCC. VCF was the most frequent AE associated with CIRT-SS.

PS-FP-6-10**The Surgical Strategies for Dumbbell-Shaped Tumors of the Upper Cervical Spine**

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Purpose: To investigate the classification, surgical approach and surgical outcome of dumbbell tumors of the upper cervical spine.

Methods: From January 2012 to April 2019, 11 cases of dumbbell-shaped tumors of upper cervical spine were analyzed retrospectively. According to PUTH (Peking University Third Hospital) classification, there were one case of type 1, six cases of type 3, three cases of type 5, and one case of type 7.

Results: Among the 11 patients, there were five males and six females, with an average age of 36.55 years (range, 28–52 years), eight cases were schwannomas, three cases were meningiomas, and two cases were neurofibromatosis. Six cases were performed tumor resection, five cases were performed tumors resection and internal fixation. The average Japanese Orthopaedic Association score pre- and postoperative was 9.64 (range, 7–12) and 13.09 (range, 12–15), respectively. The average operation time was 312.36 minutes (range, 185–480 minutes) and the average bleeding volume was 324.55 mL (range, 130–600 mL). Postoperative complications included one case of infection and three cases of cerebrospinal fluid leakage. The average follow-up time was 34.73 months (range, 3–76 months). No recurrence occurred.

Conclusions: The key to resect the dumbbell-shaped tumors of upper cervical spine completely is to select the most suitable surgical approach according to the different regions of tumors, so as to maximize the exposure to tumors and reduce the risk of surgery. Complete resection of tumors can effectively reduce the recurrence rate. When excision of the facet joints is needed to expose the tumors, internal fixation is needed to avoid instability of the spine after operation. The spinal canal tumors should be removed first to avoid spinal cord injury to the greatest extent. Surgery should be performed under a microscope to ensure a clear vision and facilitate the cooperation and operation of the surgeon and assistant. Motor evoked potential and somato-sensory evoked potential can reflect

the spinal cord nerve injury in time and should be used routinely.

PS-FP-6-11

Surgical Outcomes of Spinal Cord Tumor in Elderly Patients Using the Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire

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Purpose: There have been few studies to evaluate the impact of age on the surgical outcomes in patients with spinal cord tumor (SCT). The Japanese Orthopaedic Association (JOA) score only assesses the neurologic function, whereas the Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ), a self-administered questionnaire, includes subitems regarding not only extremity and bladder function, but cervical function and quality of life (QOL), which can comprehensively evaluate the outcomes in cervical disorders. The aim of this study is to clarify the postoperative outcomes in elderly patients aged 65 years or older compared with those in young patients who underwent surgical resection for cervical SCT using the JOACMEQ.

Methods: This study includes 97 patients (49 males, 48 females) with cervical SCT who underwent surgical treatment at single institution between 2000 and 2016 and were followed up for at least 2 years after surgery. The patients were divided into a young group (<65 years, n=65) and an old group (≥65 years, n=32). The JOA scores and JOACMEQ subitems were compared between the two groups. Further, clinical outcomes were compared between intramedullary and extramedullary tumors in the elderly patients as subanalysis.

Results: The preoperative JOA score in the old group versus the young group was 11.3±3.4 versus 14.0±2.2, respectively ($p<0.01$). Each baseline parameter in the JOACMEQ was significantly lower in the old group. In contrast, the JOA score recovery rate (36.3%±37.8% vs.

33.8%±38.3%) and the JOACMEQ effectiveness rate in each parameter (cervical spine: 51.9% vs. 60.0%, upper extremity: 52.2% vs. 36.4%, lower extremity: 39.3% vs. 48.7%, bladder: 34.5% vs. 24.0%, QOL: 36.5% vs. 35.4%) were comparable between two groups without statistical significance. The comparative analyses of the elderly patients between intramedullary and extramedullary lesions revealed that the JOA recovery rate and the lower extremity function and QOL of the JOACMEQ effectiveness rate in intramedullary tumors were significantly worse than those in extramedullary tumors.

Conclusions: Although elderly patients with cervical spinal tumors showed lower preoperative scores than younger patients, the functional and QOL recovery following surgery was comparable between the two groups. Therefore, the age at surgery did not adversely affect the clinical outcomes. In contrast, the expected postoperative course should be cautiously explained to patients with intramedullary tumor prior to surgery, due to the inferior efficacy compared to the course in extramedullary tumor.

PS-FP-6-12

A Method for Predicting the Location of Dural Attachment of Spinal Meningioma: Tumor Attachment Angle

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Purpose: Asian Pacific Islander was reported to have the highest incidence of spinal meningiomas. Spinal meningioma commonly occurs in an intradural-extramedullary position and sometimes needs resection of the dura with the tumor, causing cerebrospinal fluid leakage. Previously, we had developed a surgical procedure without need for resection of the dura mater: combined resection of meningioma and inner layer of the dura (CR-MILD), but it is difficult to perform CR-MILD in case that the dural attachment of the tumor is ventral. The surgical proce-

dure should depend on its location of dural attachment, but there is no objective method to foresee the localization. The objective of this study is to develop a method to predict the location of dural attachment of spinal meningioma.

Methods: We performed a retrospective review of the medical, radiographic, surgical, and postoperative records of patients who underwent resection of spinal meningioma at our institution between 2007 and 2018. Twenty-four patients were included. The relationships between the location of dural attachment and surgical procedures, location of tumor, dural tail sign were investigated. Considering that the dural attachment might be located against spinal cord that was pressed by the tumor, we measured a point opposite the spinal cord pressed by the tumor. First, a line connecting two vertices of spinal cord was made in an axial plane of gadolinium-enhanced magnetic resonance imaging. Second, a line parallel to this line was formed as a tangential line of the spinal canal beside spinal cord. Third, an extension line of the points of tangency and the center of the spinal canal was made. We assumed that the attachment of meningioma to the dura might be close to the intersection of this extension line and spinal canal. To digitalize the location of this intersection, we measured an angle between the extension line and medial line of the vertebra and named it tumor attachment angle (TAA).

Results: The success rate of CR-MILD depended on the location of dural attachment of the tumor. Neither the location of tumor nor dural tail sign could not exactly predict the location of dural attachment. However, when TAA is over 120°, the location of the attachment of spinal meningioma is dorsal of spinal cord in all patients of this study. The cut-off point of TAA for dorsal attachment was 99°.

Conclusions: TAA predicts the location of dural attachment of spinal meningioma, which helps surgeons to create a preoperative surgical plan.

PS-FP-6-13

Usefulness of Artificial Cerebrospinal Fluid Replacement in Intradural Surgical Procedure

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Purpose: In surgical procedure with a dural incision, such like intradural tumor resection or more, surgeon have to face the problems with postoperative intracranial hypotension and the risk of rare intracranial hemorrhages. We examined whether these risks could be reduced by injecting artificial cerebrospinal fluid into the subarachnoid space at the time of dural suture in intradural surgery.

Methods: From February 2016, a total of 32 patients (15 males and 17 females) who had received intradural surgery and underwent postoperative computed tomography (CT) scan were included. The degree of intracranial emphysematous lesions by postoperative CT, presence or absence of intracranial hypotension symptoms, and the time until relief of symptoms were evaluated. From May 2017, artificial cerebrospinal fluid (ArtCereb) refilling was started at dural suture.

Results: Significant improvement of emphysematous changes and intracranial hypotension symptoms were marked in the group with artificial cerebrospinal fluid injection. Severe pneumocephalus in postoperative CT scan had reduced to 33.3% from 72.7% and intracranial hypotension symptom had reduced to 23.8% from 54.5%.

Conclusions: Although subarachnoid space refilling by artificial cerebrospinal fluid is a simple procedure, it seems to be extremely useful for reducing the risk of postoperative low intracranial pressure and intracranial hemorrhage.

PS-FP-6-14

The Radiographic Characters and Surgical Outcomes of Spinal Meningioma Who Grade 1

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Purpose: Most spinal meningiomas are benign, but a recurrence rate of about 10% has been reported. Therefore, in order to know the imaging characteristics of benign meningioma and the risk factors for recurrence and reoperation, we investigated the imaging characteristics and histological type, surgical results, and recurrence in World Health Organization (WHO) grade 1 spinal meningiomas those were surgically treated in our department.

Methods: Twenty-six cases of WHO grade 1 spinal cord meningiomas were treated by surgical resection from June 2010 to April 2020 in our department. We investigated spinal level of tumor location, location of axial section, presence of calcification on computed tomography, presence of dural tail sign on contrast magnetic resonance imaging, dural treatment method at the time of surgery, histologic type, tumor recurrence, and re-operation in these cases.

Results: The average age was 62 years (19 females and 7 males). The tumor location level incidence was cervical spine 38%, cervical thoracic spine 4%, thoracic spine 50%, and thoracolumbar spine 8%. Tumor locations on the axial section were ventral 42%, dorsal 12%, right 15%, left 23%, and dumbbell type 8% in the dural sac. Tumor calcification was found in 46% and dural tail sign was found in 85%. In 78%, the dura mater of tumor origin was resected together with the tumor, in 4% just the inner layer was resected, and in 18%, only the attachment electric ablation was performed after the tumor resection. The histological types were meningothelial and transitional in six cases each, psammomatous in four cases, fibrous in three cases, and angiomatous and metaplastic in two cases each, and three cases were difficult to distinguish. Dural tail signs were found in 100% of psammomatous, angiomatous, and

metaplastic, but 67% of meningothelial and fibrous. Calcification was found in 100% of psammomatous, angiomatous, and metaplastic, but 33% in meningothelial and transitional. Of the 19 patients who could be followed up for more than 2 years after surgery, recurrence occurred in one patient (4%), and two cases including one recurrent case and one postoperative cerebrospinal fluid leakage were performed reoperation. Both cases were dumbbell-type tumor. The preoperative mean McCormick score of 19 cases was 2.5, and the mean at the final observation was 1.4.

Conclusions: Dural tail sign was found at a high rate in the imaging findings of WHO grade 1 spinal meningiomas. Dumbbell-type tumors are at risk of cerebrospinal fluid leakage due to poor dural repair and recurrence due to poor resection.

PS-FP-6-16

The Utility of Minimal Access and Separation Surgery in the Management of Metastatic Spine Disease

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Purpose: This study compares outcomes of percutaneous pedicle screw fixation (PPSF) to open posterior stabilization (OPS) in patients with spinal instability; and mini-open separation surgery (MOSS) to open posterior stabilization and decompression (OPSD) in patients with metastatic spinal cord compression (MSCC).

Methods: We retrospectively analyzed all consecutive patients who underwent surgery for thoracolumbar metastatic spine disease (MSD) from January 2011 to October 2017. Patients were divided into minimally invasive spine surgery (MISS) and open spine surgery (OSS) groups. Patients with spinal instability were treated with PPSF or OPS with pedicle screws. Patients with MSCC were treated with MOSS or OPSD. Outcomes measured included intraoperative blood loss, operative time, duration of hospital stay, and improvement in ASIA score. Time to initiate radiotherapy and perioperative surgical or non-surgical complications were also recorded.

Results: There were 200 eligible patients, of which 61 underwent MISS and 139 OSS for MSD. There was no significant difference in baseline characteristics between patients undergoing MISS and OSS. In the MISS group, 28 patients (45.9%) were treated for spinal instability and 33 patients (54.1%) were treated for MSCC. Whilst in the OSS group, 15 patients (10.8%) were treated for spinal instability alone and 124 (89.2%) were treated for MSCC. Patients who underwent PPSF were found to have significantly lower blood loss (95 mL vs. 564 mL, $p<0.001$) and surgical complication rates ($p<0.05$) with shorter length of stay (6 days vs. 19 days, $p<0.001$) when compared to the OPS group. Patients who underwent MOSS had significantly lower blood loss (602 mL vs. 1,008 mL) and shorter length of stay (10 days vs. 18 days, $p=0.008$) versus the OPSD group.

Conclusions: This study demonstrates the benefits of PPSF and MOSS over OPS and OPSD for the treatment of MSD with spinal instability and MSCC, respectively.

PS-FP-6-18

Do aggressive Vertebral Hemangiomas Warrant Aggressive Surgery?: Inferences from a Retrospective Surgical Cohort of 23 Patients

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Purpose: Aggressive vertebral hemangiomas (AVH) are a rare subset of benign vascular tumors that frequently presents with compressive myelopathy. Surgery for AVH can be challenging, owing to the high vascularity of the tumor. Though the results of surgical management have improved over time, there is a lack of consensus on the ideal management of this group of patients. With this background, we evaluated the outcomes of our surgical cohort.

Methods: We did a retrospective analysis of 23 patients operated on for aggressive vertebral hemangioma between 2009 to 2019 in our institute. Minimum follow-up period was 2 years. The demographic, clinical details were retrieved from the hospital information system and

telephonic interviews. Imaging (radiographs, computed tomography scan, and magnetic resonance imaging) of all patients were accessed and analyzed in the picture archiving and communication system. Tumor staging was done by Enneking staging, Weinstein-Boriani-Biagini (WBB), and spinal instability neoplastic score. The neurological recovery and recurrence rate were noted at follow-up.

Results: Fifteen females, including three in the peripartum period and eight males with a mean age of 46.39 ± 17.47 years, formed the study group. Gait instability (39.13%), pain (30.43%) radiculopathy (17.39%), and weakness (13.04%) were the presenting symptoms. Thirteen patients had neurodeficit (American Spinal Injury Association [ASIA] A-1, ASIA C-2, ASIA D-10). The most common site of lesion was the thoracic spine ($n=13$), followed by thoracolumbar (D11-L2, $n=8$) and lumbar region ($n=2$). The lesion was solitary in 56.52% ($n=13$) and multiple in 43.48% ($n=10$). A rare occurrence of two-level symptomatic AVH was noted in one patient. Surgical intervention was heterogeneous (intralesional spondylectomy with reconstruction, $n=10$; vertebroplasty, stabilization, and decompression, $n=6$; decompression and stabilization, $n=6$; decompressive laminectomy, $n=1$). Preoperative embolization reduced intraoperative blood loss and enabled tumor removal. A difference in mean blood loss between non-embolization and pre-embolization was noted (1,416.6 mL vs. 812.2 mL). All the patients had improvement of neurology and only two recurrences were noted in a mean follow-up of 55.78 ± 25.03 months.

Conclusions: Aggressive vertebral hemangiomas are benign tumors, and intralesional spondylectomy offers a good outcome with less recurrence rate. WBB staging is helpful in decision making. Preoperative embolization is safe, helps reduce intraoperative blood loss, and enables tumor removal. Pregnancy increases the chance for symptomatic AVH, and treatment in antepartum needs to be individualized.

PS-FP-7-2

Micro-organisms and Outcome of Spinal Infections: A Report of 48 Cases

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Purpose: Spinal infection (SI) is a common serious disease that can cause severe damage and disability. Recent literature trends suggest an increasing prevalence of SI. To avoid SI's sequelae, determining an early diagnosis and treatment is essential. This study aimed to describe micro-organisms and outcome of the treatment for some of SI's types.

Methods: A total of 48 patients with SI admitted at the spine unit of our hospital from 2015 to 2019 were classified into three groups based on its causes: spontaneous (n=19), post-spinal injection (n=17), and postoperation (n=12). Microorganisms, locations, complications, treatment approaches, and the outcome were analyzed.

Results: General information: male/female ratio (1.875); mean age (49 years). Pathogens: Staphylococcus aureus (52.1%); tuberculosis (29.2%); Escherichia coli (4.2%); Candida albicans (4.2%); 2 pathogens (2.1%); unknown (8.2%). Location: cervical (10.4%); thoracic (16.7%); lumbar (60.4%); sacroiliac joint (4.2%); para-spinal muscular (2.1%); spinal epidural abscess (6.2%). Group 1: spontaneous SI (n=19): pathogens: tuberculosis (73.7%); S. aureus (26.3%). Complications: sepsis (3/19, 15.8%). Treatment: conservative, 21%; surgery, 79%. Outcome: good (84.2%); fair (5.3%); bad (10.5%). Group 2: post-spinal-injection SI (n=17): risk factors: diabetes mellitus (41.7%). Type of spinal injection: acupuncture (11.8%); vertebroplasty (17.6%); trigger point and epidural injection (70.4%). Pathogens: E. coli (5.9%), C. albicans (11.8%), S. aureus (82.3%). Complication: sepsis (41.7%). Treatment: surgery (52.9%); conservative (47.1%). Outcome: good (52.8%), fair (23.6%); bad (23.6%). Group 3: postoperative SI (n=12): risk factors: diabetes mellitus (25%); blood transfusion (50%). Pathogens: S. aureus (50%); E. coli (8.3%); multiple pathogens (8.3%); unknown (33.3%). Complications: sepsis (33.3%); multiple organ failure (16.6%); mortality (1/12, 8.4%). Treatment: conservative (58.3%); surgery (41.7%). Outcome: good (33.3%); fair (33.3%); bad (33.4%).

Conclusions: SI is commonly caused by S. aureus, a high risk in diabetic patients who undergo spinal injection or surgery with blood transfusion. The complication of SI is more severe and treatment outcome is worse in postoperative and post-injection SI groups.

PS-FP-7-6

A Validated Score for Evaluating Spinal Instability to Assess Surgical Candidacy in Active Spinal Tuberculosis: An Evidence-Based Approach and Multinational Expert Consensus Study

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Study Design: Modified Delphi consensus and observational study.

Purpose: To develop an objective scoring system to determine instability in spinal tuberculosis (STB).

Overview of Literature: Multidrug chemotherapy has made STB mainly a medical disease. However, instability in STB leads to disabling spinal deformity and neurological deficit. The ability to identify and estimate instability remains largely subjective based on experience resulting in overdo or delayed surgical treatment with serious consequences to the patient.

Methods: The study was conducted in four phases: (1) A 10-member expert panel of spine surgeons with 25 years' experience performed an extensive review of literature to enlist all factors influencing management in STB and a questionnaire was developed; (2) 68 experienced spine surgeons from 12 different nations opined on the importance of each factor in an online survey; 5 factors deemed important by >70% of participants were included for further analysis; (3) 60 representative cases of STB were analyzed for several factors and their association with instability; a preliminary scoring system was developed and threshold score for determining instability was derived; and (4) results were validated in a new set of 30 cases; 10 spine fellows and orthopedic residents naïve to the scoring system evaluated these cases before and after employing the scoring system and the overall agreement, reliability and reproducibility were analyzed. This project was self-funded.

Results: A total of 68 of 76 of the invited spine surgeons participated and factors considered important by >70% of the participants were 'spine at risk' signs deemed important by all (100%), followed by severity of vertebral body loss (89.56%), cervico-thoracic/thoraco-lumbar junction involvement (86.57%), age below 15 at presentation (85.07%), and kyphotic deformity $\geq 30^\circ$ (80.60%). All these five factors considered in the scoring system were found to be associated with instability: age ≤ 15 years ($p=0.05$), cervicothoracic/thoracolumbar junction involvement ($p=0.028$), sagittal deformity angle ratio $\geq 15^\circ$ ($p<0.001$), vertebral body loss-segmental ratio ≥ 0.5 ($p<0.001$), and presence of spine at risk signs ($p<0.001$). A total score of $\geq 3/10$ was indicative of definite instability with a good sensitivity (77%) and excellent specificity (100%). The scoring system was validated in a new set of 30 cases with excellent accuracy.

Conclusions: A simple objective method of scoring system for predicting instability in STB has been developed using five main factors: young age, junctional involvement, severity of deformity, vertebral body loss, and presence of spine at risk signs.

PS-FP-7-7

Clinical, Radiological and Microbial Profile of Pyogenic Spondylodiscitis: Single-Center Data Analysis of 48 Patients

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Purpose: Pyogenic spondylodiscitis is defined as an infection of the intervertebral disc and/or adjacent vertebrae. It may occur due to hematogenous seeding during bacteremia, direct spread from an adjacent focus of infection, or inoculation during spinal surgery. The incidence of spondylodiscitis appears to be increasing due to the aging population with multiple comorbidities. However, there is a critical lack of information about natural history, long-term clinical outcomes, patient- and disease-related factors that contribute to clinical outcomes. Our objective is to describe the clinical, radiological, and microbial profiles in 48 patients.

Methods: A retrospective single-center study of 48 patients from the electronic medical record. Data were ob-

tained regarding clinical and radiological features and the microbiological diagnosis was recorded.

Results: The mean age was 52 years (range, 7–93 years), 73% of these patients are males. A pre-existing condition causing impaired immunity was present in 27 patients (56.2%): eight had diabetes mellitus, 10 had urinary tract infections, five had chronic kidney disease, one had rectal carcinoma, three had cholangitis, and three had epididymo-orchitis. Five patients (10.4%) had history of spinal surgery. Pain was the most common symptom, fever was absent in 17 patients (35.4%), and neurological deficit was seen in 10 patients (20.8%). Mean duration of symptoms was 3 weeks. Most common site is lumbar spine ($n=21$) followed by lumbosacral junction ($n=15$) and thoracic spine ($n=10$), and cervical spine ($n=2$) is the least common site. Two-disc space involvement is seen in two patients. Most common source of infection is hematogenous (22 patients [45.8%]), and an intra-abdominal pathology is seen in four patients (8.3%). Bacteria isolated from cultures in 35 patients and Gram positive seen in 20 patients (41.2%) and Gram negative seen in 15 patients (31.25%). Multiple organisms are identified in five patients (10.4%). Most common organism is *Staphylococcus aureus* followed by *Escherichia coli*.

Conclusions: We conclude that immunocompromised patients and those with medical comorbidities have a high risk of developing spondylodiscitis.

PS-FP-7-8

Treatment Results of Percutaneous Posterior Lumbar Pelvic Fusion for Lower Lumbar Purulent/Tuberculous Discitis

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Purpose: Antibiotics are the basic treatment for purulent or tuberculous discitis, but for cases with abscess formation and/or bone destruction of the endplate of vertebra, percutaneous disc dissection and drainage for the affected disc, and further percutaneous posterior fusion is performed on the cranio-caudal side of the infected disc so that activity can be restored at an early stage. However,

posterior fusion for discitis in the lower lumbar spine is somewhat difficult. In this study, we investigated the results of percutaneous posterior lumbar pelvic fusion for purulent or tuberculous discitis of the lower lumbar spine with vertebral body destruction.

Methods: Nine patients, who underwent percutaneous posterior fusion from the lower lumbar spine to the pelvis for discitis that occurred in L4–5 and/or L5–S1 with destruction of the endplate of the vertebral body from 2016 to 2019 (eight males and one female, with an average age of 71 years), were included in this study. We investigated comorbidities, preoperative treatment period, level of discitis, causative bacteria, surgical procedure, Japanese Orthopaedic Association (JOA) score as well as JOA sub-score of activities of daily living/walking ability at preoperative and final observation (15 months on average), and postoperative course.

Results: All patients had comorbidities including four cases with diabetes and atrial fibrillation in two cases each, one case of infectious aortic aneurysm, one case of caries, and three cases of the others. The average preoperative treatment period is 1 month, and the level of discitis was L3–4 and L4–5 in one case, L4–5 in three cases, L5–S in two cases, and L4–5 and L5–S in three cases. The causative bacteria were *Staphylococcus mutans*, Methicillin-resistant coagulase-negative staphylococcus, *Enterococcus faecium*, tubercle bacillus, and so forth in one case each, and unknown in three cases. The mean JOA score improved significantly to 2.6 preoperatively and 10.8 at the final observation ($p < 0.01$). Mean JOA sub-scores of activities of daily living and walking ability were significantly improved from 2.6 and 0.1 before surgery to 10.8 and 1.9 at the final observation ($p < 0.001$). One case each died of bleeding from an infectious abdominal aortic aneurysm, and one case where discitis spread to the upper lumbar spine and extended fixation to the lower thoracic spine.

Conclusions: Percutaneous posterior lumbar pelvic fusion for lower lumbar discitis significantly improved JOA scores as well as JOA sub-score of activities of daily living and walking ability.

PS-FP-7-9

Trends in Infectious Spondylitis from 2000 to 2020

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Purpose: Infectious spondylitis was a relatively rare disease in the past; however, it is becoming more common now. The reason for this trend is predicted to be the change in the disease and patient characteristics. This study aimed to investigate the trends in infectious spondylitis in the past 2 decades.

Methods: Our study included 157 cases, from 2000 to 2020, of infectious spondylitis such as purulent spondylitis and tuberculous spondylitis. Cases were divided into two groups: group 1 (2000–2009; 82 cases: 57 males and 25 females) and group 2 (2010–2020; 75 cases: 46 males and 29 females). Age, gender, causative organism, and localization examined and compared between the groups.

Results: The highest morbidity was in lumbar spine infections in both groups. The proportion of women was 30.5% in the group 1 and 38.7% in the group 2, with no significant difference ($p = 0.28$). The average age was significantly higher in the group 2 (72.6 years) than in the group 1 (68.8 years, $p < 0.01$). Compromised hosts were the cause of infection in 52.4% of the group 1 and 36.0% of the group 2, showing a significant difference. Bacterial identification rate was 70.1% in the group 1 and 77.3% in the group 2 ($p < 0.01$), and the genus *Staphylococcus* was the most common bacteria. The proportion of resistant bacteria such as Methicillin-resistant *Staphylococcus aureus* was 27.3% in the group 1 but only 6.7% in the group 2 ($p < 0.01$). Conversely, infectious diseases caused by indigenous bacteria in the oral cavity and intestines were more common in the group 2 (37.8%) than in the group 1 (13.0%), showing a significant difference ($p < 0.01$).

Conclusion: Since 2000, infectious spondylitis trends have changed when evaluated every 10 years. In recent years, infections caused by indigenous bacteria have increased more than those caused by resistant bacteria, and the causative bacteria are believed to have changed due to the increased age of patients over the 2 decades.

PS-FP-7-10

Status and Trends of Causative Bacteria of Surgical Site Infection in Spinal Surgery: A Study on 6,411 Cases

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Purpose: Surgical site infection (SSI) after spinal surgery is a significant problem for patients and healthcare economics—various preventive measures, including prophylactic drug administration. We investigated the trend of SSI rates and the trend of causative bacteria in our department over the past 10 year.

Methods: We investigated the details of postoperative SSI in all spinal surgery cases (6,411 cases) performed at our hospital from 2010 to 2019. Postoperative SSI was defined as cases requiring debridement and curettage in the operating room. In our department, cefazolin is usually used as a prophylactic antibacterial drug, and teicoplanin is also administered to patients at high risk of infection (cases with diabetes, reoperation, etc.). The cases were divided based on the presence or absence of spinal implants, and the first half (2010–2014) and the second half (2015–2019) of the studied period. Recent trends in SSI rate were investigated retrospectively using these groups.

Results: The overall SSI rate in the first half was 1.43%, then decreased significantly to 0.88% in the second half. In cases without implants, the first half's SSI rate was 1.07%, then decreased significantly to 0.37% in the second half. In cases with spinal implants, there was no significant difference in SSI rate between the first and second half (1.99% vs. 1.58%). In cases without implants, SSIs were mainly caused by multidrug-resistant bacteria in the first half (seven cases/18 cases). In the second half, the proportion was decreased (seven cases/25 cases). In case with spinal implants, the causative bacteria of multidrug-resistant bacteria decreased (nine cases/22 cases → seven cases/25 cases). However, the number of cases with *Propionibacterium acnes* increased in the second half (two cases/22 cases → 11 cases/25 cases). In all cases with *P. acnes*, all patients underwent posterior spinal fixation for adolescent idiopathic scoliosis and suffered late-onset SSI

(five cases/five cases).

Conclusions: We investigated the trends of SSI rates and the causative bacteria of SSI in spinal surgery at our hospital. In recent years, cases of SSI due to *P. Acnes* increased in AIS cases, and a modification of the perioperative protocol is required.

PS-FP-7-11

Gene Xpert/MTB RIF Assay for Spinal Tuberculosis

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Purpose: Xpert MTB/RIF assay is a rapid automated molecular test with excellent reported sensitivity, specificity for diagnosis of pulmonary and extrapulmonary *Mycobacterium tuberculosis* (MTB) infections. However, the clinical utility and accuracy in STB is not well established. The objective of the study was to report on the sensitivity, specificity and clinical utility of the Xpert MTB/RIF assay in spinal tuberculosis (STB).

Methods: A retrospective review of medical records were performed for 136 patients that underwent spinal biopsy for suspected spondylodiscitis. Reports for acid fast bacilli (AFB) smear, gram stain, pyogenic culture, MTB culture, histopathology, Xpert MTB/RIF assay, and drug sensitivity testing were reviewed. "Reference standard for diagnosis of STB" was based on positive histopathology and/or MTB culture evidence and were considered as MTB positive. Any samples returning a positive pyogenic or fungal culture were considered as MTB negative. The sensitivity, specificity for Xpert MTB/RIF was assessed against the reference standard.

Results: A total of 125 patients were considered for final analysis, 86 patients met the criteria for "reference standard for diagnosis of TB spine" (MTB positive). This includes nine patients that were MGIT culture only positive; 45 that were histopathology only positive and 32 were both culture and histopathology positive. There were 39 culture-proven (pyogenic, 37 and fungal, 2) patients included in MTB negative group. Of the 86 MTB samples that were positive 53 (61.6%) were tissue and 33 (38.4%)

were pus samples respectively. In our series, the overall analysis showed a 65.1% sensitivity, 100% specificity, 100% positive predictive value, and 56.5% negative predictive value for the Xpert MTB/RIF.

Conclusions: Gene Xpert MTB/RIF showed excellent specificity and was accurate in the identification of drug resistance. The sensitivity was 65% which was lower than reported previously in other series for spinal tuberculosis. Sampling techniques using pus samples rather than tissue samples could be a possible reason for lower sensitivity.

PS-FP-7-12

Does Forced-Air Warming Increase Surgical Site Infections in Spine Surgery? A Propensity Score-Matched Analysis

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Purpose: Forced-air warming (FAW) systems have been widely used to prevent hypothermia under anesthesia during various surgeries. Several previous reports have suggested that FAW increases the incidence of surgical site infection (SSI) after joint replacement. However, there has been no study to investigate whether FAW increase SSI following spine surgery. The purpose of this study is to compare the incidence of SSI between with and without FAW in spine surgery.

Methods: This study analyzed 245 patients who underwent spine surgery. Clinical characteristics such as age, gender, body mass index, the American Society of Anesthesiologists physical status (ASA-PS), diagnosis of diabetes mellitus, and current smoking habits were investigated. Surgical data such as surgical site, previous surgery at same site, operative time, intraoperative blood loss, and use of spinal instrumentation were evaluated. The patients were divided into two groups according to whether FAW was used or not during surgery. The application of FAW was determined by anesthesiologists. Among all participants in this study, the clinical characteristics, surgical data and incidence of SSI were compared between the two

groups. To estimate the incidence of SSI without potential biases due to various confounding factors, a propensity score pairwise matching was performed between the two groups.

Results: The FAW was used in 45 patients, and 200 patients underwent surgery without FAW. The incidence of SSI tended to be higher in patients with FAW (8.9%) compared to those without FAW (3.0%) ($p=0.07$). Patients with FAW were significantly higher ASA-PS, longer operative time, larger intraoperative blood loss, and more use of instrumentation compared to those without FAW ($p<0.01$). Propensity matching yielded 39 pairs of patients with and without FAW. In the propensity score-matched analysis, the number of patients who developed SSI was no significant difference between patients with (10.3%) and without FAW (7.7%) ($p=0.69$).

Conclusions: There have been many studies to investigate whether the use of FAW during joint surgery increases risk of SSI or not, but it remains controversial. The present study compared the incidence of SSI between with or without FAW in spine surgery for the first time. In the present study using a propensity score-matched analysis, FAW did not significantly increase the incidence of SSI. Therefore, FAW can be used for the maintenance of intraoperative normothermia during spine surgery without increasing risk of SSI when it used properly.

PS-FP-7-13

“Spine Surgery Checklist” a Step Towards Perfection Through Protocols

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Study Design: Prospective observational study.

Purpose: To evaluate the effectiveness of a novel checklist designed specifically for “spine-surgery-subspecialty”, as a means to reduce some of the common preventable human errors and major perioperative complications in spine surgery.

Overview of Literature: We propose a unique set of spine surgery specific checklist that recognizes the risk factors, anticipates the possible human errors, and thus can help to prevent their occurrence. This checklist is associated with increased patient safety awareness, improved com-

munication (keeps everyone updated regarding their responsibilities), reduction of surgical claims, and reduction in the number of postoperative complications including mortality.

Methods: It was a prospective pilot study performed at a single center including a total of 858 spine surgical patients. The patients were divided into two groups: the study group (after implementation of the checklist [2016–2017]) and the control group (before the implementation of the checklist [2015–2016]). The incidence of common preventable human errors and major perioperative complications in spine surgeries were recorded and compared between the two groups.

Results: The incidence of wrong-level surgeries was 0%. The overall incidence of preventable errors was 1.22% (5/410). The rate of adverse, near-miss, and no-harm events was 0%, 0.73% (3/410), and 0.48% (2/410), respectively. The preoperative, intraoperative, and postoperative errors were 0.48% (2/410), 0.24% (1/410), and 0.48% (2/410), respectively. The reoperation rate related to preventable errors reduced after checklist implementation. There were significant differences noted in the total preventable errors related to complications like infections, prolonged hospital stays, and unplanned hospital readmission/revision surgeries ($p < 0.001$).

Conclusions: The authors proposed first of its kind spine surgery-specific checklist which is comprehensive involving perioperative parameters. The checklist is easy, safe, and effective to reduce unforgiving errors and perioperative complications. However, its broader implementation would require its validation through large multicenter and randomized control studies.

PS-FP-7-14

Analysis of Clinical Features Regarding Concomitant Spinal and Non-spinal Osteoarticular Infections

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Objective: To reveal clinical characteristics and treatment

outcomes of patients who suffered concomitant spinal and non-spinal osteoarticular infections. Treatment of pyogenic spondylodiscitis or arthritis can be complicated with a variety of concomitant infectious processes. To the best of our knowledge, no study has to date focused on concomitant osteoarticular infections.

Methods: Between May of 2015 and May of 2019, patients over 18 years old, who were diagnosed and treated for spinal infections (spondylodiscitis and facet joint infection) or non-spinal infections (septic arthritis), were included. There were six patients with concomitant spinal and non-spinal osteoarticular infections (CI group), 31 patients with spinal infection alone (SA group), and 18 patients with arthritis alone (AA group). The data gained from the patients in the CI group were compared those in the SA group and the AA group.

Results: Factors contributing to statistical significance included past or present history of cancer (100% in the CI group, 29% in the SA group and 33% in the AA group), CRP levels (27.4 mg/dl in the CI group, 13.4 mg/dl in the SA group, and 13.8 mg/dl in the AA Group), albumin levels (2.4 g/dl in the CI group and 2.9 in both the SA group and the AA group), detection of Group B Streptococcus (GBS) (50% in the CI group, 3.2% in the SA group and 5.6% in the AA group), and duration of intravenous antibiotic therapy (131 days in the CI group, 66 days in the SA group and 29 days in the AA group).

Conclusions: Patients with concomitant spinal and non-spinal osteoarticular infections were more likely to present with a past and present history of cancer, hypoalbuminemia, higher levels of CRP and GBS bacteremia. Furthermore, they required prolonged courses of intravenous antibiotic therapy.

PS-FP-7-15

Consecutive Occurrence of Septic Arthritis and Pyogenic Spondylitis in Two Patients

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Pyogenic spondylodiscitis and arthritis are serious infec-

tious diseases. A combination of these two conditions makes treatment more difficult. The patient in case 1 is an 86-year-old female with a past medical history of breast and thyroid cancers. She was brought to our emergency room suffering from severe low back pain. Magnetic resonance imaging (MRI) showed discovertebral signal changes in the L2–L4 vertebrae. Blood cultures confirmed *Streptococcus agalactiae*. Intravenous antibiotic therapy was initiated. On day 24, the patient began to complain of pain in her left shoulder. MRI revealed synovial effusion. Arthroscopic debridement was then performed. Pathological analysis revealed an infiltration of neutrophils in the synovial tissue specimens. In contrast, her back pain continued to be severe despite treatment using a hard brace. MRI taken on day 50 showed a progressive destruction of the vertebral bodies. The patient underwent percutaneous posterior instrumentation. On day 70, the septic arthritis in the left shoulder recurred and arthroscopic irrigation was carried out again. *Corynebacterium striatum* was detected in the synovial fluid cultures. We changed the antibiotics to vancomycin, which was judged sensitive to both *Streptococcus* and *Corynebacterium*. The C-reactive protein levels were normalized on day 122. The patient in case 2 is an 87-year-old male with a past medical history of stomach cancer, diabetes mellitus, and bullous pemphigoid. He was referred to our clinic with a 1-week history of right shoulder pain and high fever was noted the day before arrival. MRI of the right shoulder showed synovial effusion. Gram staining of the shoulder aspirates indicated Gram positive bacteria. Arthroscopic debridement of the right shoulder was performed. *Staphylococcus aureus* was detected in the blood and the synovial fluid cultures. Intravenous antibiotic therapy was initiated. The patient started to complain of low back pain on day 27. MRI revealed a fluid accumulation in the L1/2 intervertebral disc with signal changes at the adjusting endplates and the vertebral bodies, which is consistent with pyogenic spondylodiscitis. A hard corset was placed on the patient. Surgical treatment was declined by the patient and his family. On day 121, the patient suffered a cardiopulmonary arrest. This was due to a pulmonary embolism. A concomitance of pyogenic spondylodiscitis with septic arthritis is possible in immunocompromised senile patients. Causative microorganisms can be different between spondylodiscitis and arthritis. Thereby diagnostic intervention to each locus is recommended. The correct timing to proceed with surgery is critical.

PS-FP-7-16

A Case of Glossopharyngeal and Hypoglossal Nerve Paralysis Secondary to Pyogenic Cervical Facet Joint Arthritis

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Jugular foramen syndrome is a rare systematic cranial neuropathy showing characteristic clinical symptoms due to jugular foramen cranial nerve paralysis. Carotid space lesions can cause cranial neuropathy. Both jugular foramen syndrome and carotid space lesions have been reported rarely in patients in otolaryngology. No cases have been reported in orthopedics. We report a case of cranial neuropathy caused by cervical pyogenic intervertebral arthritis. A 50-year-old man presented with severe neck pain, fever, and difficulty breathing. He was admitted to the orthopedics department with possible retropharyngeal abscess and pyogenic spondylitis. Antibiotic therapy was initiated; however, due to poor oxygenation, he was referred and admitted to our department. Magnetic resonance imaging showed signal changes at the left C1/2 lateral atlantoaxial joint, posterior pharynx, longus colli, carotid space, and medial deep cervical region, predominantly on the left side. Despite lymph node enlargement from the posterior pharynx to deep cervical region, there was no abscess formation. There were no signs of space-occupying lesion or signal changes in the jugular foramen. One day post-admission, his temperature had risen to 39.1°C, SpO₂ had fallen, and neck pain had worsened. Emergency surgery was decided. We suspected retropharyngeal abscess and pyogenic spondylitis. Intraoperatively, no abscess formation in the posterior pharynx, vertebral bodies, or anterior to the intervertebral discs was seen. Irrigation was performed with physiological saline, and a drain placed. Postoperatively, white blood cell count and C-reactive protein levels had decreased. On day 13 post-admission, the patient had dysphagia, deviated tongue protrusion, and curtain sign. Glossopharyngeal and hypoglossal nerve paralysis was diagnosed. The patient's swallowing functions recovered, and he was discharged on day 36. The patient had hypoglossal nerve paralysis, and we suspected that this was from pressure on the carotid space. Lateral retropharyngeal lymph nodes (LRPLN) are

present on the medial carotid space, which contains the glossopharyngeal and hypoglossal nerves. The infection can lead to LRPLN enlargement, resulting in pressure on the carotid space from medial to lateral, and cause glossopharyngeal and hypoglossal nerve paralysis.

PS-FP-7-17

Clinical Significance of Comprehensive Medicine for the Treatment of Pyogenic Spondylitis in the Elderly

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Purpose: In recent years, the number of refractory spinal infections in elderly patients with diverse comorbidities has been increasing in Japan. In addition, elderly people are prone to low nutritional status due to age-related eating disorders and changes in digestion and absorption functions. In this study, we examined the clinical efficacy of combining conventional orthopedic single-discipline treatment with multi-disciplinary comprehensive medical treatment of pyogenic spondylitis in the elderly.

Methods: The study included 54 patients aged 65 years and older who were treated for pyogenic spondylitis between 2016 and 2019. The patients were divided into two groups: 41 patients managed by a single orthopedic department (non-intervention group) and 13 patients managed with a combination of conventional orthopedic single-specialty treatment and comprehensive medical treatment care. In addition to conventional single discipline care, the Japanese Nurse Practitioner (JNP) played a central role in comprehensive medical care by treatment strategy. The JNP also played an active role in the correction of polypharmacy such as reduction of these medications may be risky for the elderly when used excessively. Serum albumin level was used for nutritional assessment and Barthel Index for quality of life assessment, and the degree of improvement between the two points was calculated at admission and discharge.

Results: The per capita doses of nonsteroidal anti-inflammatory drugs and opioid analgesics were reduced to 13% and 9% of the non-intervention group, respectively, resulting in acetaminophen-centered analgesic control.

The mean serum albumin level at admission was 2.94 g/dL in the non-intervention group and 2.62 g/dL in the intervention group. At discharge, it was 3.16 g/dL in the non-intervention group and 3.32 g/dL in the intervention group. The mean Barthel Index at admission was 23.1 points in the non-intervention group and 18.2 points in the intervention group. There was an improvement of Barthel Index to 38.8 points in the non-intervention group compared to 44.1 points in the intervention group by discharge. There was a significant improvement in the intervention group compared to the non-intervention group ($p<0.05$).

Conclusions: Nutritional and pharmaceutical management of elderly infected patients is an important factor in determining the outcome of surgical care. Although JNP in Japan is still not well recognized, we believe that it is an important and effective profession for the development of comprehensive medical care, and we hope to improve clinical outcomes by implementing it in conjunction with orthopedic care.

PS-FP-7-19

Tuberculous Osteomyelitis of the Ischium: A Case Report and Review of Literature

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Gluteal pain can be a presenting symptom of numerous pathologies arising from the spine, pelvis and hips and can pose a challenging problem to orthopedic surgeons. We report a unique case of tuberculous osteomyelitis of the ischium in a young immunocompetent individual presenting as gluteal pain. A high index of suspicion, early diagnosis and prompt management is mandatory to promote complete healing and prevent complications.

PS-FP-7-21

Characterization of Biofilms in Explanted Pedicle Screws Retrieved from Aseptic Pseudarthrosis Cases

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Purpose: A previous retrieval analysis of implants from patients with pseudoarthrosis and pedicle screw loosening show high levels of bacterial contamination at the pedicle of the vertebra. Recent literature has highlighted the correlation of pseudoarthrosis and pedicle screw loosening with subchronic infection at the pedicle of the vertebra. The objective of the current study is to characterize the supposedly “aseptic” pedicle screw loosening in patients undergoing revision surgery and to determine both the frequency and visual architecture of biofilms on implant surfaces.

Methods: Pedicle screw explants from 10 consecutive patients undergoing revision spine surgery for pseudoarthrosis were collected and fixed in 3% glutaraldehyde solution. The exclusion criteria were as follows: age <18 years; surgery for causes related to trauma, tumors, or primary infection; use of cemented screws; an anterior- only approach; and lack of radiographic data (to determine the presence or absence of radiolucent rim and confirm screw loosening). From the collected samples, eight patient swabs from tissues around the implants were sent for cultures to assess bacterial infiltration in tissues beyond the biofilm. Additionally, each of these implants were analyzed thoroughly by using scanning electron microscopy and X-ray spectroscopy to evaluate the architecture of the biofilm. The implants were also analyzed using energy dispersive X-ray spectroscopy. Pearson’s correlation coefficient statistics was used to measure the linear correlation between the two paired variables, namely, screw loosening and biofilm.

Results: The study was successful in capturing the visual architecture of the biofilm on retrieved implants. A total of 77% of pseudoarthrosis cases presented with loose

pedicle screws, and 72% of cases showed biofilms on the implants. Statistical tests demonstrated that the confirmed cases of screw loosening (as identified by radiographic halo) and the detection of biofilms were positively correlated. Areas with biofilms always tested negative for calcium phosphate (bone mineralization), whereas areas without biofilms tested positive for calcium phosphate. Intraoperative tissue and swab cultures of the surrounding screws did not demonstrate bacteria growth on cultures.

Conclusions: In the absence of the clinical presentation of infection, impregnated bacteria could form a biofilm around an implant, and this biofilm can remain undetected via contemporary diagnostic methods, including swabbing. Implant biofilm is frequently present in “aseptic” pseudoarthrosis cases. The major limitation of this study is its relatively small sample size and the statistical nonsignificant correlation between screw loosening and biofilms.

PS-FP-7-22

How Does the Absence or Presence of Pedicle Screw Guard Effect Bacterial Contamination at the Screw-Bone Interface during Spinal Fusion: A Multicenter Study

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Purpose: The current data on postoperative infections in spinal fusion surgeries indicate occurrence in the range of 2%–13%. These numbers might be underestimated due to various reasons as cited in the publications, highlighting the magnitude of the issue. While current practice includes applications of vancomycin immediately before closure, it is theoretically impossible to irrigate the screw-bone interface following the surgery. Therefore, any contamination associated with the pedicle screw before implantation is permanent. This can be potentially harmful, as it can cause deep-bone infection, or hardware loosening at the screw-bone interface. This forms the basis for improved monitoring and introduction of effective pre-

ventive measures. The objective of this study was to assess the bacterial contamination in current practices of pedicle screw handling in spinal fusion surgeries and evaluate the efficacy of the novel method of using an intraoperative, sterile implant guard for screws against the same.

Methods: Two groups of pre-sterile individually packaged pedicle screws, one incased in a sterile, protective guard (group 1: G) and the other without such a guard (group 2: NG), 31 samples in each group were distributed over 28 spinal fusion surgeries at five independent hospitals groups. Each were loaded onto the insertion device by the scrub tech and left on the sterile table. Twenty minutes later, the lead surgeon who had just finished preparing the surgical site, handles the pedicle screw, to check the fit with the insertion device. Then, instead of implantation, it was transferred to a sterile container using fresh sterile gloves for bacterial analysis.

Results: The standard unguarded pedicle screws presented bioburden in the range of 105 to 107 colonies forming units per screw, whereas the guarded pedicle screws showed no bioburden. The bacteria genus identified from cultures were *Staphylococcus* and *Micrococcus*, the two most common genera reported in surgical site infection cases.

Conclusions: The result of this study indicates that the current processes related to handling of pedicle screws leads to bacterial contamination of pedicle screws, and thereby the screw-bone interface. This can be potentially avoided by using a sterile guard, in which the screws are sterilely prepackaged until implantation. The authors advocate for this change in current practice to move towards a safer, more economic practice.

PS-FP-7-23

Poor Nutritional Status and Chronic Kidney Disease Might Be Risk Factors in Elderly Patients with Pyogenic Spondylitis

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Purpose: Faced with a super-aging society, infection is a life-threatening disease. The incidence of pyogenic spondylitis is not decreasing in our hospital, and relevant lit-

erature (PubMed) is increasing worldwide. In particular, elderly patients are relatively frail; therefore, we hypothesized that the nutritional status is quite poor in patients with pyogenic spondylitis. To examine the nutritional status and relative factors in patients with pyogenic spondylitis.

Methods: We retrospectively reviewed 23 patients (16 males, seven females) hospitalized with pyogenic spondylitis between 2018 and 2020 in Kyushu Rosai Hospital. To confirm pyogenic spondylitis, magnetic resonance imaging or computed tomography was performed in addition to laboratory tests. The mode of onset was evaluated using the Kulowski classification. Since the infection was related to a poor nutritional status and immunocompromised host, the nutritional status was evaluated based on the Controlling Nutrition Status (CONUT) score. As previously reported, chronic kidney disease (CKD) is associated with comorbid lifestyle-related diseases such as cardiovascular disease and diabetes mellitus. Such diseases, especially in elderly individuals, may be associated with a low nutritional status. Therefore, we evaluated renal function using the Cockcroft and Gault (C-G) formula. We statistically analyzed the correlation between the CONUT score and C-G results.

Results: Regarding the patient demographics, the mean age at the onset of pyogenic spondylitis was 70±13 years. In our study, according to the Kulowski classification, 74% of the patients had subacute (n=11, 48%) or chronic-type (n=6, 26%) onset. C-G calculations revealed that 70% of the patients had CKD worse than stage G3a. All the patients were classified into the CONUT-low group (≤ 2) or CONUT-high group (≥ 3). The CONUT score was correlated with the C-G results ($r=-0.52$).

Conclusions: Since the CONUT score is based on the serum albumin level, total cholesterol level, and total lymphocyte count, the CONUT score may reflect malnutrition and the systemic inflammation status. Since pyogenic spondylitis is an inflammatory disease, the malnutrition status may further aggravate spondylitis. CKD is also linked to the malnutrition status. Our study suggests that patients with pyogenic spondylitis potentially have malnutrition and CKD. Therefore, an active nutritional intervention may contribute to treatment in addition to the usual treatment for pyogenic spondylitis.

PS-FP-7-24

Evaluating Reprocessed Pedicle Screws: Characterization of Contaminants and Efficiency of the Process

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Purpose: Pedicle screws are almost synonymous with the term spinal fusion. Processing of these implants is a multi-step process that comes under the ambit of the sterilization processing department, managing activities such as receiving contaminated implants, sterilizing them, and redistributing them in the facility. An efficient process across the different steps is vital for the proper surgical management of the patients, leading to avoidance of costly delays and surgical site infection. The design of pedicle screws raises a concern regarding the practicality of a repeated cleaning process, at the heart of which lies the manufacturer's instruction for cleaning and sterilization. The objective of this study was to evaluate the nonmicrobial contaminants prevalent on the pedicle screws used for spine surgery and the underlying practice cause behind the source.

Methods: The study design consisted of two components: (1) evaluation of pedicle screws for presence of residual nonmicrobial contaminants and (2) comparison of manufacturer prescribed guideline versus actual practice of the steps and time required. The first component comprised a randomized selection of six pedicle screws and its assessment using optical microscopy, scanning electron microscopy with energy dispersive spectroscopy, and Fourier transform infrared spectroscopy. The second component involved a detailed review of implant reprocessing guidelines and its applicability.

Results: Three types of contaminants were identified: corrosion, saccharide of unknown origin, and soap residue mixed with and were mostly present at the interfaces with low permeability. In addition, the data from tabulation of manufacturer's guideline identified at least 19 disjoint steps and a minimum of 19 man-hours required for reprocessing, whereas the real-time observation revealed the reprocessing time of 1 hour 17 minutes.

Conclusions: An interesting observation is that while we are seeing innovations across healthcare, the processes associated with reprocessing implants has stayed unaltered. Our results showed corrosion, carbohydrate, fat, and soap on reprocessed pedicle screw implants obtained from reprocessed implant sets in active clinical use. These results indicate the cleanliness profile of reprocessed devices both during reprocessing and prior to sterilization. At par with this, are the deficiencies in cleaning and inspection methodology prescribed by the manufacturers for cleaning these single-use devices.

PS-FP-7-26

All-Posterior Approach in Surgical Management of Thoracolumbar Tuberculosis: A Prospective Randomized Study Comparing Posterior-Only Stabilization versus Global Reconstruction

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Purpose: Although no doubts exist regarding the surgical indications for spinal tuberculosis, uncertainty still persists in deciding between posterior-only stabilization or global reconstruction in thoracolumbar disease. We performed a prospective randomized study comparing these two techniques and evaluated their safety and efficacy in terms of clinic-radiological outcome parameters.

Methods: 58 patients with preliminary diagnosis of spinal tuberculosis affecting thoracic and lumbar spine were randomly allocated into two groups: group A (n=29): posterior-only stabilization; group B (n=29): global reconstruction (posterior stabilization+anterior reconstruction through a single stage all-posterior approach). Patient demographic data, clinical and operative details, complications, and duration of hospital stay were recorded. Radiological measurements included preoperative vertebral bone loss, Cobb's angle, kyphosis correction, loss of correction, angle loss rate, and fusion time. Functional outcome measurements included Visual Analog Scale and Oswestry Disability Index (ODI) scoring preoperatively and at final follow-up. Neurological assessment was performed using American Spinal Cord Injury Association impairment scale. Minimal follow-up period was 2 years.

Results: Group A had shorter surgical duration and better

ODI score ($p < 0.05$). Kyphosis correction was comparable between two groups ($p > 0.05$). Loss of correction and angle loss rate were higher in group A, though not statistically significant ($p > 0.05$). All achieved bony fusion with no significant difference. Functional and neurological outcomes showed improvement in both groups. Subgroup analysis showed no significant difference between autograft and metallic cage used for anterior reconstruction in group B.

Conclusions: Posterior-only stabilization and global reconstruction are equally effective in surgical management of thoracolumbar tuberculosis, though global reconstruction may result in better maintenance of kyphosis correction.

PS-FP-7-27

Development of Tuberculosis Spine Instability Score (TSIS): An Evidence-Based and Expert Consensus-Based Content Validation Study Among Spine Surgeons

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Purpose: Over the years, a number of authors have used different definitions of instability in tuberculosis (TB) spine. However, no clear consensus exists to define instability in TB spine. Currently, diagnosis of instability is primarily experience-based which may lead to considerable variability and misdiagnosis in the hands of a relatively in-experienced spine surgeon. Considering the potential complications this entity entails, a universally accepted scoring criteria is very important for accurate and uniform diagnosis of instability in TB spine. Questions: (1) What are the factors predicting instability in TB spine? (2) To develop a novel scoring system for diagnosing instability in tuberculosis (TB) spine using evidence from pre-existing literature followed by an expert-panel consensus for validating the content.

Methods: The development of TB spine instability score (TSIS) followed a two-step process: one designing the instrument and the other obtaining judgmental evidence. The instrument design included domain specification, item identification and allotment and finally instrument construction. For the second part of judgmental evidence a panel of experts was appointed to make appropriate modifications and

content validation for finalizing the scoring instrument.

Results: The comprehensive scoring criteria to diagnose instability in TB spine was approved after three rounds of expert panel discussions and comprised of age, location of the lesion, pain, degree of kyphosis, vertebral body loss, involvement of posterior spinal elements, multifocal contiguous disease, and presence of intervertebral or paraspinal abscess. All the factors were found to have index of content validation more than 0.75 after final round of panel discussion. The scores for each item and category specification were based on the findings of systematic review further refined by expert-panel.

Conclusions: TSIS is a comprehensive scoring system integrating demographic, anatomical, clinical and radiological factors aimed at diagnosing instability in TB spine. The classification determines indications for surgical stabilization in patients with TB spine, especially with no or little neurological deficit. However, it also aids surgical decision making when used in context with other key elements such as neurological deficit, patient health factors and osteoporosis.

PS-FP-8-1

The Characteristics of the Young Patients with Cervical Ossification of the Posterior Longitudinal Ligament of the Spine: A Multicenter Cross-Sectional Study

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Purpose: Ossification of the posterior longitudinal liga-

ment of the spine (OPLL) is characterized by heterotopic bone formation in the posterior longitudinal ligament of the spine. Although the patients with OPLL are more common in the 60s and 70s, we know that there are markedly young patients (e.g., early 40s). However, to the best of our knowledge, there is few reports characterize young patients with cervical OPLL in terms of the imaging features, subjective symptoms, and activities of daily living (ADL) problems. The aim of the present study is to characterize young patients with cervical OPLL in terms of the imaging features, subjective symptoms, and ADL problems.

Methods: This is the multicenter cross-sectional study. Two hundred and thirty-seven Japanese symptomatic patients with cervical OPLL confirmed by standard X-rays collected from 16 institutions belonging to the Japanese Multicenter Research Organization for Ossification of the Spinal Ligament formed by the Japanese Ministry of Health, Labor and Welfare were recruited. Whole spine computed tomography data as well as demographic data such as age, gender, patients-based evaluations, and the 36-item Short Form Health Survey (SF-36) were evaluated.

Results: Young group (≤ 45 years old) consisted of 23 patients (eight females and 15 males), accounting for 9.7% of the total. Their characteristics were high body mass index (BMI), significant involvement of trauma in the onset and deterioration of symptoms, and the predominance of thoracic OPLL. The patient-based evaluations did not show a significant difference between the young and non-young groups, or between the genders in the young group except for bodily pain (BP) of SF-36. Female patients in young group had significantly low BP score of SF-36 than that of male in young group.

Conclusions: Characteristics of young patients with cervical OPLL were high BMI, significant involvement of trauma in the onset and deterioration of symptoms, lower BP score of SF-36 in female, and the predominance of thoracic OPLL.

PS-FP-8-2

Reduction and Fusion of Thoracic Ossification of the Posterior Longitudinal Ligament after Posterior Decompression with Instrumented Fixation by Pedicle Screw Insertion into All Ossified Vertebrae

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Purpose: To investigate the reduction and fusion in pre-operative discontinuous ossification of the posterior longitudinal ligament (OPLL) after posterior decompression with instrumented fixation by pedicle screw insertion into all ossified vertebrae in patients with thoracic OPLL (T-OPLL).

Methods: Twenty-three patients with T-OPLL who underwent posterior decompression with instrumented fixation by pedicle screw insertion into all ossified vertebrae were analyzed based on sagittal multi-planner reconstruction-computed tomography (MPR-CT) images obtained just before surgery and at a follow-up examination. Pedicle screws were inserted in all vertebral bodies within the range of ossification. Screw insertion was carried out prior to decompression and temporary rod fixation was constantly conducted on one side at the time of the decompression procedure. Changes in the thickness of the OPLL were investigated using sagittal MPR-CT images obtained just before surgery and at a follow-up examination. It was also investigated whether or not bone fusion of OPLL was obtained in the preoperative discontinuous OPLL at the time of follow-up.

Results: Bone fusion of the OPLL was observed in all cases. The thickness of the OPLL showed an average reduction of 1.14 mm. The average reduction rate of the OPLL was 15.0%. There was a significant correlation between the reduction in thickness of the OPLL and the pre-operative thickness of the OPLL. The results indicate that the OPLL can be expected to be reduced by approximately 15% of the pre-operative thickness of the OPLL.

Conclusions: Pedicle screw fixation into all ossified vertebrae reduced the thickness of ossification by approximately 15% in comparison to the thickness of ossification

prior to surgery and resulted in bone fusion at the discontinuous ossification in 100% of all cases. Strong fixation using a pedicle screw system not only rapidly improved the dynamic factors but also gradually improved the static compression factors of the affected spinal cord.

PS-FP-8-3

Does Diabetes Affect the Surgical Outcomes in Cases with Cervical Ossification of the Posterior Longitudinal Ligament? A Multicenter Study from Asia Pacific Spine Study Group

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Purpose: It is well known that morbidity rate of diabetes mellitus (DM) is higher in the patients with ossification of the posterior longitudinal ligament (OPLL). Because the DM inflicts adverse effect on the microvascular and nervous system, a concern remains about the relation of this metabolic pathology with surgical outcomes for the cervical OPLL. The purpose of this study is to evaluate the surgical outcomes of cervical OPLL in patients who had DM.

Methods: This retrospective study included 253 patients with clinically and radiographically confirmed cervical OPLL who were treated at four institutions in three countries (China, Korea, and Japan) between 2010 and 2016. All patients were followed for at least 2 years. Demographic, imaging, and surgical information were collected, and patients were evaluated using cervical Japanese Orthopaedic Association (JOA) scores and the Visual Analog Scale (VAS) for the neck.

Results: Forty-seven patients had the DM and showed higher prevalence of hypertension ($p=0.01$) and cardiovascular diseases ($p<0.01$). Although they presented worse preoperative JOA scores compared to non-DM patients

(10.5 ± 3.1 vs. 11.8 ± 3.2 , $p=0.01$), comparable neurologic recovery was achieved in the DM group at final follow-up regardless of preoperative hemoglobin A1c levels (13.9 ± 2.9 vs. 14.2 ± 2.6 , $p=0.41$). There was no significant difference in the result of VAS at pre- and post-surgery. Regarding perioperative complications, however, the cases with DM presented higher frequency of C5 palsy (14.9% vs. 5.8%, $p=0.04$). Similar trend was observed when surgical procedure was limited to laminoplasty.

Conclusions: This is the first multicenter Asian study to evaluate the impact of DM on cervical OPLL patients. Even in the DM cases, surgical results were favorable regardless of preoperative hemoglobin A1c levels or operative procedures. However, caution is warranted for the occurrence of C5 palsy after surgery in the DM patients.

PS-FP-8-5

Comparison of Decompression Alone and Decompression Plus Fusion for Thoracic Myelopathy Due to Ossification of the Ligamentum Flavum

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Purpose: The aim of this study was to clarify the clinical outcomes in patients undergoing decompression alone versus decompression with fusion for ossification of the ligamentum flavum (OLF) of the thoracic vertebrae.

Methods: Thirty-seven patients who underwent surgical treatment for thoracic myelopathy between 2010 and 2015 at multiple centers were included in this analysis. Surgical treatment included either decompression or a decompression plus fusion procedure. We investigated the patients' characteristics and pre- and postoperative thoracic myelopathy using the Japanese Orthopaedic Association (JOA) score. Differences in these factors between decompression and decompression plus fusion were examined.

Results: Decompression alone was performed in 18 cases (48.6%), and decompression plus fusion was performed in 19 cases (51.4%). The decompression plus fusion group showed greater blood loss and a longer operative time

than the decompression group. Decompression plus fusion was significantly more frequently performed in patients with thoracic OLF combined with ossification of the posterior longitudinal ligament (OPLL). The preoperative JOA score was lower and JOA recovery rate at final follow-up was significantly higher in cases treated with decompression plus fusion. There were no significant differences between the two groups in the rate of intraoperative complications and reoperation, number of OLF levels, preoperative duration of symptoms, and final JOA score.

Conclusions: Decompression plus fusion was performed more often for OLF patients with severe thoracic myelopathy and OPLL. However, since surgical invasiveness is greater with decompression plus fusion, selection of the surgical procedure should be carefully considered in individual cases.

PS-FP-8-7

Factors Having Significant Relationship with Postoperative Neck Pain Deterioration for Cervical Ossification of the Posterior Longitudinal Ligament: Prospective Registry Study

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Purpose: Postoperative neck pain had been reported as one of the problematic postoperative complications of surgery for cervical ossification of the posterior longitudinal ligament (OPLL). The aim of the present study was to elucidate factors having significant correlation with postoperative deterioration of neck pain in cervical OPLL.

Methods: The present registry included 478 patients who underwent cervical spine surgery for myelopathy caused by cervical OPLL. We excluded the patients who lacks preoperative neck pain evaluation. Thus, we included 438 cervical OPLL patients. Neck pain was evaluated with Visual Analog Scale (VAS, 0–100 mm) preoperatively, 6 months, and 2 years after surgery. Postoperative neck pain deterioration was defined as 20 mm or more increase of VAS neck pain. Patient factors including age at surgery, sex, body mass index, disease duration, and diabetes mellitus were collected. Neurological status was assessed with Japanese Orthopedic Association score for evaluating cervical myelopathy. Imaging factors were analyzed as followings: types of OPLL, canal narrowing rate, postoperative change of C2–7 angle, change of C2–7 range of motion, and spinal cord signal intensity change in magnetic resonance imaging T2 weighted image. Surgical factors including surgical procedures (laminoplasty, posterior decompression with instrumented fusion [PDF], anterior decompression and fusion [ADF] and anteroposterior decompression and fusion [A-P]) and number of levels fused were evaluated. We analyzed the influence of above-mentioned factors on postoperative neck pain deterioration.

Results: Six months after surgery, 51 cases (11.6 %) showed postoperative neck pain deterioration, whereas remaining 437 cases (88.4%) showed no deterioration and

76 cases (17.4 %) showed postoperative neck pain deterioration 2 years after surgery. Amongst fifty cases showing postoperative neck pain deterioration 6 months after surgery, 23 cases showed attenuation of neck pain and remaining 27 cases showed no recovery of neck pain. Thus, neck pain deterioration in 49 out of 76 cases occurred from 6 months to 2 years after surgery. Six months after surgery, the rate of neck pain deterioration in laminoplasty and PDF groups was significantly higher than that in ADF and A-P groups. Two years after surgery, levels fused was significantly correlated with neck pain deterioration.

Conclusions: Posterior approach significantly associated with neck pain deterioration 6 months after surgery and number of levels fused significantly associated with neck pain deterioration 2 years after surgery.

PS-FP-8-8

Characteristics of Ossification of the Ligamentum Flavum of the Thoracic Spine

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Purpose: The pathophysiology of thoracic ossification of the ligamentum flavum is not well understood and is often overlooked. Especially at the lower thoracic spine level, it is often difficult to distinguish from lumbar spinal disease. Therefore, we investigated the symptoms of ossification of the ligamentum flavum (OYL) at the lower thoracic spine level, which was surgically treated at our hospital.

Methods: The subjects were 21 patients (12 males, nine females; average age, 73 years) treated from 2020 to 2021. All patients underwent posterior decompression and fixation. The rate the previous doctor was able to diagnose as thoracic OYL accurately and the symptoms and physical examination of OYL were evaluated.

Results: The rate the previous doctor was able to diagnose as thoracic OYL were 33%. The subjective symptoms were low back pain in 24%, leg pain in 48%, numbness in the lower limbs in 67%, and unsteady on the legs in 48%. In addition, 43% of cases had worsening symptoms due to supine position or lumbar extension. Neurological findings were hyperactive deep tendon reflexes of lower limb in 57%, Romberg sign in 33%, and heel knee test in 48%.

Conclusions: A lot of cases of thoracic OYL were not able to be diagnosed accurately. Hyperactive tendon reflexes in the lower limbs were seen in only about half. In some cases, lower limb symptoms worsen when the lower back is extended, which is mistaken for lumbar spine disease. In fact, there is a tendency to overlook thoracic OYL when the patient had lumbar spinal stenosis. Because ossification compresses the spinal cord from posterior, it is also characterized by the tendency for posterior cord syndrome to occur.

PS-FP-9-3

Posterior Spinal Fusion with Pedicle Screws for Atlantoaxial Instability in Children

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Purpose: Surgical treatment of atlantoaxial instability (AAI) in children is still a challenge due to tiny vertebrae and the high complication rate which has been reported since several decades ago. However, surgical technique, perioperative management, spinal implant, and perioperative radiographic evaluations have made remarkable progress. The purpose of this study is to report complications of posterior fusion for AAI in children and to evaluate the screw placement accuracy.

Methods: A total of 31 pediatric patients underwent primary posterior fusion for AAI from January 2004 to December 2017 (18 boys, 13 girls; mean age, 7.4 years) and were followed for an average of 7.4 years. The pathology included 18 Down syndrome, three skeletal dysplasia, and one Coffin-Siris syndrome. Nine cases were idiopathic and all the cases had os odontoideum. C1–C2 or C1–C3 fusions were performed in 22 patients and occipito-cervical fusions in nine patients. We analyzed their past history, operating time, estimated blood loss (EBL), and perioperative and intraoperative complications. Postoperative computed tomography was used to assess screw accuracy using the established Neo classification (grade 0: no perforation, grade 1: perforation <2 mm, grade 2: perforation ≥2 and <4 mm, grade 3: perforation ≥4 mm).

Results: Seventeen patients had histories of cardiovascular diseases, but their cardiac functions were evaluated to tolerate general anesthesia. The mean operating time was

260.7±71.2 minutes and the mean EBL was 144.2±122.7 mL. Complications related to the operation occurred in eight patients (25.8%). They included one hydrocephalus due to dural tear, one bone graft donor site deep infection, two temporary neurological deficit which were fully recovered, one superficial infection, and four implant loosening. Patients underwent 108 screw fixations (43 C1 lateral mass screws, 50 C2 pedicle screws, seven C3 pedicle screws, and eight C2 laminar screws). A total of 34 (79.1%) of the 43 C1 lateral mass screw placements were categorized as grade 0, 7 (16.3%) were grade 1, 1 (2.3%) was grade 2, and 1 (2.3%) was grade 3. A total of 44 (77.2%) of the 57 pedicle screw placements were categorized as grade 0, 11 (19.3%) were grade 1, 0 were grade 2, and 2 (3.5%) were grade 3.

Conclusions: The complication rate of upper-cervical fusion in children was still high. However, the placement of screws was almost accurate and safe even for tiny vertebrae and bone pathology. There seemed to be no reason to avoid surgical intervention to upper-cervical instability in children.

PS-FP-9-4

Biologic Agents Preserve the C-2 Pedicle in Patients with Rheumatoid Arthritis: A Comparative Imaging Study Using Three-Dimensional Computed Tomography

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Purpose: To investigate whether biologic agents (BAs) reduce a narrow C-2 pedicle screw (PS) trajectory, which is often a key stabilizer in surgical treatment, in patients with rheumatoid arthritis (RA).

Methods: A total of 100 RA patients treated with and without BAs (BA [+] group [n=50] and BA [-] group [n=50]), respectively, were included in the present study. Computed tomography (CT) images of their cervical spine, including C-2, were analyzed. The maximum screw diameter (MSD) at C-2 that could be inserted without breaching the cortex, measured on three-dimensional images using a CT-based navigation system, was compared between the groups

with and without BA administration. Furthermore, the destruction of the atlantoaxial joint was examined using CT images. The risk factors for a narrow C-2 pedicle were elucidated among the patients treated with BAs.

Results: The pedicle in the BA (+) group had a significantly larger C-2 MSD than the BA (-) group (6.00 mm vs. 5.13 mm, $p<0.001$), with less destruction of the atlantoaxial joint. Among the BA (+) group, a longer period until the initial administration of BAs and RA disease duration were associated with a narrow C-2 pedicle.

Conclusions: This study suggests that BAs can maintain the trajectory for C-2 PS, which acts as a key stabilizer in surgical management for rheumatoid cervical spine, by halting the destruction of the atlantoaxial joint. Early introduction of BAs can be especially important to prevent the narrowing of the C-2 pedicle.

PS-FP-9-5

Non-traumatic Atlantoaxial Rotatory Fixation in an Adult Patient Treated by a Closed Reduction under General Anesthesia in Chronic Phase

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Purpose: Atlantoaxial rotatory fixation (AARF) is a common condition in the pediatric population. The majority of acute AARF cases in the pediatric population can be treated by non-surgical treatment. In contrast, AARF is an extremely rare condition in the adult population. The therapeutic management for adult AARF is controversial, and there have been no reports of non-traumatic AARF in adult patients. We experienced the case of non-traumatic and chronic AARF in an adult patient treated by a closed reduction under general anesthesia.

Methods: A 42-year-old female suffered from a severe neck pain and irreducible cervical rotation after waking up. She visited a previous hospital 18 days after onset and was admitted for 3 weeks to undergo Glisson's head halter traction. However, no improvement was observed, and the

patient was subsequently referred to our hospital 2 months after onset. She exhibited a typical cock-robin position. Her neck remained in a fixed rotated position to the left, and her neck movement to the right side was severely restricted. She denied any history of trauma, infectious diseases, psychiatric diseases, or surgeries related to her cervical spine. The cervical radiographs and computed tomography (CT) scans revealed torticollis to the right and C1 rotation with normal atlantodental interval. There were no obvious fractures, ligament injury, or any other inflammatory findings in CT scans and magnetic resonance imaging. There was no C2 facet deformity or C1–C2 bony union on three-dimensional CT images in the plane position. According to her radiographs and CT scans, a diagnosis of Fielding classification type I, Pang's classification type 2, and Ishii's grade I AARF was confirmed.

Results: She eventually underwent closed reduction under general anesthesia. The operator held her mandible with his thumbs and her neck with his other fingers, provided careful traction in the cephalic direction, and rotated her neck gradually to the right while palpating for crepitus. Her neck was fully rotated to the right after 10 minutes of manipulation, and the reduction was confirmed by fluoroscopy. Immediately after waking up from general anesthesia, her neck pain and irreducible cervical rotation dramatically improved without any complications such as neurological deficit or fractures. Two years after closed reduction, she had no neck pain or recurrence of limited cervical rotation.

Conclusions: A closed reduction under general anesthesia for non-traumatic AARF in adult patients might be an effective treatment option, even for chronic cases or intractable cases by traction treatment.

PS-FP-10-1

The Ipsilateral Epiphyseal and Central Endplate Hounsfield Units Accurately Predicts Intraoperative Endplate Violation and Delayed Cage Subsidence with Oblique Lateral Interbody Fusion

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Purpose: There are favorable results with oblique lateral interbody fusion (OLIF) to achieve indirect decompression. Some of the most dreaded complications include intraoperative endplate violations and delayed cage subsidence. The endplate plays an important role in distributing compressive load across a functional spinal unit. The Hounsfield units (HUs) can provide detailed information regarding bone quality across endplates at surgical levels. We aimed to investigate the risk factors for intraoperative endplate violations and delayed cage subsidence after OLIF surgery.

Methods: A total of 61 consecutive patients (mean age, 65.1±9.5 years; 107 segments) who underwent OLIF with or without posterior instrumentation from May 2015 to April 2019 were studied. Intraoperative endplate violation was defined as more than 2 mm collapse of the cage into the endplate of the adjacent vertebral body on sagittal reconstructed computed tomography images immediate postoperatively. Delayed cage subsidence was evaluated using lateral radiographs and defined as more than 2 mm migration of the cage into the adjacent vertebral endplate at 1-month follow-up or later. As potential contributors, bone mineral density, number of surgical levels, preoperative and postoperative disc height and Hounsfield units (HUs) at different regions of the endplate were obtained along with other demographic factors.

Results: Total postoperative cage subsidence was identified in 45 surgical levels (42.0%) in 26 patients (42.6%) up till postoperative 1-year follow-up. These consisted of 25 intraoperative endplate violation segments (23.4%) and 20 levels (18.7%) with delayed cage subsidence. Low HU value at the ipsilateral epiphyseal ring was an independent

risk factor for intraoperative endplate violation ($p=0.01$) with a cut-off value of 326.21 HUs (sensitivity 79.0%, specificity 77.3%). Low HU values at the central endplate had a significant correlation with delayed cage subsidence in stand-alone cases ($p=0.01$) with a cut-off value of 296.42 HUs (sensitivity 76.9%, specificity 76.6%).

Conclusions: HUs of the endplate are good predictors for intraoperative endplate violation and cage subsidence since they can represent the regional bone quality of the endplate in contact with the implant. These are important parameters for consideration preoperatively to plan for cage sizes and posterior instrumentation.

PS-FP-10-3

A New Full Endoscopy System and Intradiscal Irrigator Combined with a Novel Annular Repair Device for the Treatment of Lumbar Disc Herniation

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Purpose: The aim of this study was to determine the technical feasibility, clinical safety, and efficacies of a new transforaminal approach endoscopic system for the treatment of lumbar disc herniation. The new serial therapeutic system includes a novel endoscopy system, an intradiscal irrigator, and a full endoscopic annular repairment device.

Methods: From October 2017 to June 2019, we enrolled 16 patients 21 to 46 years of age, with imaging confirmation of single-level disk herniation between L3 and L5 (L3/L4 level, three cases; L4/L5 level, eight cases; L5/S1 level, five cases) with disk height ≥ 5 mm, and who failed ≥ 6

weeks of nonsurgical treatment. Magnetic resonance imaging with T1- and T2-weighted axial and sagittal images, multiplanar computed tomography, and flexion/extension X-rays were performed. All patients had lumbar radiculopathy with positive straight leg raise or femoral stretch test. All patients underwent transforaminal approach endoscopic discectomy use the novel endoscopic system, after discectomy we used the novel irrigator inserted into the tears of annulus fibrosus for intradiscal irrigation, then we used a novel full endoscopic annular repairment device close the annular defects which was an automatic stitching and tying device. The Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) were observed before operation and at 1 day, 1 month, 6 months, and last follow-up after the operation.

Results: The procedure was successfully performed in all cases. Average operation time was 95 minutes. Average blood loss was 15.3 ± 3.8 mL. At last follow-up (9.6 ± 1.7 months), all patients experienced a minimally clinically important improvement of their VAS for ipsilateral leg pain, which improved from 7.3 ± 0.2 preoperatively to 1.8 ± 0.3 postoperatively ($p=0.001$). The ODI improved from 52 ± 3.8 preoperatively to 20.1 ± 4.4 at last follow-up ($p=0.001$). There was no postoperative complication and recurrence of disc herniation.

Conclusions: Early results showed the use of the new transforaminal approach endoscopic irrigation and annular repairment system for the treatment of lumbar disc herniation are beneficial for short term outcomes demonstrating reduction in symptomatic disc reherniation with low postoperative complication rates. Long-term studies are required to further investigate the efficacy of such devices.

PS-FP-10-4

A Novel Annular Repair Technique Combined with Platelet-Rich Plasma Intradiscal Injection: A New Serial Therapeutic Model for the Treatment of Lumbar Disc Herniation

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Purpose: This study aims to evaluate the clinical safety and efficacies of a novel microdiscectomy annular repairment technique combined with autologous platelet-rich plasma (A-PRP) intradiscal injection for the treatment of lumbar disc herniation.

Methods: From July 2017 to December 2018, this study recruited 15 patients with lumbar disc herniation (L4/5, four cases; L5/S1, 11 cases) who underwent tubular microdiscectomy and used a novel annulus fibrosus repairment device close the annular defects which was an automatic stitching and tying device. The patients underwent A-PRP 2.1±0.2 mL intradiscal injection 1 week, 1 month, and 2 month after microdiscectomy annular repair surgery. The pre- and postoperative neurological function and pain status were evaluated by the Visual Analog Scale (VAS) score and the Oswestry Disability Index (ODI). The assessment also data including operation time, the quantity of bleeding, and intraoperative and postoperative complications were recorded. Patients were followed up at intervals of preoperative, postoperative 1 week, 1 months, 3 months, and last follow-up.

Results: The procedure was successfully performed in all cases. No case required conversion to an open procedure. The mean age of patients was 36.6 years. Average operation time was 85 minutes, Average blood loss was 35.3±6.2mL. The preoperative symptoms were alleviated

significantly after surgery. All the standardized measures improved significantly. At the last follow-up, including VAS score (7.9±1.2 to 1.1±0.5, $p<0.001$) and ODI (75.3 to 9.6, $p<0.001$). There was no postoperative complication and recurrence of disc herniation.

Conclusions: Early results showed the use of the novel annular fibrosus repairment technique and PRP intradiscal injection are beneficial for short-term outcomes demonstrating reduction in symptomatic disc reherniation with low postoperative complication rates. Long-term studies are required to further investigate the efficacy of such devices. Direct mechanical annular repair and A-PRP biological therapy may promote degenerative intervertebral disc regeneration and remodeling after minimally invasive spine surgical discectomy.

PS-FP-10-5

Overcorrection of Fractured Vertebrae Increases the Incidence of Adjacent Fractures After Balloon Kyphoplasty: A Retrospective Study

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Purpose: There are reports that the restoration height of fractured vertebrae relates to the incidence of adjacent fractures when kyphoplasty is performed. However, the possible correction amount may be influenced by the instability of the fractured vertebra. Consideration of the relationship between vertebral instability and the degree of correction is necessary to investigate whether the correction amount by kyphoplasty contributes to the incidence of adjacent fractures. This study aimed to investigate whether the correction amount by kyphoplasty is associated with the incidence of adjacent vertebral fractures.

Methods: Data from 61 patients without and 25 patients with adjacent vertebral fractures at 6 months after balloon kyphoplasty (BKP) were retrospectively analyzed. We compared age, sex, body mass index, site of the fracture, existence of past vertebral fracture, kyphosis angle of the fractured vertebra, fractured vertebral instability, corrected angle, corrected height, cement amount, and

cement leakage between the groups. A linear regression model was used to determine the relationship between vertebral instability and corrected angle or height and to divide patients into the overcorrection and undercorrection groups. The patients above the regression line with 95% confidence interval were determined as having an overcorrection while those under were determined to be undercorrected. The incidence rate of adjacent fractures was compared between these two groups.

Results: Fractured vertebral instability and corrected amount were detected as risk factors for adjacent fractures ($p < 0.01$). The corrected angle and height correlated with fractured vertebral instability, $\rho = 0.6447$ and 0.4909 , respectively. Vertebral fractures overcorrected for instability led to a higher incidence rate of adjacent fractures (42.4% [14/33] and 46.9% [15/32] with overcorrection vs. 10.7% [3/28] and 13.3% [4/30] with undercorrection for angle and height, respectively; $p < 0.01$).

Conclusions: Overcorrection of fractured vertebrae may associate with the increased incidence of adjacent fractures when BKP is performed.

PS-FP-10-6

Pros and Cons of Full Endoscopic Surgery for Cervical Radiculopathy

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Purpose: Although posterior surgery for cervical radiculopathy has been widely used, there is scarce amount of knowledge about pros and cons of surgery with endoscope with rigid working channel. Results of posterior surgery for cervical radiculopathy using full endoscopic discectomy (FED) were retrospectively reviewed. Technical issues and pitfalls of this surgery were also discussed.

Methods: Seven patients that underwent posterior decompression surgery using FED systems have completed 12-month follow-up. All of the patients were suffered from radiculopathy due to cervical disc herniation.

Results: Mean surgical time was 97 minutes and bleeding were minimum in all cases. There were no intraoperative incidents. Average radiculopathy score of the patients before surgery was 10.8, which was improved to 17.5 at

3 months and was 18.0 at 1 year. Surgery using FED devices, which have working port inside has substantial benefit to reduce soft tissue damage owing to their reduced size compared to other optic devices. On the other hand, surgical instruments that can be used with the devices have limitation in their size because they have to be able to pass through working port, and also have limitation in their motion axis, that is reciprocal and rotatory manner. Maximal precaution is necessary for not being lost in orientation. Severe degenerative change makes it more difficult to correctly locate neural tissue and surrounding compression factors. Closer viewing point obtained by deeper placement of scope to the neural structures makes it possible not only to observe them more clearly, but also give some possibility to reduce amount of bone resection in order to viewing target tissue. This feature also makes procedures safer and more comfortable when surgeons once have got used to. To appreciate this advantage, precise orientation and strict bleeding control are mandatory. Perfusion used in FED surgery makes it possible to release vessels from other surrounding tissues by hydrostatic pressure, thus make it easier to control bleeding from epidural vessels. Debris and fat tissue floating in perfusion liquid will be obstacles in the field and should be properly managed.

Conclusions: Deep and closer eye point is a substantial advantage in FED surgery. On the other hand, migration of the scope into spinal canal should be carefully avoided to prevent neurologic complications. Although the small diameter of the devices give substantial benefit to FED surgery, this feature can result in a higher possibility of wrong level surgery and this risk should also be considered.

PS-FP-10-7

Functional Outcomes of Loupe Assisted Discectomy in Patients with Lumbar Disc Herniation

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Purpose: To evaluate the efficacy of loupe-assisted discectomy in patients with lumbar disc herniation.

Methods: It is a retrospective observational study. A sample

of 61 consecutive patients was taken who were operated in a major tertiary care hospital of Lahore. The study took data from patients of herniated lumbar disc who were between the ages of 18–80 years and were operated by the same surgeon over the period of 1 year. Patients with spinal canal stenosis, previous history of lumbar disc surgery and patients with multilevel disc herniation were excluded from the study. A purpose-built questionnaire was used to record demographic and clinical data. Preoperative pain score by the pain Visual Analog Scale (VAS) and functional outcomes by the MMC were assessed upon enrollment in the study. The postoperative pain score by the pain VAS and functional outcomes by the MMC were assessed at 6-month follow-up. Data was entered and analyzed by using IBM SPSS ver. 22.0 (IBM Corp., Armonk, NY, USA).

Results: A total of 39 out of 61 patients were females while 22 were males. L4–L5 was the most common level of surgery and 42 (68.8%) patients had surgery of this level. The number of patients having surgeries of L3–L4, L2–L3, and L1–L2 were 11 (18%), 6 (9.8%), and 2 (3.2%), respectively. A total of 58 patients (95%) reported no pain or restriction of mobility at 6-month follow-up and hence, fell in “excellent” category of the MMC. Only 3 (5%) patients reported occasional non-radicular pain and fell in “good” category of the MMC. None of the subjects were still handicapped or reported continued objective symptoms of root involvement after the surgery.

Conclusions: The long-term results of loupe assisted lumbar discectomy are substantial and almost all the patients in the study got back to their normal routine of physical activities. So, Loupe assisted discectomy is safe and comparable with endoscopic discectomy and other minimally invasive modalities of discectomy.

PS-FP-10-8

Indirect Neural Decompression by Transforaminal Lumbar Interbody Fusion Using Minimally Invasive Spine Surgery for Lumbar Degenerative Spondylolisthesis: Comparison with Lateral Lumbar Interbody Fusion

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Purpose: To compare indirect neural decompression (IDD) effect by transforaminal lumbar interbody fusion using minimally invasive spine surgery (MIS-TLIF) with that by lateral lumbar interbody fusion (LLIF) for lumbar degenerative spondylolisthesis (LDS).

Methods: Thirty-three patients with LDS at L4/5 level (mean age, 64.1 years) who underwent MIS-TLIF (15 patients) or LLIF (18 patients) were included in this study. We analyzed operation time (OT), intraoperative blood loss (BL), changes in local intervertebral angle (IVA), slip rate (SR), intervertebral disc height (DH), and changes in the L4/5 canal area on magnetic resonance imaging scans (between preoperative and 1 week postoperatively).

Results: The mean OT/BL in the two procedures were equivalent (MIS-TLIF: 150 minutes/47 g, LLIF: 160 minutes/32 g). Regarding the IVA, SR, and DH, there was no significant difference between two procedures; similarly, the L4/5 canal area were also equivalent (MIS-TLIF: 51.5 to 96.3 mm², LLIF: 65.2 to 94.3 mm²).

Discussion: There have been many reports showing good IDD by LLIF. However, in consideration of the potential risk of critical organ damage, the LLIF should be adopted with care especially for the L4/5 level lesions. Our MIS-TLIF can be also have good IDD effect, and therefore, this procedure should be considered as an option for treating LDS.

PS-FP-10-9

Transforaminal Full-Endoscopic Discectomy for the Patients with Down-Migrated Lumbar Disc Herniation under Local Anesthesia

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Purpose: The application of transforaminal full-endoscopic discectomy (TELD) for down-migrated lumbar disc herniation (DM-LDH) is difficult because of interference with surrounding anatomical bony structures. Therefore, in general, interlaminar full-endoscopic discectomy is conducted.

Methods: Between January 2014 and March 2020, among 203 patients who underwent TELD in our institution, 169 patients who have excluded the cases of recurred LDH, lateral-type LDH, and multiply operated back were included in this study. All patients underwent TELD under local anesthesia. The definition of DM-LDH was that the top of LDH was below the cranial endplate line of the caudal vertebra (E line) on the sagittal magnetic resonance imaging (MRI) T2 weighted image. We retrospectively evaluated preoperative/postoperative MRIs and clinical results. The distance of the tip of DM-LDH below the E-line was measured on preoperative MRIs, and removal of DM-LDH was checked on postoperative MRIs. Clinical results on follow-up visits were evaluated by MacNab's criteria.

Results: Twenty-nine patients (21 males, eight females) had DM-LDH, and their mean age was 39.2 years old. Preoperative MRI showed that the average distance of DM-LDH was 8.1 mm (range, 4.2 to 15.0 mm). On the lateral view of the lumbar radiograph, tips of DM-LDH in six patients were far from the midline of pedicle line (highly DM-LDH). Postoperative MRI revealed that 10 patients achieved complete removal of DM-LDH, 17 cases did the partial reduction of DM-LDH, and two patients remained DM-LDH. Among 29 patients, 16 patients were excellent, 11 patients were good, and two patients were fair on MacNab's criteria.

Conclusion: Present study revealed satisfactory clinical

results on MacNab's criteria for the patients who had DM-LDH and underwent TELD under local anesthesia. There were two patients who were not achieved satisfactory results in TELD. One remained DM-LDH on postoperative MRI, and the other had highly DM-LDH. However, among six patients who had highly DM-LDH, four patients achieved excellent clinical results. Foraminoplasty is the procedure of widening the intervertebral foramen using a high-speed drill which removes the ventral side of the supra-articular process and the cranial side of the pedicle. TELD with foraminoplasty could visualize the lateral part of DM-LDH and help easier resection.

PS-FP-10-10

Transforaminal Full-Endoscopic Ventral Facetectomy: Mid-Term Results and Factors Associated with Fair/Poor Outcome

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Purpose: The aim of this study was to examine the postoperative results of transforaminal full-endoscopic ventral facetectomy (TF-FEVF) for lateral recess stenosis (LRS) and to elucidate the factors associated with poor surgical outcome.

Methods: This study involved 85 patients (47 males) who underwent FEVF for LRS. Mean age was 70.5 years and mean follow-up duration was 14.8 months. Data were collected on sex, age, surgical level, diagnosis, history of spinal surgery at the same level, and duration of follow-up. Diagnosis was categorized as lumbar spinal stenosis with or without disc bulging. Clinical evaluation was performed using the modified MacNab criteria. Magnetic resonance imaging was used to evaluate the degree of disc degeneration, vertebral endplate degeneration, disc height, thickening of the ligamentum flavum, and stenosis. Bony stenosis was evaluated using computed tomography. Using the modified MacNab criteria, we compared all variables between patients with excellent/good outcome (E/G

group) and those with fair/poor outcome (F/P group).

Results: According to the modified MacNab score, the outcome at the final follow-up was excellent in 39 cases, good in 21, fair in 13, and poor in 12. There was no significant difference in sex, age, diagnosis, history of spinal surgery, or duration of follow-up between the 60 cases (70.6%) in the E/G group and the 25 in the F/P group (29.4%). Imaging evaluation revealed statistically significant differences in sagittal angulation (4.3° vs. 8.1° , $p < 0.05$), sagittal translation (0.7 mm vs 1.6 mm, $p < 0.05$), and Cobb angle (-0.5° vs. -1.9° , $p < 0.05$) between the E/G group and the F/P group.

Conclusions: Mid-term results of FEVF surgery were generally favorable. Factors associated with fair/poor outcome of FEVF were large sagittal angulation, large sagittal translation, and concave side.

PS-FP-10-11

Unintentional Facet Fusion without Bone Grafting after Minimally Invasive Lumbar Interbody Fusion: A Retrospective Study of Percutaneous Endoscopic Transforaminal Lumbar Interbody Fusion

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Purpose: We previously developed a percutaneous endoscopic transforaminal lumbar interbody fusion (PETLIF) procedure. During postoperative follow-up, we encountered patients in whom bone fusion occurred between opened facet joints, despite not having bone grafting in the facet joints. In this study, we investigated the frequency and tendencies of facet fusion following PETLIF in comparison with open transforaminal lumbar interbody fusion (TLIF).

Methods: Subjects underwent either single-level PETLIF or open TLIF at our hospital from April 2015 to March 2019. Patients were assessed with lumbar X-ray images and computed tomography (CT) prior to surgery, immediately after surgery, and 1 year after surgery. Comparative statistical analyses of each parameter of patient back-

ground and image findings were conducted between the PETLIF and TLIF groups.

Results: Forty-two patients with PETLIF and 27 patients with open-TLIF were evaluated for facet fusion by CT at 1-year postoperatively. Facet fusion was observed in 26 of 42 post-PETLIF patients (61.9%). The average inter-facet distance increased from 1.3 mm prior to surgery to 4.5 mm after surgery, and facet fusion was observed under the opened conditions of 3.8 mm at 1 year. There were no significant differences in patient background, correction loss of segmental lordosis, or inter-facet distance between the facet fusion and facet non-fusion subgroups. Facet fusion was observed among three patients in the open TLIF group (11.1%), which was significantly lower than in the PETLIF group ($p < 0.01$). There were no significant differences in the rate of interbody bone bridge formation or correction loss of segmental lordosis between the PETLIF and open TLIF group ($p = 0.28$, $p = 0.07$, respectively).

Conclusions: Bone ingrowth and facet fusion was achieved over time within the facet joints that were opened through indirect decompression after PETLIF. To address the mechanism for facet fusion without bone grafting, we hypothesized that the preserved facet joints potentially became the base bed for spontaneous bone fusion due to the preserved facet joint capsule and surrounding soft tissue, which maintained cranio-caudal facet traffic and blood circulation in the facet joints. The complete preservation of the facet joints was considered a key advantage of minimally invasive lumbar interbody fusion procedures.

PS-FP-10-12

The Advantages of Revisional Transforaminal Full-Endoscopic Spine Surgery for Patients Underwent Posterior Spine Surgery

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Purpose: Revisional lumbar spinal surgery by posterior

approach is more challenging than primary surgery due to epidural or perineural scar tissue. It demands to further removal of posterior structure to confirm intact bony landmarks and could cause operation-related instability, so fusion surgery was often selected. However, adjacent segment disease after fusion surgery could be a problem and further exposure of posterior muscles could cause multiple operated back syndrome. To resolve these problems, we have performed transforaminal full-endoscopic spine surgery (TF-FES) for patients underwent posterior lumbar surgery. The purpose of this study is to evaluate clinical outcomes of revisional TF-FES and describe the advantages.

Methods: Forty-eight consecutive patients (60 levels) underwent revisional TF-FES for under local anesthesia. Revisional surgery was defined as the surgery after ipsilateral partial laminectomy in the same intervertebral level and/or lumbar fusion surgery in the adjacent level. Intraoperative blood loss, operation time, and the rate of complication were evaluated. Postoperative clinical outcomes were assessed by modified Macnab criteria outcome and Visual Analog Scale (VAS) for leg pain, back pain, and leg numbness. In addition, we compared the outcome of revisional FES cases and primary FES cases matched for age, sex, level, and procedure of FES.

Results: The mean operation time was 70.5 ± 14.4 minutes (range, 52–106 minutes), and blood loss was unmeasurable. The clinical outcomes were rated as follows: excellent in 16 levels (26.7%), good in 28 levels (46.7%), fair in 10 levels (16.7%), poor in 6 levels (10.0%). The mean preoperative VAS for back pain was 6.0 ± 2.6 , for leg pain was 6.8 ± 2.4 , and for leg numbness was 6.3 ± 2.8 . At the last follow-up, the mean postoperative VAS for back pain was 4.3 ± 2.5 , for leg pain was 3.8 ± 2.6 , and for leg numbness was 4.6 ± 3.2 . VAS score was significantly improved ($p < 0.05$). In addition, no significant difference was observed in the operation time, blood loss, and complication rate between revisional FES and primary FES.

Conclusions: Clinical outcomes of revisional TF-FES for patients with a history of posterior lumbar spine surgery was good. We consider the advantages of revisional TF-FES are avoiding effect of adhesion due to another route and preserving posterior structures. It could provide only decompression without fusion due to avoiding operation-related instability. In addition, it can be performed in an awake and aware state under local anesthesia and direct decompression for foraminal and lateral recess stenosis can be done. TF-FES could be an effective procedure for

patients underwent posterior lumbar spine.

PS-FP-10-13

Risk Assessment of Abdominal and Retroperitoneal Organ Injuries Performing Transforaminal Full-Endoscopic Spine Surgery

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Purpose: Transforaminal full-endoscopic spine surgery (TF-FES) is a minimally invasive procedure for the surgical treatment of lumbar hernia and degenerative disease and has several advantages for the patients. Severe complications such as abdominal and retroperitoneal injuries have never been reported. However, the biggest pitfall of minimally invasive spine surgery is that we cannot visualize the anatomical structures during approaching the affected surgical site. TF-FES has risks of abdominal and retroperitoneal organs injuries due to taking the insertion point outside. The purpose of this study is to investigate organs that could exist in the trajectory of TF-FES.

Methods: We evaluated whether organs (liver, ascending and descending colon, kidney, spleen) and bones (rib, iliac crest) appear in the trajectory of TF-FES using preoperative lumbar spine computed tomography image taken in the prone position. Fifty cases (33 males and 17 females) were evaluated at each L1/2–L5/S1 disc level. The mean age was 52.0 years (range, 17–91 years). We assumed the medial interpedicular line as the cannula installation position. The maximum tilt angle of the trajectory inserted without interfering with organs (liver, ascending and descending colon, kidney, spleen) and bones (rib, iliac crest) was measured.

Results: The organs/bones (number of cases; right/left) interfered with the trajectory when tilted up to 90° were kidney (19/18), rib (21/20), spleen (-/1), and colon (0/1) at L1/2. Similarly, kidney (11/14), rib (1/3), and colon (3/2) at L2/3, kidney (1/1) and colon (6/7) at L3/4, colon

(1/0) and iliac crest (23/20) at L4/5, and iliac crest (50/50) at L5/ S1, respectively. When interfered with any bones/ organs, the mean±standard deviation tilt angle (right/left) was 74.7°±8.6°/74.1°±9.6° at L1/2, 77.8°±9.0°/79.3°±7.7° at L2/3, and 82.8°±7.0°/84.0°±4.2° at L3/4, 70.5°±9.5°/70.0°±7.7° at L4/5, and 50.1°±6.4°/50.4°±7.0° at L5/S1, respectively.

Conclusions: Abdominal and retroperitoneal organs could appear backward than the tangent line of the posterior edge of the disc in the upper lumbar intervertebral disc level. It is risky to approach from far-lateral point horizontally, in particular in the upper lumbar level. It is important to assess the possible risk to avoid the severe complication in FES.

PS-FP-10-14

Is Bipolar Release of Sternocleidomastoid Muscle Necessary for Neglected Congenital Muscular Torticollis?

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Purpose: The majority of congenital muscular torticollis (CMT) resolves spontaneously or improves by non-surgical treatment during infancy. Although surgical releases of the affected sternocleidomastoid muscle (SCM) are required for resistant or neglected CMT, there has been rarely reported in adolescent or adult patients. Here, we assessed surgical outcomes of bipolar and unipolar release of SCM in adolescent or adult patients with neglected CMT.

Methods: Eleven consecutive patients with neglected CMT who underwent surgical release of the affected SCM were enrolled. All patients complained of cosmetic problems and restricted range of motion (ROM) of the cervical spine. Three patients were treated by bipolar release of SCM (B group), and eight patients were treated by unipolar release of SCM (U group). All patients were received physical therapy and early mobilization after sur-

gery. Clinical and radiographic outcomes were compared between the two groups, and Student t-test was used for statistical analysis.

Results: Mean age was 40 years in B group, and 24 years in U group. There was no significant difference between the two groups. Operative time was significantly shorter in U group (60 minutes) compared to B group (41 minutes) ($p<0.01$). There was no significant difference in blood loss between the two groups. Cervicomandibular angle (CMA) significantly improved from 11° to 3° in B group ($p<0.01$), and from 15° to 3° in U group ($p<0.01$) after surgery. The ratios of the difference between preoperative and postoperative angles per preoperative angle of CMA were 75% in both groups, and there was no significant difference between the two groups. C2 sagittal vertical axis improved from 29 to 15 mm in B group ($p=0.20$), and that was significantly improved 33 to 21 mm in U group ($p<0.05$). All patients improved cosmetic problems and cervical ROM. Cheng and Tang's scoring were 17 points in both groups, and there was no significant difference between the two groups. There were no major complications, although one transient neurological deficit of greater auricular nerve was observed in B group.

Conclusions: We found no significant differences of surgical outcomes between bipolar and unipolar release of SCM even in adolescent or adult patients with neglected CMT. Unipolar release of SCM and early mobilization would be a less invasive procedure, reducing surgical scar, a risk of greater auricular nerve damage, and operative time.

PS-FP-10-15

Usefulness and Problems of the Double Endplates Penetrating Screw Technique for Patients with Diffuse Idiopathic Skeletal Hyperostosis

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Purpose: We have developed the single or double end-

plates penetrating screw (SEPS/DEPS) technique which is a novel percutaneous pedicle screw (PPS) insertion technique suitable for vertebral body fracture patients with diffuse idiopathic skeletal hyperostosis (DISH). The purpose of this study is to compare the effectiveness of this SEPS/DEPS technique with the conventional pedicle screw technique.

Methods: The screw is inserted upwards from the outer caudal side of the pedicle toward the inner cranial side. Vertebrae affected with DISH were inserted with screws using the SEPS/DEPS technique, whereas non-fused vertebrae were inserted with screws using the conventional PPS technique. Twenty patients were treated with SEPS/DEPS: 12 with osteoporotic vertebral body fracture, three with pyogenic spondylitis, and one with metastatic spinal tumor. Seven patients were treated with SEPS/DEPS technique only (D group) and 13 patients with a hybrid of both the SEPS/DEPS and the conventional PPS technique (H group). We compared the rates of implant failures and the revision surgery between the D group and the H group.

Results: In the D group, 72 screws were inserted using the SEPS/DEPS techniques. In the H group, 98 screws were inserted with the SEPS/DEPS technique and 78 screws were inserted with the conventional PPS technique. There was no implant failure in the D group; however, in the H group, loosening was observed in 10 out of 78 screws (12.8%) by the conventional PPS technique, in two out of 98 screws (2%) by the SEPS/DEPS technique, with a significant difference ($p=0.005$). In the D group, PLIF was performed in a patient due to adjacent segment disorder after bone fusion. In the H group, balloon kyphoplasty was performed in three patients due to the adjacent vertebral body fracture in four patients.

Conclusion: This novel SEPS/DEPS technique is a useful method for preventing implant failures due to its strong fixation of the fused vertebra by DISH; however, long-term follow-up is necessary because failure tends to occur at the distal end of fixation even after bone fusion.

PS-FP-10-18

Percutaneous Transforaminal Endoscopic Surgery and Oblique Lateral Interbody Fusion with Self-Lock Cage for Surgical Treatment of L5 Spondylolisthesis

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Purpose: We designed percutaneous transforaminal endoscopic surgery (PTES) under local anesthesia and oblique lateral interbody fusion (OLIF) with self-lock cage through abdominal lateral retroperitoneal approach in a right oblique position for the treatment of L5 spondylolisthesis in order to obtain the direct neurologic decompression, rigid fixation and high fusion rate, and protect the rectus abdominis and its sheath, paraspinal muscles, and bone structures as much as possible. The purpose of study is to evaluate the feasibility, efficacy, and safety of this surgical method.

Methods: Twelve cases of L5 spondylolisthesis with nerve root symptoms were included in this study. PTES was performed under local anesthesia in a prone position, and then the patients underwent OLIF with self-lock cage through abdominal lateral retroperitoneal approach with the external oblique, internal oblique and transverse abdominal muscles bluntly separated in turn for L5/S1 in a right oblique position under general anesthesia. Back and leg pain were preoperatively and postoperatively evaluated using Visual Analog Scale (VAS). And the clinical outcomes were evaluated with Oswestry Disability Index (ODI) at the 1-year follow-up. The fusion status was assessed according to the Bridwell's posterior fusion grades.

Results: The mean duration of operation was 47.6 ± 6.8 minutes per level for PTES and 79.4 ± 11.7 minutes for OLIF. The mean frequency of intraoperative fluoroscopy was 5 times (range, 4–10 times) per level for PTES and 6 times (range, 5–9 times) for OLIF. There was a mean blood loss of 20 mL (range, 15–50 mL). The mean stay at the hospital was 4 days (range, 3–5 days). The average follow-up duration was 19 months (range, 12–24 months). For the clinical evaluation, the VAS pain index and the ODI showed excellent outcomes. Fusion grades based on the Bridwell grading system at 1-year follow-up were

grade I in eight segments (66.7%), grade II in four segments (33.3%). No patients had any form of permanent iatrogenic nerve damage and a major complication. No failure of instruments was observed.

Conclusions: PTES and OLIF with self-lock cage is a good choice of minimally invasive surgery for L5 spondylolisthesis, which can get direct neurologic decompression, easy reduction, rigid fixation, and solid fusion, and hardly destroy the rectus abdominis and its sheath, paraspinal muscles, and bone structures. OLIF for L5/S1 in a right oblique position could let abdominal contents move to contralateral side with gravity, which makes exposure of surgical vision easier.

PS-FP-10-20

Full Endoscopic Posterior Cervical Foraminotomy under Lateral Decubitus Position with Local Anesthesia

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Purpose: Almost half of the worldwide population is expected to experience clinically significant neck pain, and some severe cases require surgical interventions. Here we introduce a novel minimally invasive endoscopic technique as an alternative way for simple decompression for patients with foraminal stenosis and contraindications to general anesthesia, allowing for minimal muscle dissection, shortened surgical time, and reduced complications.

Methods: Patients with cervical foraminal stenosis with severe pain and medical comorbidities that increase the risk of general anesthetic were included in the study. First, the patient is placed in the lateral decubitus position with the asymptomatic side down and the neck parallel to the table. The posterior neck is draped, and subcutaneous bupivacaine 0.25% is injected for local anesthetic. Then working portal is placed on the facet joint aiming medial pedicle line with fluoroscopic guidance, approaching the midline to obliques posteroanterior on the side and at the level of the patient's pain. With the maximum fluoro-

scopic magnification, the neural foramen is placed at the center of the fluoroscopic field of view and kept in place throughout the surgery. An endoscopic port is placed over the needle tract, and decompression is performed by removing the inferior facet of the upper lamina and partial removal of the inferior lamina's superior facet. Adequate foraminal decompression is obtained through bony removal until the dura mater's lateral border is visualized.

Results: Nine patients (eight males, one females; mean age, 50 years), who have complaints of pain but refused general anesthesia or patients with a difficult airway, were treated with an average operation time of 55 minutes. All nine cases had significant improvement in cervical radicular pain via the Visual Analog Scale (VAS). The median improvement of VAS was 7, and there were no perioperative complications.

Conclusions: Awake endoscopic cervical foraminal decompression is a feasible alternative to standard approaches for patients with a difficult airway or underlying pulmonary diseases, reducing the risks inherent in general anesthesia and cranial fixation.

PS-FP-10-21

Three-Year Clinical Outcomes after Minimally Invasive Sacroiliac Joint Arthrodesis Using Triangular Implants in Japan: A Pilot Study of Five Cases

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Purpose: Sacroiliac joint (SIJ) arthrodesis using a minimally invasive technique, particularly the triangular implant system, is performed in patients with SIJ dysfunction in the United States and Europe. We report the three-year clinical outcomes of the first minimally invasive SIJ arthrodesis procedures using the implants performed in Japan.

Methods: A total of five patients (one man and four women; age, 56.4±16.9 years) with SIJ pain who under-

went SIJ arthrodesis using a triangular implant system in 2017 were included. In addition to operation time and blood loss, pain intensity (Visual Analog Scale [VAS]) and functional impairment (Oswestry Disability Index [ODI]) were assessed preoperatively and at 36-month follow-up. Computed tomography image-based evaluation of implant loosening and satisfaction with the surgery was also evaluated at 12 and 36 months.

Results: The surgical time was 67.7 ± 13.1 minutes and blood loss was 7.4 ± 6.9 mL. The mean VAS value improved significantly from 88.0 ± 8.4 to 33.6 ± 31.9 mm at 3 months and was maintained at 46.4 ± 30.9 mm at 36 months ($p < 0.05$). The mean ODI improved significantly from $76.4\% \pm 3.8\%$ to $46.2\% \pm 21.9\%$ at 6 months postoperatively ($p < 0.05$), but without significant improvements thereafter: $46.94\% \pm 23.7\%$ (12 months) and $66.4\% \pm 8.6\%$ (36 months). Three of five patients showed at least one implant loosening on the sacrum side. A total of 80% (4/5) of patients reported satisfaction with the surgery at 12 months and 60% (3/5) at 36 months.

Conclusions: Using a triangular implant system yielded somewhat poorer results in our study than in previous provider-supported studies; however, this technique was a valuable option to minimize invasiveness in SIJ surgery. Patients should be carefully selected and the degree of bony fragility of the sacrum in elderly patients should be considered.

PS-FP-10-24

Does Prophylactic Use of Topical Gelatin-Thrombin Matrix Sealant Affect Postoperative Drainage Volume and Hematoma Formation after Microendoscopic Spine Surgery?: A Randomized Controlled Trial

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Purpose: There has been no data on whether postoperative epidural hematoma (PEH) is suppressed by these agents when administered in microendoscopic spine surgery. The objective of this study was to investigate the effect

of topical gelatin-thrombin matrix sealant (TGTMS) on bleeding and PEH formation in lumbar microendoscopic surgery.

Methods: This is a randomized controlled trial (RCT) with additional prospective observational cohort. Patients were registered from July 2017 to September 2018 and 103 patients undergoing microendoscopic laminectomy for lumbar spinal stenosis at a single institution were enrolled. The primary outcome was the drainage volume within 48 hours after surgery. Secondary outcomes were the Numerical Rating Scale (NRS) of leg pain on the second (NRS2) and seventh day (NRS7) after surgery and the hematoma area ratio (HAR) in horizontal images on magnetic resonance imaging (MRI). In the RCT, 41 cases that received TGTMS (F group) were compared with 41 control group cases (C group) that did not receive TGTMS at the end of the procedure. Drainage volume, NRS2, NRS7, and HAR on MRI were evaluated. Nineteen cases were excluded from the RCT (I group) due to difficulty of hemostasis during surgery and the intentional use of TGTMS for hemostasis. I group was compared with C group in the drainage volume and NRS of leg pain as a prospective observational study.

Results: The RCT demonstrated no statistically significant difference in drainage volume between those receiving TGTMS (117.0 ± 71.7 ; mean \pm standard deviation) and controls (125.0 ± 127.0) ($p = 0.345$). The NRS2 and NRS7 was 3.5 ± 2.6 and 2.8 ± 2.5 in the F group, respectively, and 3.1 ± 2.6 and 2.1 ± 2.3 in the C group, respectively. The HAR on MRI was 0.19 ± 0.19 in the F group and 0.17 ± 0.13 in the C group. There was no significant difference in postoperative leg pain and HAR ($p = 0.644$ for NRS2, $p = 0.129$ for NRS7, and $p = 0.705$ for HAR). In the secondary observational cohort, the drainage volume in the I group was 118.3 ± 151.4 , and NRS2 and NRS7 was 3.5 ± 2.0 and 2.6 ± 2.6 , respectively. There were no statistically significant differences in drainage volume ($p = 0.386$) or postoperative NRS of leg pain between these two groups ($p = 0.981$ and 0.477 for NRS2 and NRS7, respectively).

Conclusions: The prophylactic use of TGTMS in patients undergoing microendoscopic laminotomy for lumbar spinal stenosis did not demonstrate any difference in postoperative bleeding or PEH. Nonetheless, for patients that had active bleeding that required the use of TGTMS, there was no evidence of difference in postoperative clinical outcomes relative to controls.

PS-FP-10-26

Comparison Between Clinical Outcomes of Simultaneous Parallel Anterior and Posterior Combined Lumbar Spine Surgery Using Intraoperative Three-Dimensional Fluoroscopy-Based Navigation (SPAPS) and Minimally Invasive Posterior/Transforaminal Lumbar Interbody Fusion

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Purpose: Minimally invasive posterior/transforaminal lumbar interbody fusion (MI-PLIF/TLIF) is a surgery commonly performed for lumbar interbody fusion. Since 2016, we have been performing a new surgery named simultaneous parallel anterior and posterior combined lumbar spine surgery under intraoperative three-dimensional fluoroscopy-based navigation (SPAPS) for degenerative lumbar disease. This study aims to compare the clinical outcomes of SPAPS and MI-PLIF/TLIF.

Methods: We retrospectively reviewed data from 56 patients who underwent SPAPS or MI-PLIF/TLIF for single-level degenerative lumbar disease in our hospital between April 2016 and December 2019. Twenty-five patients underwent SPAPS (group S), and 31 patients underwent MI-PLIF/TLIF (group PT). The patients were followed up for ≥ 6 months. The mean age was 63.7 years in group S and 69.5 years in group PT. The following items were evaluated: operative time, estimated blood loss (EBL), perioperative complications, Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), and Visual Analog Scale (VAS) scores, preoperatively and at 6 months postoperatively.

Results: The surgical time and EBL were significantly better in group S (119.1 minutes and 82.5 mL, respectively) than those in group PT (167.0 minutes and 160.1 mL, respectively) ($p < 0.01$). One patient in group PT showed an epidural hematoma postoperatively and required reoperation. The postoperative scores of JOABPEQ and VAS significantly improved in both groups, and no significant differences were observed between the groups.

Conclusions: SPAPS was associated with a shorter operative time and lesser EBL than MI-PLIF/TLIF. Further, SPAPS may contribute to lower medical costs because of

the reduced operative time and material costs.

PS-FP-10-27

Evaluation of Cement Leakage Using Computed Tomography after Balloon Kyphoplasty: Comparison between Patients Underwent within 4 Weeks and Patients Underwent after 4 Weeks

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Purpose: To evaluate prevalence of cement leakage using computed tomography after balloon kyphoplasty (BKP) for osteoporotic vertebral fracture (OVF). To compare prevalence of cement leakage and factors affect cement leakage between patients underwent within 4 weeks after injury and patients underwent after 4 weeks.

Methods: In this study, 115 patients (male: 39 patients, female: 76 patients; mean age, 80.2 ± 6.8 years) underwent BKP for OVF were enrolled. The patients were divided into two groups according to time to BKP after injury. Group A ($n=60$) consists of patients underwent within 4 weeks and group B ($n=55$) consists of patients underwent after 4 weeks. Within a few days after BKP, cement leakage was evaluated using computed tomography. Prevalence of cement leakage was compared between two groups. According to presence of cement leakage, each group was divided into two subgroups (group A leakage+, group A leakage-, group B leakage+, group B leakage-). In each group, age, sex, cleft vertebral, range of motion (ROM) of vertebral body, amount of cement, and maximum diastolic pressure were compared.

Results: Prevalence of cement leakage was higher in group A ($p=0.001$). Maximum diastolic pressure was higher in group A leakage+ ($p=0.03$). Prevalence of cleft, ROM of vertebral body, and maximum diastolic pressure were higher and amount of cement leakage was less in group B leakage+ ($p=0.008$, $p < 0.001$, $p=0.02$, $p=0.001$, respectively). There was no major perioperative complication.

Conclusions: Prevalence of cement leakage after BKP for OVF was higher in patients underwent within 4 weeks

after injury compared with patients underwent after 4 weeks. Factors affect cement leakage were different according to time of BKP after injury.

PS-FP-10-28

Decompression Procedure Using Unilateral Biportal Endoscopy for Thoracic Myelopathy Caused by Ossification of the Ligamentum Flavum: A Technical Note and Preliminary Clinical Results

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Purpose: The use of conventional spinal decompression surgery for thoracic ossification of ligament flavum (OLF) can be limited by technical difficulties and a restricted field of vision. The purpose of this study is to describe the technique for decompression procedure using unilateral biportal endoscopy (UBE) for thoracic OLF and analysis of clinical postoperative results.

Methods: The authors performed a unilateral laminotomy with bilateral decompression using a unilateral biportal endoscopy in patients with thoracic OLF. The authors enrolled only patients who underwent follow-up for longer than 12 months after UBE. Fifty-eight patients were enrolled in this study. This approach was based on two portals: one portal was used for continuous input and endoscopic viewing and the other portal was used for continuous output and manipulating the instruments used in the decompression procedures.

Results: Neural decompression was effectively performed in all enrolled patients. The male-to-female ratio was 3:1. Involvement of the upper thoracic region was seen 11 times; of the middle region 8 times, and of the lower region 40 times (several patients had involvement in more than one region). About half of the patients complained of gait disturbance on admission caused by the markedly enlarged OLF. A dural tear in one patient was the only observed complication.

Conclusions: From a surgical point of view, UBE is very similar to microscopic spinal surgery, permitting good visualization of the contralateral sublaminar areas. The au-

thors suggest that the UBE, which is a minimally invasive procedure, is an alternative treatment option for thoracic OLF.

PS-FP-10-29

Treatment Results of Minimally Invasive Lateral Lumbar Disc Herniated Disk in Our Department

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Purpose: Good treatment with various surgical methods such as open surgery with Wiltse approach, endoscopic surgery, and fusion surgery as a surgical method for lateral lumbar disc herniated disk (lateral LDH) including the intervertebral foramen and extravertebral foramen. Results have been reported. We report on the results of surgery using a microscope and a cylindrical retractor in our department.

Methods: Since April 2018, 14 patients (male:female ratio=11:7; average age, 67.4 years) who have undergone surgical treatment for lateral LDH in our department were included. As a surgical method, the patient was placed in the abdominal position under inhalation anesthesia, a vertical incision was added 2 cm, and a hernia was removed under a surgical microscope (Leica, M720 OH5) using a cylindrical retractor (METRx, Medtronic). NIM-ECLIPSE E4 SYSTEM (Medtronic) was used for postoperative monitoring, triggered electromyogram (tEMG) was recorded using a bipolar stimulation electrode when nerve root identification was difficult, and Floseal (Baxter) was used for peri-nerve bleeding. The evaluation items were high surgical level, presence or absence of tEMG recording, postoperative complications, changes in local alignment as image evaluation before and after surgery, and Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ). The average operation time is 121.8 minutes and the estimated bleeding volume is 25.6 mL. The average follow-up period was 3.6 months (range, 1.2 to 34.8 months).

Results: The surgical levels were L2/3 (2 cases), L3/4 (5 cases), L4/5 (6 cases), and L5/S (4 cases). The tEMG record was recordable in 11 of 13 cases, and no postopera-

tive neurological complications were observed. Changes in local scoliosis before and after surgery were observed in five cases with two or more exacerbations of scoliosis. JOABPEQ pain improved significantly in the second year (preoperative average 28.4 → postoperative 2 years 85.5), and gait and society improved significantly in all 6 months to 2 years after the operation, but the lumbar spine and psychology No significant improvement was observed (non-repeated measures analysis of variance).

Considerations: Although this method showed deterioration of postoperative kyphoscoliosis in 35.7%, it is possible to identify nerve roots by using intraoperative monitoring together, and it is performed with minimal invasiveness by an operator who is proficient in open surgery without fixation. It was considered that LDH was superior in that it was relatively easy to introduce compared to endoscopic surgery.

PS-FP-10-31

Effectiveness of Foraminoplasty in Transforaminal Full-Endoscopic Discectomy for L5–S1 Disc Herniation Under Local Anesthesia

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Purpose: Full-endoscopic discectomy (FED) is a minimally invasive surgery for lumbar disc herniation (LDH). Especially in transforaminal FED (TF-FED), surgeon can perform FED under local anesthesia. However, it is difficult to approach for L5–S1 level in case of high-iliac and facet hypertrophy. After our introduction of foraminoplasty, the drilling technique of superior articular process (SAP) using high-speed bur, we have performed TF-FED for L5–S1 LDH. This study aimed to reveal the effectiveness of foraminoplasty in TF-FED.

Methods: We retrospectively reviewed 42 cases who had undergone TF-FED for L5–S1 LDH in our hospital after 2014 (followed up at least 6 months). Height of iliac in X-ray (type 1–6: 1–4 low-, 5–6 high iliac), migration of LDH in magnetic resonance imaging (zone 1–4: 1–2 up-, 3–4 down-migrate) and alpha angle in CT (angle between iliac crest and SAP) were recorded. Macnab criteria was used

for clinical outcomes.

Results: Foraminoplasty was required in 22 cases (group 1), and wasn't required in 20 cases (group 2). No differences in migration between two groups. The ratio of high iliac was significantly higher in group 1 (group 1: 63%, group 2: 50%). The average alpha angle was 52.1° in group 1 and 60.4° in group 2, respectively. In group 1, postoperative alpha average angle was 60.8°. According to Macnab criteria, excellent 20, good 2 in group 1, excellent 10, good 9, poor 1 in group 2. No postoperative complication had seen in both groups.

Conclusions: Foraminoplasty should be effective technique for L5–S1 LDH even in high iliac and down migration LDH.

PS-FP-10-32

Examination of Radiation Exposure in Lateral Lumbar Fusion Surgery Using Intraoperative Computed Tomography Navigation

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Purpose: In recent years, the reduction of radiation exposure by utilizing computer-assisted surgery with intraoperative computed tomography (CT) navigation has been reported. However, reports on the actual patient exposure dose are limited. At our institution, we are increasingly using intraoperative CT navigation in lateral lumbar interbody fusion (LLIF) surgery to improve surgical precision compared to LLIF surgery using C-arm fluoroscopy. This study investigates the intraoperative radiation dose in LLIF surgery using intraoperative CT navigation for the patient and surgeons.

Methods: From April to September 2020, radiation exposure was examined in 12 LLIF cases (eight males, four females; average age, 72.4 years). Glass radiation dose meters were placed on the patient's neck, left anterior chest, and lower abdomen, and also on the outside and inside surface of the chest area of the surgeon's radiation protective gear.

Results: The average fluoroscopy time was 125.6±70.9

seconds, and the average radiation dose was 2.0 ± 1.6 mGy. The radiation exposure of the patient according to area is as follows: neck, 0.097 ± 0.069 mGy; left anterior chest, 0.20 ± 0.12 mGy, and lower abdomen 2.02 ± 1.67 mGy. The surgeon's radiation dose was 0.029 ± 0.024 mGy inside and 0.119 ± 0.111 mGy outside the protective clothing. Reported that the average radiation dose to LLIF patients using the C-arm was 25.2 ± 21 mGy. The radiation exposure in this study using intraoperative CT navigation was lower at 2.02 mGy, but we concede that these values cannot be simply compared. In addition, Taher et al. reported exposure of 2.19 ± 2.07 mGy for the surgeons with CT navigation.

Conclusions: Compared with radiation exposure in LLIF surgery using C-arm which we reported in the past, there was less radiation exposure, and we believe that intraoperative CT navigation not only improves surgical precision but decreases radiation exposure for both patients and surgeons.

PS-FP-10-33

The Efficacy of Epiduroscopic Adhesiolysis on Failed Back Surgery Syndrome

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Purpose: Symptoms of Failed Back Surgery Syndrome (FBSS) include low back pain, radicular pain, restricted range of motion, muscle spasms, changes in motor and reflex function especially in lower limbs. Among the many treatment options of FBSS, successful results of epiduroscopic adhesiolysis, which is relatively less invasive, have been previously reported. Epiduroscopy allows the adhesions to be removed mechanically by directly showing them, and at the same time, it allows the application of an anti-adhesion barrier (steroid, hyaluronidase, etc.) to the epidural space. We aimed to compare the results of treatment with mechanical lysis with epiduroscopy and steroid hyaluronidase injection according to the stabilization status of patients with FBSS.

Methods: A total of 47 patients were included with a mean age of 62.4 years (33–81), 28 women and 19 men. Among them, 20 were previously stabilized and 27 were non-

stabilized. They all had persistent chronic back pain and radicular pain despite of medication and physical rehabilitation. Visual Analog Scale (VAS) for pain and Oswestry Disability Index (ODI) were evaluated preoperatively, after 1 month, 6 months and 1 year after the epiduroscopic adhesiolysis. The preoperative VAS was 7.4 ± 70.234 , 3.8 ± 0.395 in the first postoperative month, 4.2 ± 0.414 in the 6th month and 5.05 ± 0.438 in the first year. The preoperative ODI was 78.88 ± 1.82 , 54.43 ± 3.32 in the first postoperative month, 58.58 ± 3.45 in the sixth month and 62.16 ± 3.42 in the first year.

Results: All patients, and also the subgroups (gender and stabilized/non-stabilized) improved significantly in pain (VAS) and disability (ODI) at all postoperatively visits. There was no statistically significant difference between the stabilized and non-stabilized groups in both preoperative scores and postoperative controls ($p > 0.05$). However, the scores gradually returned to the preoperative value thereafter. A slight worsening in VAS and ODI was noticed over time in both groups.

Conclusions: We suggest that epidural adhesiolysis, has both therapeutic and diagnostic effects, combined with hyaluronidase and steroid injection is an effective treatment for back and radicular pain in patients with FBSS. Long-term randomized controlled studies are needed to better understand the efficacy of epiduroscopic adhesiolysis in FBSS.

PS-FP-10-34

Retrospective Study of Clinical and Radiological Outcomes of Minimally Invasive Transforaminal Lumbar Interbody Fusion for High-Grade Spondylolisthesis: Series of 24 Patients with 2-Year Follow-up

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Purpose: High-grade spondylolisthesis has been variably defined but the most accepted definition is to cases with more than 50% displacement and listhesis with Meyerding grade three and higher. After the failure of appropriate nonoperative measures for controlling the symptoms, postural deformity, slip progression, the operative meth-

ods are indicated. The surgical management of high-grade spondylolisthesis is a technically demanding. Many surgical methods have been reported have like posterior in situ fusion, instrumented posterior fusion with or without reduction, combined anterior and posterior procedures, spondylectomy with reduction of L4 to the sacrum (for spondyloptosis), posterior interbody fusion with trans-sacral fixation. Although use of minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) spine surgery for high-grade spondylolisthesis have not been widely reported in literature.

Methods: A retrospective review of all patients with high-grade spondylolisthesis who were treated by the same surgeon at single institution was performed. The local institutional review board approved the study. Between 2017 and 2019, there were 24 patients, who were surgically treated for high-grade spondylolisthesis of the lumbosacral junction associated with severe and persistent low back pain and/or leg pain, or a neurologic deficit, after the failure of nonoperative treatment. Preoperative pain (Visual Analog Scale [VAS] score), functional ability (Oswestry Disability Index [ODI], 36-item Short Form Health Survey [SF36]), radiological parameters (slip angle, slip grade, foraminal height, lumbar lordosis) were compared with postoperative recordings at the last follow-up. Operative time, blood loss, and hospital stay were studied. Functional improvement (SF36, ODI) and fusion (Bridwell fusion criteria) were assessed. Statistical analysis with changes in parameters from preoperative to 2 years were analyzed. The aim of this study is to show the clinical, surgical and radiographic results associated with the MIS TLIF for high-grade spondylolisthesis in 24 patients.

Results: VAS score improved from 8 (7–9) to 0 (0–2) and ODI improved from 39 to 4, also physical and mental components of SF-36 showed improved. Radiological parameters slip angle, slip grade, disc height, foraminal height showed improvement. All 24 patients showed grade I fusion as per Bridwell Grading on follow-up.

Conclusions: This study shows MIS TLIF for the treatment of high grades of spondylolisthesis is effective. Patients with solid fusion and adequate decompression by MIS techniques can achieve good results. Although larger, prospective randomized controlled trials with longer follow-up are required to establish long-term results.

PS-FP-11-1

Comparative Study for Navigated Drill and Navigated Probe for Cervical Pedicle Screw Insertion

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Purpose: Perforation of the cervical pedicle screw, especially lateral perforation, may lead critical complications, such as vertebral injury. Sub-axial cervical spines (C3–6) are at risk of complications because these levels have limited area and angle. The purpose of this study was to compare navigated drill and navigated probe for insertion of cervical pedicle screws at C3–6.

Methods: A total of 60 cases treated with cervical pedicle screws at C3–6 was retrospectively investigated. Cervical trauma was the main etiology of the surgery (53/60). Thirty cases with 107 cervical pedicle screws using navigated drill (group D) and 30 cases with 100 cervical pedicle screws using navigated probe (group P) were compared. Perforation rate (Neo classification: grade 0, none; grade 1, <2 mm; grade 2, 2–4 mm; grade 3, >4 mm), and the anatomical medial angle of the pedicle and the actual angle of the screw were investigated.

Results: Ten cases of grade 1 perforation were identified in each group. No grade 2 or 3 perforation was found in each group. Perforation rate were 4% (4/101) in group D and 8.2% (8/98) in group P when excluding cases with pedicle width under 3.5 mm (minimal screw size). All perforations were at medial in group D and at lateral in group P. There was no statistical difference in the anatomical angle of the pedicle in each group. Mean medial angle of the pedicle screws was 24.2° in group D and 30.9° in group P ($p < 0.05$).

Conclusions: Group D had lower perforation rate and smaller medial angle than group P. Medial perforation of the cervical screw is believed to be safer than lateral perforation. However, lateral perforation is more common than medial perforation, because the lateral cortical wall is thinner than the medial one, retracted muscles resist to direct medial, and the insertion torque rotates the vertebra to the lateral. Navigated drill enable to make a pathway at the hard medial wall of the pedicle which is impossible even with a navigated probe. Moreover, navigated drill does not require excessive exposure to the lat-

eral nor excessive power while making a pilot hole, which would be helpful for preventing lateral screw perforation. Navigated drill can be a useful option for insertion of the cervical pedicle screw because of its easiness and safeness.

PS-FP-11-2

Accuracy of Pedicle Screw Placement in Early Onset Scoliosis Using Intraoperative Computed Tomography and Image-Guided Navigation

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Purpose: Pedicle screws (PS) frequently used for spinal instrumentation in early onset scoliosis (EOS). High rates of PS malposition have been reported in EOS. Recently, intraoperative computed tomography (CT) and image-guided navigation have become available. The purpose of this study was to evaluate the accuracy of PS placement in EOS using intraoperative CT (O-arm) and image-guided navigation versus conventional freehand technique.

Methods: Between 2007 and 2019, 284 PS were placed in 36 consecutive patients with EOS. Mean age at surgery was 7.3 years. PS were divided into O-arm navigation group (OA group: n=168 PS, 19 patients) and conventional freehand technique group (FH group: n=116 PS, 17 patients). The grade of pedicle perforation and the morphology of pedicle were investigated. Each PS were assigned a grade of 0 to 3. Grade 0 and 1 penetrations were considered satisfactory, whereas grades 2 and 3 were regarded as major perforations. Pedicle width (PW) and left/right pedicle width ratio (PR) were measured for the morphology of pedicle. The grade of pedicle perforation was compared between the two groups. The correlations between the grade of pedicle perforation and the morphology of pedicle (PW and PR) were analyzed. And the cut off value of the morphology of pedicle that causes grade 2 and 3 perforation was examined.

Results: Grade 0 and 1 penetrations were 166 in OA group and 102 in FH group. Grade 2 and 3 perforations were 2 in OA group and 14 in FH group. In FH group, the rate of

grade 2 and 3 perforation (12%) was significantly higher than OA group (1.2%) ($p=0.0001$). In OA group, the grade of pedicle perforation and the morphology of pedicle (PW and PR) were not related. In FH group, the grade of pedicle perforation and PW were not related. But the median PR of grade 2 and 3 (1.3) was significantly higher than that of grade 0 and 1 (1.1) ($p=0.0073$). In receiver operating curve analysis of the pedicle in major perforation and PR, the cut-off value of PR that causes major perforation was 1.2 (area under the curve=0.71).

Conclusions: O-arm and image-guided navigation improved the accuracy of PS placement in EOS. Using conventional freehand technique, PS misplacement occurs because the morphology of pedicles is not correctly recognized in EOS with asymmetrical, malformed vertebral bodies. O-arm and image-guided navigation are valuable tools for the safe placement PS in EOS with significant spine deformity and altered anatomy.

PS-FP-11-3

C-Arm Free Lumbar Interbody Fusion

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Lumbar interbody fusion surgeries (oblique lateral interbody fusion [OLIF], direct lateral interbody fusion [DLIF], transforaminal lumbar interbody fusion [TLIF], posterior lumbar interbody fusion [PLIF], etc.) have been well recognized as effective procedures for degenerative spinal disorders. On the other hands, minimally invasive spine surgeries have been developed in the recent decades. However, minimally invasive procedures require the C-arm assistance. Since 2015, the authors have used the O-arm (Medtronic) navigation in the minimally invasive spine surgeries for the degenerative spinal diseases including spine deformity, spine trauma, spinal canal stenosis and so on. In this paper, the authors describe the benefits of the O-arm navigation for the minimally invasive spine fusion surgeries. In this 3 years, 100 cases of spinal defor-

mity associated with lumbar canal stenosis were treated by OLIF and 200 cases of lumbar canal stenosis including listhesis and foraminal stenosis were treated by minimally invasive TLIF (MIS-TLIF). Both of all cases with OLIF and MIS-TLIF were operated with the assistance of O-arm navigation. None of these surgeries were performed with the assistance of C-arm fluoroscopy. In the OLIF group, the position of interbody cages (Clydesdale: Medtronic) on the navigation monitor were compared with postoperative computed tomography (CT). There were some differences between navigation monitor and postoperative CT in the depth (5 mm mean) and degree (3° mean) of cage position. In all cases of OLIF and MIS-TLIF, the screw positions were also compared between navigation monitor. There were some differences in the depth (3 mm mean) and degrees (2° mean) of screw positions. The malposition of percutaneously inserted pedicle screws were 0.8% in this study. So, the accuracy of O-arm navigation is thought to be acceptable. In the fusion surgeries with O-arm navigation, C-arm shots is not necessary. For the surgeons, anesthesiologists and all staff in the operating room, the radiation dosage can be decreased to 0 level in O-arm navigated surgeries. Recently, the occupational radiation exposure has been the big issue. The surgical procedures without fluoroscopy have been preferable. In conclusion, the O-arm navigation has great benefits for the treatment with lumbar interbody fusion in the realm of the accuracy and the radiation exposure.

PS-FP-11-4

Robot-Assisted Minimally Invasive Transforaminal Lumbar Interbody Fusion in the Treatment of Lumbar Spondylolisthesis

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Purpose: To compare the clinical efficacy between robot-assisted minimally-invasive transforaminal lumbar interbody fusion (robot-assisted MIS-TLIF) and traditional open TLIF surgery in the treatment of lumbar spondylolisthesis.

Methods: According to the inclusion and exclusion criteria, 48 cases with lumbar spondylolisthesis who received

surgical treatment from Jun 2016 to Dec 2017 in the Spinal Surgery Department of Beijing Jishuitan Hospital were analyzed in this study, including 23 patients who received robot-assisted MIS-TLIF and 25 patients who received traditional open TLIF surgery. The two groups were compared in terms of pedicle screw accuracy evaluated by Gertzbein-Robbins classification on postoperative computed tomography (CT), operation time, blood loss, postoperative drainage, hospitalization, time to independent ambulation, low back pain evaluated by Visual Analog Scale (VAS), lumbar function evaluated by Oswestry Disability Index (ODI), paraspinal muscles atrophy on magnetic resonance imaging, and complications.

Results: Postoperative CT showed that grade A screws rate in the robot-assisted MIS-TLIF group was significantly more than that of the open surgery group ($\chi^2=4.698$, $p=0.025$). Compared with the open surgery group, the robot-assisted MIS-TLIF group had significantly less intraoperative blood loss, less postoperative drainage, shorter hospitalization, shorter time to independent ambulation, and lower VAS at three-dimensional postoperation ($p<0.05$). However, the duration of surgery was longer. The VAS of the robot-assisted MIS-TLIF group decreased from 6.9 ± 1.8 at preoperation to 2.1 ± 0.8 at postoperation, 1.8 ± 0.7 at 6-month follow-up and 1.6 ± 0.5 at 2-year follow-up. The VAS of the open surgery group decreased from 6.5 ± 1.7 at preoperation to 3.7 ± 2.1 at postoperation, 2.1 ± 0.6 at 6-month follow-up and 1.9 ± 0.5 at 2-year follow-up. The ODI of the robot-assisted MIS-TLIF group decreased from $57.8\%\pm 8.9\%$ at preoperation to $18.6\%\pm 4.7\%$ at postoperation, $15.7\%\pm 3.9\%$ at 6-month follow-up and $14.6\%\pm 3.7\%$ At 2-year follow-up. The ODI of the open surgery group decreased from $56.9\%\pm 8.8\%$ at preoperation to $20.8\%\pm 5.1\%$ at postoperation, $17.3\%\pm 4.2\%$ at 6-month follow-up and $16.5\%\pm 3.8\%$ at 2-year follow-up. Paraspinal muscle cross-sectional area in 2-year follow-up in patients of the open surgery group decreased significantly than in patients of MIS-TLIF group ($p=0.016$).

Conclusions: In the treatment of lumbar spondylolisthesis, robot-assisted MIS-TLIF may lead to more precise pedicle screw placement, less intraoperative blood loss, less postoperative drainage, less postoperative pain, quicker recovery, and less paraspinal muscle atrophy than traditional open surgery.

PS-FP-11-6

Comparison Between Machine-Vision Image Guided Surgery System and Robotic Guidance System for Pediatric Idiopathic Scoliosis Spine Surgery

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Purpose: Advances in spinal navigation and robotics have transformed modern spinal surgery. However, there is a paucity of literature comparing both systems in posterior spinal fusion (PSF) surgery for idiopathic scoliosis. In this study, radiation exposure data and other clinical parameters in PSF surgery were compared between a novel machine-vision image guided surgery (MvIGS) spine navigation system and a robotic guidance system (RGS).

Methods: A retrospective intraoperative and radiographic chart review was conducted for all adolescent idiopathic and juvenile idiopathic scoliosis patients who had undergone PSF in our institution between August 2018 and January 2021. Radiological and clinical data such as number of fluoroscopy images taken, duration of intraoperative radiation exposure, total intraoperative radiation dose, estimated blood loss, operative time per level fused and length of hospital stay were analyzed.

Results: A total of 26 patients met the inclusion criteria for study: 13 patients using MvIGS were compared with 13 patients using RGS. Patients in both groups had the same gender distribution (85% females) and similar mean age (14.8±2.51 years vs. 14.1±1.83 years, $p=0.400$). Compared with patients in the RGS group, the use of MvIGS significantly halved the number of fluoroscopy images taken (20.6±6.74 shots vs. 46.2±15.7 shots, $p<0.001$), duration of intraoperative radiation exposure (24.3±8.86 seconds vs. 49.8±18.5 seconds, $p<0.001$) and estimated blood loss in patients (515±385 mL vs. 1,080±850 mL, $p=0.038$). A significant decrease of 62% in total intraoperative radiation dose was also observed in the MvIGS group compared to the RGS group (73.8±44.4 cGycm² vs. 194±206 cGycm², $p=0.05$). Both groups had similar total operative time (376±101 minutes vs. 375±66.7 minutes, $p=0.968$). While operative time per level fused was shorter in the MvIGS

group (34.2±6.83 minutes vs. 36.4±6.56 minutes), along with a shorter length of hospital stay (6.54±3.50 days vs. 7.54±2.76 days), the differences were not statistically significant.

Conclusions: Compared with the RGS, the use of MvIGS required fewer fluoroscopy images intraoperatively, resulting in a significantly shorter duration of radiation exposure and lower cumulative intraoperative radiation dose. Blood loss in the MvIGS group was also significantly reduced compared with patients in the RGS group.

PS-FP-11-7

Safety of Pin Insertion Position for Iliac Reference Guide in Spinal Navigation

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Purpose: In intraoperative navigation, it is important to fix the reference guide to the patient's body safely. During thoracic and lumbar surgery, it is common to insert two pins into the ilium to insert the reference guide. But, the certainty and safety of the method have not been discussed much until now. In this study, we evaluate the insertion position of the iliac pin for the spinal navigation.

Methods: From December 2019 to October 2020, 48 patients (mean age: 71.2 years old; range, 45–89 years old; 30 males, 18 females) underwent spine surgery assisted with a Siemens flat panel three-dimensional (3D) C arm and a Brainlab navigation system with a pin inserted into the ilium and the reference guide fixed. After the two pins inserted the iliac wing, we evaluated pin position of the iliac bone by 3D C arm and the presence or absence of deviation of the pin into the pelvic cavity and spinal canal. Also, we evaluate number of cortical bones (ilium and sacrum) through which the pin penetrates.

Results: In all cases, the reference guide fixations were good, and there were no complications during or after surgery. No obvious deviation into the spinal canal was observed, but there were four cases in which deviation into the spinal canal was borderline. Deviation into the pelvic cavity was observed in six cases, of which four cases

were within 5 mm and two cases were more than 5 mm. Regarding the number of cortical bones penetrated by the pin, 11 cases had one cortical bone, 29 cases had two cortical bones, seven cases had three cortical bones, and one case had four cortical bones in proximal pin. In distal pin, 15 cases had one cortical bone, 25 cases had two cortical bones, eight cases had three cortical bones, and 0 case had four cortical bones. And the average number of cortical bones penetrated was 2.0 in proximal and 1.9 in distal.

Conclusions: Although it is widely practiced to insert pins into the ilium in prone spinal surgery, six cases deviated into the pelvic cavity and four cases were borderline to deviate into the spinal canal in this study. Fortunately, no complications were observed, but there was a risk of damage to the large blood vessels, intestines, and nerves, so we need take care of pins position.

PS-FP-11-8

O Arm Navigation Assisted Minimally Invasive Transforaminal Lumbar Interbody Fusion for Degenerative Lumbar Disease: Study of 83 Patients

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Purpose: Minimally invasive spine fusion surgery (MIS) rates has increased as treatment of choice for spinal ailments over last 2 decades. Patient satisfaction, better surgical outcomes, faster recovery, shorter duration of hospital stay, and early return to work has made minimally invasive procedures like MIS transforaminal interbody fusion (MIS TLIF) more popular. This technique of O arm assisted MIS TLIF has proved decreased rates of postoperative morbidity, dural leaks, and postoperative infection. This study aims to do analysis the clinical and radiological outcomes of O arm assisted minimally invasive lumbar fusion techniques for degenerative lumbar ailments.

Methods: From October 2017 to December 2019, 83 patients of Indian population with degenerative lumbar spinal stenosis were evaluated for minimum 1 year in terms of clinical factors like Visual Analog Scale (VAS), Oswestry Disability Index score (ODI), and 36-item Short Form Health Survey (SF-36) score and radiological factors like

fusion rate, disc height, disc angle, and foraminal height were assessed.

Results: After 1-year follow-up, the patient's functional improvement based VAS, ODI, and SF 36 scores was significant. Radiological outcomes like disc height, disc angle, foraminal height showed improvement. The rate of accuracy of pedicle screw fixation was 99%

Conclusions: Good functional and radiological outcomes can be achieved with O ARM assisted MIS TLIF. The results are comparable with other fusion techniques.

PS-FP-12-1

Effectiveness of Nitinol in Motion-Preserving Stabilization of Lumbar Spine

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Purpose: The standard of surgical treatment of lumbar degenerative disc disease is decompression of neural structures of the spinal canal with the instrumentation. However, these interventions lead to a number of complications, such as adjacent segment disease, pseudoarthrosis, and bone resorption around the pedicle screws. Dynamic stabilization proved to be an effective surgical technique in our prospective study conducted on 252 patients. All patients showed significant improvement according to the Oswestry Disability Index (ODI), 36-item Short Form Health Survey (SF-36), and Visual Analog Scale (VAS) at all control periods up to 5 years after surgery.

Methods: We analyzed the results of surgical treatment of 123 patients with degenerative diseases of the lumbar spine, who were treated using nitinol rods from 2011 to 2017 in our department. The control group consisted of 129 patients, who were treated using standard rigid rods made of titanium. Taking into account the results of preoperative examination of patients, the tactics of further surgical treatment were determined, based on which the patients (n=252) were divided into five groups depending on the level of fixation. Radiographs, computed tomography, magnetic resonance imaging, and clinical outcomes were examined preoperatively, and at 6-, 24-, 48-, and 60-month follow-up.

Results: The results were evaluated according to the VAS, SF-36, and ODI questionnaires. In both cases (rigid and dynamic stabilization), statistically significant improvements were noted in the postoperative period ($p < 0.01$). In both groups, in comparison with preoperative values, improvement was observed in all control periods, which were highly statistically significant ($p < 0.01$). Assessment of mobility in the segment stabilized using dynamic nitinol rods demonstrated average conserved range of motions of 4.8° . In total, 16 of the 252 treated patients had complications (6.35%). In the group with dynamic nitinol rod stabilization, there were five complications (4.0%), and in the group with rigid rods (11, 8.53%).

Conclusions: Pedicle screw fixation of the lumbosacral spine with the use of nitinol rods is an effective technology that allows to conserve mobility in the lumbosacral spine in combination with a stable fixation.

PS-FP-12-2

Is There a Place for Surgical Repair in Adults with Spondylolysis or Grade I Spondylolisthesis?: A Systematic Review and Treatment Algorithm

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Purpose: Surgical repair is less explored than fusion in adults with spondylolysis/low-grade isthmic spondylolisthesis, due to associated disc-degeneration with increasing age. We conducted a systematic review to: (1) describe characteristics of adults suitable for pars-repair, and (2) evaluate effectiveness and safety of pars-repair techniques in adults.

Methods: This review is in accordance with PRISMA-P-guidelines and registered with PROSPERO (CRD 42020189208). Studies in English, including patients ≥ 18 -years with spondylolysis/grade-I spondylolisthesis treated with standard pars-repair techniques, were considered eligible. A systematic search was performed in June 2020 in PubMed/Embase/Scopus/Web-of-Science databases. MeSH terms for search were “spondylolysis”

and “spondylolisthesis”, while free-text words included “pars interarticularis”, “pars defects”, “repair”, “pars repair”, “surgical repair”, “Buck*”, “Scott*”, “Scott wiring”, “modified Scott”, “Morscher*”, “pedicle”, “screw”, “pedicle-screw-rod-system”, “pedicle-screw-hook-system”, “minimally invasive”, “minimal access”, “endoscopic”, “percutaneous”, “navigation”, “image-guided”, and “robot*”. Search strings were developed by combining MeSH and free-text words using Boolean operators. The abstracts of articles from four data bases were screened initially by three independent reviewers. Full-text of shortlisted articles after removal of duplicates were further screened by three reviewers. Any conflict in article selection was discussed and resolved. Quality assessment was done using Joanna Briggs Institute critical appraisal checklist for selection of final articles. Data was extracted from finalized articles into an approved template and narrative synthesis was conducted.

Results: A total of 5,813 articles were retrieved. Initial screening resulted in identification of 289 articles. Of these, 111-articles (PubMed [n=34]; Embase [n=51]; Scopus [n=20]; Web-of-Science [n=6]) were available for full-text review after removal of duplicates. Full-text screening resulted in exclusion of 64 articles. A final 47 articles including 590 adults were available for data extraction after quality assessment. A high proportion of patients were young adults (18–35 years, 93%). Male:female ratio was 4.4:1. Lysis defect was primarily bilateral (96.4%) with L5 being the most involved level (68.5%). Majority had no disc degeneration (84%). Spondylolysis was primary diagnosis in 86%. Diagnostic pars-infiltration test was conducted in 22 studies. Conservative-therapy prior to pars-repair ranged from 3–72 months. Buck’s repair was the commonest technique (27 studies, n=372), and pedicle screw-rod method was the least explored. Successful repair was reported in 86% treated with Buck’s and $\geq 90\%$ with other techniques. Improvement in pain/functional outcomes, union rate and rate-of-return to sports was high and comparable across all techniques. Positive long-term (≥ 2 years) outcomes were noted in $>80\%$ patients. Complication-rate was 11.9%, with implant loosening accounting for majority of cases.

Conclusions: We have established feasibility, success, safety, and long-term effectiveness of pars-repair in selected adults with spondylolysis/grade-I spondylolisthesis. We propose the following parameters for optimizing selection of adults for pars-repair, regardless of technique: (1) age,

18–45-years, (2) no/minimal disc/facet-degeneration on magnetic resonance imaging, (3) normal discography, and (4) positive pars-infiltration test.

PS-FP-12-3

A New Surgical Strategy for Type 1 Modic Change Using Transforaminal Full-Endoscopic Disc Cleaning Surgery

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Purpose: It has been reported that Modic change of the lumbar spine endplate includes three types: edema or inflammation for type 1, fatty marrow change for type 2, and sclerotic change for type 3, and type1 Modic change may be related to the chronic low back pain. The anti-inflammatory drugs, and intra-discal injection of steroid were main treatment. But some cases were resisted conservative treatment and require fusion surgery. The fusion surgery may cause the adjacent degeneration; thus, motion preservation surgery is better, if possible. We performed transforaminal full-endoscopic disc cleaning (FEDC) surgery for patient of type 1 Modic change who complained chronic low back pain.

Methods: The subjects were five patients, seven intervertebral discs (three males, two females) who underwent FEDC under local anesthesia at our hospital. Mean age was 51 years old (32–73). Before surgery, intervertebral disc block was performed in all cases to confirm reproducibility and effectiveness. In the surgical procedure, a canula is placed on the surface of the intervertebral disc by a transforaminal approach, the superior articular process is partially resected for avoid existing nerve injury, and the canula is inserted into the intervertebral disc, and disc cleaning and end plate ablation using radiofrequency are performed. After surgery, antibiotics and anti-inflammatory drugs are taken orally, and semi-rigid corset are prescribed.

Results: The average duration of illness was 10.2 years (3–18 years). The average postoperative follow-up period is 4.6 months (1–12 months). The affected vertebral bodies were below: L2/L3, 1; L3/4, 1; L4/5, 2; and L5/S1, 3. As a characteristic of the symptom, all cases complained of forward bending pain and low back pain when they are waking up. Postoperative low back pain Visual Analog Scale improved to two or less in all cases.

Conclusions: Type1 Modic change is thought to be one of the signs of instability, but it also occurs in the intervertebral space without degeneration in young people, and we are considering the possibility of infection.

In all cases, low back pain improved, and some cases in which the high signal zone disappeared on magnetic resonance imaging-short tau inversion recovery images were experienced, and this is a new surgical strategy for type1 Modic change, which is difficult to treat.

PS-FP-12-6

Does Vertebral Body Tethering Cause Disc and Facet Joint Degeneration? A Magnetic Resonance Imaging Study with Minimum 2-Year Follow-up

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Purpose: Disc health after various growth modulation

techniques have been assessed in animal models, and tethering was claimed to prevent degeneration due to its less rigid nature compared to other growth-friendly techniques. Yet, the results of animal studies wherein tethering is applied on healthy spines to create a deformity cannot be extrapolated to humans, in which tethering is used for deformity correction. As biomechanical properties are different, effects of vertebral body tethering (VBT) in clinical series are not precisely acknowledged. There are concerns that VBT may cause degeneration at intermediate and adjacent levels.

Methods: Retrospective analysis of prospectively collected data. Demographic, perioperative and radiographic data were collected. Overcorrection, mechanical and pulmonary complications, and reoperations were recorded. Magnetic resonance imaging (MRIs) taken before surgery and at ≥ 2 years follow-up were evaluated for degeneration at the intermediate and adjacent segment discs and facet joints by a blinded senior radiologist. Discs were assessed using Pfirrmann grade. Facet joint degeneration was graded on a scale of 0–3. Changes from preoperative to follow-up MRIs were analyzed using McNemar's test and related samples marginal homogeneity test.

Results: A total of 25 (23 females, 2 males) consecutive adolescent idiopathic scoliosis patients with a mean follow-up of 29 (24–62) months who underwent thoracoscopic VBT between 2014 and 2017 were included. The mean age at surgery was 12.2 (10–14) years and median Sanders stage was 3 (1–7). A mean of 7.7 ± 1.1 (6–11) levels were tethered. Preoperative mean height of 155.3 (130–178) cm was increased to 163.4 (149–187) cm at latest follow-up. The mean preoperative main thoracic curve magnitude of $46^\circ \pm 7.7^\circ$ was corrected to $23.3^\circ \pm 5.9^\circ$ at first erect, which was modulated to $12^\circ \pm 11.5^\circ$ during follow-up. There was 1 (4%) broken tether, 5 (20%) overcorrected curves, 3 (12%) implant-related complications, and 1 (4%) reoperation for a thoracoscopic tether release before the follow-up MRI was obtained. A total of 217 levels of discs and bilateral facet joints, were evaluated in the preoperative and follow-up MRI images. Analyses of disc and facet scores revealed no significant differences between patients. One case (4%) that had an increase in disc scores, already had multi-level moderate degeneration preoperatively, while another case (4%) displayed a single-level new-onset grade-2 bilateral facet degeneration.

Conclusions: This study reports MRI findings of 25 adolescents (Sanders 2–7) who had undergone thoracoscopic

VBT surgery. At an average of 29 months (24–62) after growth modulation, radiographic degenerative findings were not present in 97.7% of the intermediate and adjacent discs and 99.3% of the facet joints. Studies with longer follow-up are warranted.

PS-FP-12-7

Is Thoracoscopic Vertebral Body Tethering a Pulmonary Function Declining or Improving Surgery?

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Purpose: Previous studies have shown that anterior spinal fusion significantly decreased forced vital capacity (FVC)% and forced expiratory volume in 1 second (FEV1)% after scoliosis surgery in adolescents. Similar concerns were raised for thoracoscopic vertebral body tethering (VBT), which, as an anterior technique, may cause deterioration in pulmonary function.

Methods: Data were collected preoperatively, at 6 weeks, 1 year, 2 years, and latest follow-up. All-thoracoscopic technique was used to approach thoracic vertebra, while retroperitoneal approach was used to access lumbar vertebra. Demographic, clinical, radiographic data, and complications were analyzed. Curve sizes at each follow-up were compared using repeated-measures analysis of variance. Preoperative, 1-year, and 2-years postoperative FEV1% and FVC% were compared using paired-sample t-test in thoracic group and Wilcoxon test for thoracolumbar and double-curve groups.

Results: A total of 54 (51 females, three males) consecutive adolescent idiopathic scoliosis patients with a mean

age of 12.4 ± 1.5 years, and a mean follow-up of 31 (24–57) months who underwent thoracoscopic VBT between 2014–2018 were included. Patients (78%) were Lenke 1 (19 A, 6 Ar, 13 B, and 4 C modifiers) and there were one, two, six, and two patients with Lenke 2, 3, 5 and 6 patterns, respectively. Preoperatively, 30 (58.8%) patients were premenarchal (median Sanders: 3 [1–7], Risser: 0 [0–5]). A median of 7 (5–11) levels was tethered. Patients grew 7 cm on average. 87% of the patients reached skeletal maturity. The mean preoperative main thoracic curve of $48^\circ \pm 9.4^\circ$ was corrected to $24.7^\circ \pm 7.2^\circ$ at first erect, which was modulated to $16.1^\circ \pm 12.4^\circ$ during follow-up. A total of 6 (11.1%) patients experienced pulmonary complications (2 ipsilateral and 1 contralateral atelectasis, 1 lobar atelectasis, 1 pleural effusion, and 1 chylothorax). Thoracic VBT resulted in significantly improved pulmonary function at 1-year (mean FVC%, 79.6 to 85.2, $p=0.014$; mean FEV1%, 80.1 to 87.8, $p=0.001$). No difference was observed between 1- and 2-year follow-up (final mean FVC% 87.5 and final mean FEV1% 90). Thoracolumbar and double-curve VBT; however, were similar between preoperative and 1-year follow-up (mean FVC%, from 81.8 to 83.7; mean FEV1%, 82.7 to 86.5 for thoracolumbar and mean FVC%, 82.2 to 82.6; mean FEV1%, 82.4 to 85.7 for double-curve).

Conclusions: This study reports the effects of thoracic, thoracolumbar, and double-curve VBT on pulmonary functions for 54 consecutive patients with a mean follow-up of 31 months. As an anterior approach, thoracoscopic VBT surgery did not have detrimental effects on pulmonary function in short-term follow-up. Thoracic-only VBT surgery resulted in improved pulmonary function at 1-year, which was preserved at 2-year follow-up. Thoracolumbar and double-curve VBT surgeries did not cause worsening in pulmonary at 1-year follow-up.

PS-FP-12-8

Two- to 5-Year Follow-up Results After Thoracoscopic Vertebral Body Tethering: A Single Surgeon's Experience

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Purpose: There is a paucity of information on clinical and radiographical outcomes of vertebral body tethering (VBT). Current information is not yet strong enough to convince surgeons to include this surgical technique to their armamentarium.

Methods: Retrospective analysis of prospectively collected data. Data were collected preoperatively, at 6-week, 1-year, 2-year, and latest follow-up. Demographic, perioperative, clinical, radiographic data, and complications were analyzed. Curve sizes at each follow-up were compared using repeated-measures analysis of variance. Respiratory function was compared between preoperative, 1 year, and 2 years postoperative.

Results: A total of 42 (40 females, two males consecutive adolescent idiopathic scoliosis patients with a mean age of 12.1 ± 1.5 years at surgery, and a mean follow-up of 33 (24–62) months who underwent thoracoscopic VBT between 2014–2018 were included. 95% of the patients showed Lenke 1 pattern (21 A, 4 Ar, 11 B, and 1 C modifier) and 5% were Lenke 2. Preoperatively, 25 (62.5%) patients were premenarchal (median Sanders: 3 [1–7], median Risser: 1 [0–5]). A median of 7 (6–9) levels was tethered. Mean surgical time was 240 ± 70 (123–360) minutes. Patients grew 8

cm on average; height measurements showing significant increase at each follow-up time point ($p < 0.001$). Patients (88%) reached skeletal maturity at final follow-up. Upper thoracic (UT), main thoracic (MT), and thoracolumbar/lumbar (TLL) curves showed significant decrease at each follow-up time point. No significant changes were noted in kyphosis and lordosis ($p < 0.05$). Forced vital capacity (FVC)% and forced expiratory volume in 1 second (FEV1)% showed significant increase from preop to 1 year, as well as from 1 to 2 years (mean FVC% 80.5, 85.2, and 87.6, respectively; mean FEV1% 80.5, 87.8, and 90.4, respectively, $p < 0.001$). Pulmonary, mechanical and curve behavior complications rates were 12%, 19%, and 33%, respectively. Two patients (4.8%) were converted to fusion. At final follow-up, 92% patients had $\leq 30^\circ$ residual curve. The Scoliosis Research Society-22 mental health, self-image and subtotal scores increased significantly.

Conclusions: This study reports a single European center experience on 42 consecutive patients with ≥ 2 -years follow-up who had undergone thoracic-only VBT surgery. Surgical correction was followed by growth-dependent correction attained during follow-up. Spontaneous correction was also noted in the non-operated upper thoracic and thoracolumbar levels. Pulmonary function showed a gradual increase. Thoracoscopic VBT surgery prevented fusion in 95% of patients of whom 92% had good radiographic ($\leq 30^\circ$ residual curve) and clinical outcomes; however, it is not without complications. Overall pulmonary, mechanical and curve behavior complications rates were 12%, 19%, and 33%, respectively. Some complications may be avoided with a better understanding of the growth modulation and advancement of technical skills and technology.

PS-FP-12-9

Clinical and Radiographic Outcome at 7 Years of Follow-up after Cervical Total Disc Replacement

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Purpose: This retrospective study was done to investigate long term efficacy of cervical total disc replacement (CTDR) with regards to its clinical and radiological outcome.

Methods: A total of 32 patients (male:female, 22:10; mean age, 39.9 years; range, 29–55 years) who were treated with single-level CTDR between 2009 to 2013 were retrospectively analyzed. The records of clinical and radiological examinations were assessed preoperatively and postoperatively at 1-, 5-, and 7-year follow-up (FU). Clinical scores outcome included scores such as Neck Disability Index (NDI), Visual Analog Scale (VAS)-arm and neck pain. The radiological outcome variables included range of motion of implanted prosthesis between maximum flexion-extension radiographs, radiographic heterotopic ossifications (HO), and adjacent segment disease (ASD). Complications and revision surgeries were also explored.

Results: All the clinical outcome scores were statistically significant at any time during FU period. At 7-year FU, mean improvement was NDI (26–6), VASarm (6.3–2), VASneck (6.6–2.2) ($p < 0.05$). An increase in the incidence of HO was seen during postoperative course. Grade 4 HO with solid fusion (9.38%), grade 3 (18.75%), grade 2 (25%), grade 1 (37.5%), and grade 0 (9.38%). There was no significant correlation between HO and clinical scores. The prosthesis mobility declined from 9.2° preoperatively to 9° at 1-year FU and 7.5° and 7.3° at 5- and 7-year FU. Radiographic ASD was seen in 11/32 (34.37%); however, in only 3/32 (9.38%) had clinical symptoms which were managed conservatively. There was a positive correlation between poor device mobility and occurrence of ASD and ASD appeared earlier in cases with grade 3 or 4 HO.

Conclusions: In this study, favorable 7-year FU clinical and radiological outcomes were observed. Clinically motion restricting HO was associated with higher ASD.

PS-FP-13-1

Fully-Automated Deep Learning Prediction of Spinal Deformity Alignment Irrespective of Image Quality Obtained via Smartphone Photographs

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Purpose: For facilitating communication, it is popular for

spine specialists to take photos of radiographs with smartphones. An automatic tool to accurately detect vertebral landmarks and alignment provides easy and highly useful information for surgeons. Original X-rays are not easily accessible for telemedicine and existing deep learning-based automated Cobb angle (CA) predictions are not accurate on suboptimal quality X-rays. The aim of study was to develop an automated CA prediction system irrespective of image quality, with no restrictions on curve patterns to facilitate clinical practice and telemedicine.

Methods: A total of 367 consecutive patients attending a scoliosis clinic were recruited prospectively and their coronal X-rays were re-captured using mobile phones. Five-fold cross-validation was conducted (five experiments, each with 294 images to train a deep neural network named Spine_HRNet for endplates landmarks and endvertebrae detection, and the remaining 73 images were used to test). The predicted heatmaps of the vertebral landmarks were visualized to enhance interpretability of Spine_HRNet. Per-landmark-absolute-errors and recall of the landmark detection results were calculated to assess the accuracy of the predicted landmarks. Further calculated CAs were quantitatively compared with the spine specialists measured ground truth (GT).

Results: The average per-landmark absolute distance error and the recall of the detected endplates landmarks were 2.8 pixels and 0.99, indicating a highly accurate detection. The predicted CAs were all significantly correlated with GT ($p < 0.01$). Compared with GT, the mean error was 3.73° – 4.15° and standard error of the measurement was 0.8° – 1.7° for the predicted CAs at different spinal regions.

Conclusions: This is the first study using Spine_HRNet on non-original X-rays to automatically and accurately predict vertebral landmarks of the scoliotic spine. Spine_HRNet's applicability is evidenced by our thorough cross-validation, which can be used with telemedicine to facilitate fast reliable auto-diagnosis and follow-up.

PS-FP-13-3

Evaluation of the Basal Metabolism of Degenerative Lumbar Intervertebral Discs Based on Pfirmann Grade and Presence of Instability

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Purpose: Intervertebral disc (IVD) degeneration is implicated in back pain, a leading cause of spine-related disability. It may also cause segmental instability. Both local and systemic inflammatory processes have been implicated in the pathophysiology of IVD degeneration, though it is unclear if Pfirmann grade severity or presence of instability affects degenerative IVD metabolism. These differences have not previously been investigated. Hence, this study was designed to examine the basal metabolism of degenerative lumbar IVD tissues collected from patients undergoing lumbar microdiscectomy or fusion with the hypothesis that tissues from patients with higher Pfirmann grades and those with instability would produce significantly higher levels of degradative enzymes and inflammatory mediators.

Methods: Degenerative IVD tissue excised as part of a standard-of-care spinal surgery, was obtained from patients (n=7; mean age, 53, 4 female) being treated for symptomatic degenerative lumbar IVD disorders. Pfirmann grading (1–5) of the IVD was determined by evaluation of magnetic resonance imaging (grade 3, n=3; grade 4, n=4), and for instability as defined by the presence of a spondylolisthesis on upright lateral radiographs (unstable, n=2; stable, n=5). Tissues comprised of degenerative nucleus pulposus (NP) was collected and explants were created. Cultured for 3 days, after which media were collected for biomarker evaluation. Media analyses: Media were tested for monocyte chemoattractant protein (MMP)-1, MMP-2, MMP-3, MMP-7, MMP-8, MMP-9, MMP-13, tissue inhibitor of metalloproteinase (TIMP)-1, TIMP-2, TIMP-3, TIMP-4, growth-related oncogene (GRO)- α , monocyte chemoattractant protein (MCP)-3, platelet-derived growth factor (PDGF)-AA, PDGF-AB/BB, interleukin (IL)-2, IL-4, IL-6, IL-8, MCP-1, macrophage inflammatory protein (MIP)-1 α , MIP-1 β , RANTES

(regulated on activation, normal T cell expressed and secreted), tumor necrosis factor (TNF)- α , and vascular endothelial growth factor (VEGF) using commercially available assays. Statistical analysis: Significant differences between groups were determined by t-test or rank sum test with significance set at $p \leq 0.05$.

Results: No significant differences between basal biomarker production by degenerative IVD tissues of Pfirrmann grade 3 versus 4 discs. However, tissues from degenerative IVDs with instability were found to produce significantly higher levels of MMP-8, and significantly lower levels of MMP-1, MMP-2, and MMP-13 compared to tissues from stable degenerative IVDs.

Conclusions: No significant difference in the metabolism of IVD tissues with a Pfirrmann grade of 3 or 4. However, the presence of instability in the degenerated lumbar IVD resulted in a significant increase in the production of MMP-8, but the production of other degradative enzymes was significantly decreased. Further study is required to determine in IVD architecture relates to changes in tissue metabolism, and its pathophysiology may provide insight into potential therapies for prevention and treatment of lumbar intervertebral disc degeneration.

PS-FP-13-4

Basal and Cytokine-Stimulated Biomarker Production by Degenerative Lumbar Discs from Microdiscectomy versus Interbody Fusion Patients

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Purpose: Intervertebral disc (IVD) degeneration is implicated in back pain, a leading cause of a spine-related disability. Both local and systemic inflammatory processes have been associated with IVD degeneration, though it is unclear if differences between these processes exist in degenerative IVDs of patients undergoing lumbar microdiscectomy versus lumbar interbody fusion. Hence, this study was designed to examine basal and cytokine-stim-

ulated metabolic responses of degenerative lumbar IVD tissues collected from patients undergoing lumbar microdiscectomy or interbody fusion with the hypothesis that tissues from patients undergoing fusion would produce significantly higher levels of degradative enzymes and inflammatory mediators under both basal and cytokine-stimulated conditions when compared to tissues from microdiscectomy.

Methods: Degenerative IVDs excised as part of a standard-of-care spinal surgery, lumbar microdiscectomy (n=3) or fusion (n=4) surgery was obtained from patients (n=7; mean age, 53, 4 female). Tissues comprised of nucleus pulposus (NP) was collected. Two explants per disc were randomly assigned to the 10 ng/mL interleukin (IL)-1 β stimulation group (IL) or the untreated basal metabolism group (BASAL). Tissues were cultured for 3 days, after which media were collected for biomarker evaluation. Media analyses: Media were tested for monocyte chemoattractant protein (MMP)-1, MMP-2, MMP-3, MMP-7, MMP-8, MMP-9, MMP-13, tissue inhibitor of metalloproteinase (TIMP)-1, TIMP-2, TIMP-3, TIMP-4, growth-related oncogene (GRO)- α , monocyte chemoattractant protein (MCP)-3, platelet-derived growth factor (PDGF)-AA, PDGF-AB/BB, IL-2, IL-4, IL-6, IL-8, MCP-1, macrophage inflammatory protein (MIP)-1 α , MIP-1 β , RANTES (regulated on activation, normal T cell expressed and secreted), tumor necrosis factor (TNF)- α , and vascular endothelial growth factor (VEGF) using commercially available assays. Statistical analysis: Significant differences between groups were determined by t-test using SPSS with significance set at $p \leq 0.05$.

Results: In the BASAL group, only the production of MMP-8, TIMP-4, and PDGF AA was significantly higher in the IVD tissues from the fusion cohort compared to that from the microdiscectomy group. In response to cytokine stimulation with IL-1 β , tissues in the fusion group responded with significantly greater production of TIMP-2, TIMP-4, PDGF-AA, IL-6, IL-8, MIP-1 β , and VEGF when compared to the response by the tissues from the microdiscectomy patients.

Conclusions: Basal inflammatory and degradative metabolism of degenerative lumbar IVD tissues collected from microdiscectomy versus fusion patients was not significantly different, since MMP-8 and TIMP-4 were the only biomarkers significantly different between the two patient groups. Tissues from the lumbar fusion patients do appear to be more sensitive to cytokine stimulation compared to

those from the microdiscectomy. The biochemical processes and clinical significance require further study. A deeper understanding of this phenomenon may provide insight into potential therapies for prevention and treatment of lumbar intervertebral disc degeneration.

PS-FP-13-5

Ubiquitin Mediated Proteasome Degradation Leading to Glutamic Acid Accumulation Could Be the Cause for Poor Clinical Outcomes in Patients with Modic Changes

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Study Design: Experimental analysis.

Purpose: This study aimed to investigate the biological basis of this poor outcome, to investigate the basis of inflammation and probe the possibility of sub clinical infection as an etiology of Modic changes (MC). We also aim to identify biological biomarkers and potential targets for molecular therapy.

Overview of Literature: Patients with MC form a distinct clinical subset with higher intensity of pain, poor clinical and surgical outcomes, and higher incidence of recurrence. MC also is an independent risk factor for increased postoperative surgical site infection.

Methods: Nucleus pulposus (NP) from 24 patients undergoing microdiscectomy for disc herniation (14 discs with MC and 10 without Modic changes [NMC]) were procured. The overall expression of proteins, biological processes, protein-protein, and metabolite interactions were analyzed and compared. The role of bacterial infection was investigated by documenting the host defense response proteins (HDRPs) and immunological pathways activated in patients with MC.

Results: Label-free proteomic approach with stringent filters revealed a total of 208 proteins in MC and 193 in NMC groups. Forty-five proteins were specific to MC

(30) to NMC and 163 common to both. Downregulated proteins in MC belonged to components of extracellular matrix such as collagens (COL- 6A1, 6A2, 6A3, 11A1, 12A1, and 20A1), and proteoglycans (versican [VCAN], and biglycan [BGN]). Inflammatory molecules (plasminogen [PLG], angiogenin [ANG], fibroblast growth factor-binding protein 2 [FGFBP2], tetranectin [CLEC3B], cartilage acidic protein 1 [CRTAC1], kininogen [KNG-1], chitinase-3-like protein 2 [CHI3L2], and ferritin [FTL]) were expressed only in the MC group. The significantly altered pathways in MC included Fc fragment of immunoglobulin G receptor IIIa (FCGR3A)-mediated phagocytosis, regulation of toll-like receptors by endogenous ligand, neutrophil, and platelet degranulation.

Conclusions: Our study confirms that MC represents an intense inflammatory status with probable basis of bacteria induced host defense response and immune activation. Downstream effects leading to ubiquitin mediated proteasomal degradation of extracellular matrix proteins and the resulting metabolites such as glutamic acid could be the possible cause of poor outcomes in these patients. Documenting the expression of inflammatory molecules, immune mechanisms and host defense response proteins suggests a bacterial role in pathological mechanisms of MC and its associated poor outcome. Further, ubiquitin mediated proteasomal degradation and accumulation of glutamate in discs with MC might serve as targets for molecular therapy to improve clinical/surgical outcomes in these patients.

PS-FP-13-6

Histopathological and Cytogenetic Analysis of Lumbar Epidural Lipomatosis

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Purpose: Spinal epidural lipomatosis (SEL) is characterized by the abnormal accumulation of unencapsulated adipose tissue in the spinal epidural space. Lumbar epidural lipomatosis (LEL) is found in 39%–42% of patients

with SEL, and L4–5 is the most commonly involved level. Symptomatic LEL occurs in middle age and is most often seen in men. Lipomas are common and can occur anywhere in the body, but spinal lipomas rarely occur. In both spinal lipoma and LEL, histopathological findings show mature adipocytes that vary only slightly in size and shape and have small, eccentric nuclei. It is difficult to distinguish between spinal lipoma and LEL by histopathological findings alone. Therefore, additional diagnostic tools are necessary to distinguish between true spinal lipoma and LEL. To date, cytogenetic studies of LEL have not been reported. The purpose of this study was to elucidate the histopathological and cytogenetic characteristics in patients with LEL who had undergone decompressive spinal surgery.

Methods: Six patients undergoing decompressive spinal surgery (all men; mean age, 71.3 years) were enrolled between 2011 and 2015. Three cases were steroid-induced and three cases were diagnosed as idiopathic LEL. All patients presented with neurological deficits in the lower extremities, with cauda equina syndrome (CES) in 4 cases, radiculopathy and CES in one case, and radiculopathy in one case. We compared the differences in histological morphology between the subcutaneous fat tissue and epidural fat tissue in each patient. We also analyzed the karyotype of resected epidural lipomatous tissue using the G-band method.

Results: The epidural adipocytes were histologically more irregular and smaller compared with the subcutaneous adipocytes in all cases. The mean size of subcutaneous adipocytes and epidural adipocytes was $5,485.6 \pm 2,584.1 \mu\text{m}^2$ and $2,705.4 \pm 1,069.1 \mu\text{m}^2$, respectively. In all cases of both idiopathic and secondary LEL, the loss of chromosome Y was seen on cytogenetic analysis.

Conclusions: The mechanisms related to the development of LEL are not well understood. Although all of the patients in our study were men, we believe the loss of the Y chromosome might contribute to the development of LEL. Although both histological changes of epidural adipocytes and loss of the Y chromosome may be effects rather than causes, these findings may be related to the onset and development of LEL.

PS-FP-13-7

Prolonged Use of Narcotics after Spine Surgery: A Requirement or a Privilege

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Purpose: The purpose of this study was to find out if the narcotic analgesics are really required as much as they are usually prescribed after spine surgeries or do, they just work as a privilege for the patients and the surgeon.

Methods: This is a retrospective observational study. The study utilized the data of 89 patients between the ages of 25 to 65 years operated from October, 2019 to June, 2020. Adults who underwent one of four common spinal surgical procedures (discectomy, decompression, lumbar posterolateral fusion, or lumbar interbody arthrodesis) were included in the study while patients with causes of pain other than spine were excluded. Patients were discharged on combination of Paracetamol (325 mg) and Tramadol (HCl, 37.5 mg) twice daily per oral and the patients were assessed at 2-, 4-, and 8-week intervals. Patients were assessed about the need of narcotics use after the specified period of time. The collected data was then analyzed in IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA).

Results: Out of total 89 patients included in the study, 31 (34.8%) were males while 58 (65.16%) were females. Thirty-one of the patients underwent lumbar discectomy, 25 patients underwent decompression, 21 patients underwent lumbar interbody arthrodesis, and 12 patients underwent lumbar posterolateral fusion. Some patients (87.64%) didn't feel the need to continue the narcotic pain killers after 2 weeks of operation. Only 12.36% of the subjects required to continue the narcotics for 4 weeks after surgery.

Conclusions: After 2 weeks of surgery, nearly all patients had discontinued opioid use. These results indicate that spine surgery among opioid-naive patients is not a major driver of long-term narcotics use especially in Asian countries like Pakistan. On the contrary, these narcotics are luxuriously given to patients in the western countries. Main reasons being in developing countries like Pakistan, the bill of these medicines has to be covered by the patients themselves and not by health insurance companies. Additionally, the addiction to drugs, alcohol and other central nervous system suppressing agents is also less

prevalent in Pakistan. Hence, prolonged and avoidable use of narcotics after spine surgery is more of a privilege than a requirement.

PS-FP-13-8

Posterior Rod Strain in a Long Spinal Fusion to the Pelvis: An In-Vitro Experimental Study Using Synthetic Lumbopelvic Bone Models

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Purpose: Despite the improvement in surgical techniques and instruments, there are still high rates of rod fracture (RF) associate in a long spinal fusion, especially in the treatment of adult spinal deformity (ASD). Thus, improved understanding of RF could be valuable for surgical planning. The aim of this study is to investigate mechanical stress on posterior rods in the setting of lumbopelvic fixation for the recent treatment of ASD.

Methods: Synthetic lumbopelvic bone models were instrumented with intervertebral cages, pedicle screws and S2-alar-iliac screws, and rods. The construct was placed in a testing device, and compressive loads were applied. Strain on the rods was measured using strain gauges on the dorsal aspect of each rod.

Results: When the models were instrumented using titanium alloy rods with the contour of 30° and lateral interbody cages, posterior rod strain was significantly higher in the lower segment (L5/S1) than in the upper segment (L2/3) ($p=0.009$). Changing rod contour from 30° to 50° caused a 36% increase in strain in the lower segment (L5/S1). Changing rods from titanium alloy to cobalt-chromium caused a 140% increase in strain in the upper segment (L2/3), whereas a 28% decrease in strain in the upper segment (L5/S1). Using transverse fixators or changing cages from laterally-placed to posteriorly-placed ones did not add significantly additional rod strain in any of the segments.

Conclusions: In the setting of lumbopelvic fixation using currently available surgical techniques for ASD, the posterior rod strain was larger at the lumbosacral junction than

at the upper lumbar spine and depended on the contour and material of rods.

PS-FP-13-9

The Possible Involvement of the Oxidized LDL/LOX-1 System in Ligamentum Flavum Hypertrophy in the Patients with Lumbar Spinal Canal Stenosis

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Purpose: The patients with lumbar spinal canal stenosis (LSS) patients often have arteriosclerosis. Oxidized low-density lipoprotein (LDL) is clinically known to be involved in the development of arteriosclerosis through lectin-like oxidized LDL receptor-1 (LOX-1) binding. Here, we aimed to elucidate the potential involvement of oxidized LDL/LOX-1 system in ligamentum flavum (LF) hypertrophy.

Methods: Forty-five samples were collected from LF tissues of the patients who underwent posterior lumbar spinal surgery for LSS or lumbar disc herniation. Immunohistochemistry for LOX-1 was performed using human LF samples. The correlation between the cross-sectional area (CSA) of LF under axial magnetic resonance imaging and the total counts of LOX-1-positive cells was examined. In in vitro study, we treated the cells with inflammatory cytokines tumor necrosis factor (TNF)- α and interleukin (IL)-1 β , oxidized LDL, and simvastatin. The mRNA expressions of LOX-1 and LF hypertrophy markers including type I collagen, type III collagen, and COX-2 were assessed by real-time reverse transcriptase polymerase chain reaction and the protein expression of LOX-1 by immunocytochemistry. Phosphorylation of MAPKs (p38 mitogen-activated protein kinase) and nuclear factor- κ B (NF- κ b) was evaluated by Western blot after treatment with oxidized LDL and simvastatin.

Results: The protein expression of LOX-1 and the CSA of LF were positively correlated ($r=0.37$). The in-vitro TNF- α

and IL-1 β treatments increased both mRNA and protein expression of LOX-1 in LF cells. Conversely, simvastatin treatment significantly neutralized the oxidized LDL-mediated induction of the mRNA expressions of type I collagen, type III collagen, and COX-2. Western blot analysis showed that oxidized LDL activated the signaling of p38, Erk (extracellular signal-regulated kinase), JNK (c-jun-N-terminal kinase), and NF- κ b in LF cells, and that simvastatin treatment reduced the phosphorylation of all these signaling.

Conclusions: We found a link between the oxidized LDL/LOX-1 system and LF hypertrophy. Our results indicate that the oxidized LDL/LOX-1 system may be a potential therapeutic target for LSS.

PS-FP-13-12

Laser Resonance Frequency Analysis of Pedicle Screw Stability: A Cadaveric Model Bone Study

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Purpose: Insertion torque and pull-out force are generally used for evaluating pedicle screw stability at the laboratory level. However, these techniques are bone-invasive, and it is therefore, impossible to perform them more than once after the pedicle screw has been inserted. We developed a novel device to perform resonance frequency analysis (RFA) using a laser that is non-invasive, non-contact, and repeatable technique for applications in the field of spinal surgery. Here, we examined the relationships among three test forces, namely, insertion torque, pull-out force, and Laser-RFA using model bones and cadaveric vertebrae.

Methods: Six different types of model bones (30 materials) and nine fresh non-frozen cadaveric human lumbar

vertebrae (18 pedicles) were tested. We inserted the Association pedicle screw (Kyocera Medical Corp., Osaka, Japan). Three kinds of test forces, namely, peak torque as a part of insertion torque (Nm), pull-out force (N), and Laser-RFA (Hz) were performed. Pearson's correlation coefficients (R) were used to evaluate relationships among the three test forces in model bones and vertebrae.

Results: Model bones: There was a strong correlation between insertion torque and pull-out strength ($R=0.901$, $p<0.001$) as previously reported. Laser-RFA showed strong correlations with insertion torque and pull-out strength using (both: $R=0.931$, $p<0.01$). Vertebrae: There was a strong correlation between insertion torque and pull-out strength ($R=0.823$, $p<0.01$). Laser RFA showed strong correlation with insertion torque ($R=0.811$, $p<0.001$) and moderate correlation with pull-out strength ($R=0.644$, $p<0.01$). Overall, the results for vertebrae tended to have lower correlation coefficients than those for model bone.

Conclusions: In dentistry, unlike insertion torque and pull-out strength, which reflect axial force, RFA reflects stability when the implant is tilted sideways, which is more similar to the multidirectional stress applied to implants in vivo. We previously indicated that the RFA tends to have a similar tendency even with the pedicle screw using the dental RFA device. There is a possibility that results of Laser-RFA indicate the correct pedicle screw fixation strength than insertion torque and pull-out strength as the same as dental RFA system. For the continued development of pedicle screws, a quantitative, repeatable, and non-invasive method to measure implant stability is necessary. Our findings lend a strong support for the hypothesis that Laser-RFA is a suitable method for evaluating pedicle screw stability.

PS-FP-13-14

Do Academic Pediatric Orthopaedists Who Treat Spine Receive Increased Industry Funding?

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Purpose: There is disparity within the orthopedic subspecialties with regards to industry funding in the United States, with spine surgeons being one of the highest compensated recipients, and pediatric orthopaedists being the lowest. The purpose of this study was to investigate the impact of clinical interest in spine on industry funding to pediatric orthopedic providers. We hypothesized that a clinical interest in the treatment of spine deformities would be associated with increased industry funding for pediatric orthopaedists. To provide appropriate perspective, this study also aimed to determine whether gender, academic rank, region, and scholarly productivity were associated with industry payments to pediatric orthopedic surgeons.

Methods: This study was a retrospective cross-sectional analysis of industry payments to academic pediatric orthopedic surgeons in 2016. Academic orthopedic surgery departments in the United States were identified using Fellowship and Residency Electronic Database. We collected publicly available data on specialty training, gender, faculty rank, region, and years since residency from institutional websites. Surgeons who completed at least one fellowship in pediatric orthopedics were included. Clinical interest in spine for pediatric orthopaedists was determined by information on faculty profile pages. Scholarly productivity data was obtained as H-index from Scopus, a major abstract and citation database for peer-reviewed studies. Industry funding data from 2016 was collected from the Centers for Medicare and Medicaid Services Open Payments Database.

Results: Of the 339 pediatric orthopaedists included in our analysis, 76% (257) were men and 24% (82) were

women. Approximately half (54%) declared an expertise in spine. Clinical interest in spine was not associated with increased industry payments: \$178 (interquartile range [IQR], \$66–\$1,500) vs. \$132 (IQR, \$35–\$1,442); $p=0.17$. Overall, men received more industry funding than women (median: \$162 [IQR, \$63–\$2,056] vs. \$111 [IQR, \$23–\$591]; $p=0.02$). Surgeons with higher H-index earned more from industry ($r=0.14$, $p=0.01$).

Conclusions: Despite spine surgeons being among the highest industry earners within the entire field of orthopedics, clinical involvement with spine was not associated with increased industry payments to academic pediatric orthopaedists. In the studied group, higher H-index and male gender were associated with increased industry payments, while region, years in practice, and academic rank were not.

PS-FP-13-15

The Efficacy of C5a Receptor Antagonist for Human iPSC-Derived Neural Stem/Progenitor Cell Transplantation in the Injured Spinal Cord of Mice

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Purpose: We previously reported the efficacy of human-iPS derived neural stem/progenitor cell (hiPSC-NS/PC) transplantation for spinal cord injury (SCI) in the sub-acute phase. However, this procedure is not effective in the acute phase due to the inflammatory response occurring immediately after SCI, which weakens transplanted cell survival and differentiation. C5a, which is one of the complement components, is a powerful chemoattractant and recruits inflammatory cells through binding C5a receptor. Therefore, the objective of this study is to suppress the inflammatory response immediately after SCI using C5a receptor antagonist (C5aRA) as an immunosuppressant, thus improving the efficacy of hiPSC-NS/PC transplantation for SCI in acute phase.

Methods: We used immunodeficient SCID-Beige mice that lack lymphocytes and natural killer cells. First, to evaluate the influence of C5aRA on the inflammatory response post-SCI, we induced a thoracic spinal contusion injury in mice. We quantified inflammatory cytokines and inflammatory cells in injured spinal cord tissues using quantitative polymerase chain reaction (qPCR), RNA sequence, and flow-cytometry. Next, we divided the SCI mice into four groups (phosphate-buffered saline [PBS] only, C5aRA only, PBS+transplantation [PBS+TP], C5aRA+transplantation [C5aRA+TP]). Immediately after SCI, C5aRA or PBS was administered once a day for 4 consecutive days, and then, 5.0×10^5 hiPSC-NS/PCs were transplanted into the lesion epicenter on day 4. We evaluated cell survival rate by Bioluminescent Imaging (BLI), hindlimb motor function by Basso Mouse Scale score, and the differentiation profile of the graft hiPSC-NS/PCs by immunohistochemistry.

Results: C5aRA administration significantly reduced interleukin (IL)-1b, IL-6, and tumor necrosis factor- α at 12 hours and macrophages at 4 days after SCI ($p < 0.05$). RNA sequence revealed that C5a inhibition reduced several inflammatory cytokines at 12 hours and 1 day after SCI and apoptotic marker at 4 days after SCI. The C5aRA+TP group had better functional improvement as compared to the PBS only group ($p < 0.05$). BLI revealed that the C5aRA+TP group had a significantly higher cell survival rate compared to the PBS +TP group ($p < 0.05$). There was no significant difference in the differentiation profiles of the graft hiPSC-NS/PCs between C5aRA+TP group and PBS+TP group.

Conclusions: The present study demonstrated that administration of C5aRA could suppress the inflammatory response during the acute phase of SCI, and also improve the survival rate of transplanted hiPSC-NS/PCs and enhance motor functional restoration. hiPSC-NS/PCs transplanted with C5aRA are a promising treatment for acute phase SCI patients.

PS-FP-13-16

Cytokine Changes Cultured Cells Harvested from Cervical Spine of Patients with Ossification of the Posterior Longitudinal Ligament

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Purpose: Ossification of the posterior longitudinal ligament (OPLL) progresses gradually for a prolonged period, which may lead to serious spinal cord complications. During OPLL, the regulation of cell differentiation at the ossification front plays an indispensable role. Additionally, cytokines production may be affected during the maturation of cells, such as chondroblast or osteoblast. This study is designed to investigate the cytokine networks in OPLL, using immunohistochemical examination and suspension array cytokine analysis. In particular, we focused on interleukin (IL)-6 and examined the correlation with the expression of transcription factors.

Methods: Ligamentous samples were harvested from 12 patients with OPLL who underwent spinal surgery (seven men and five women; six segmental types; six continuous types; mean age, 54.8 years at time of surgery; range, 42–92 years). Tissue sections were used for in-vitro culture to obtain primary cells through migration methods. Cytokine profile of cultured cells, deriving from OPLL patients, was compared with the cytokine profile of seven subjects from non-OPLL patients using the suspension array system to measure the concentration of 27 inflammatory cytokines or growth factors. The sections were also examined by immunohistochemistry for the expression of these cytokines. IL-6 was added (0, 10, 50, 100 ng/mL) to the cultured cells prepared by the migration method, the expression of Sox9, Runx2, and SIRT1 in the cells was observed by immunoblot analysis.

Results: Suspension array evaluation of the cultured cells showed that the expression of IL-6, basic fibroblast growth factor, and RANTES (regulated on activation, normal T cell expressed and secreted) were significant in patients with OPLL. In continuous type OPLL, the expression of IL-6 and RANTES were especially high. In OPLL groups, Sox9 and SIRT1 decreased and Runx2 increased due to the addition of IL-6. In the control group, no significant

change in expression was observed. Immunohistochemistry showed that Sox9 and SIRT1 expressions were positive for chondrocytes and mesenchymal cells on the ossification front, and Runx2 was strongly positive for mesenchymal cells near the ossification front.

Conclusions: SIRT1 is a factor involved in biological processes such as cell lifespan and aging. It has been pointed out that the expression of SIRT1 is suppressed by inflammatory cytokines, and the decrease in SIRT1 expression due to the addition of IL-6 makes osteoblast differentiation more significant than chondrocyte differentiation from mesenchymal stem cells. It was thought that this would promote ossification.

PS-FP-13-17

Automatic Recognition of Whole Spine Sagittal Alignment and Curvature Analysis through a Deep Learning Technique

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Purpose: Various spinal shapes and positional parameters have been proposed to describe human sagittal balance. Deep learning (DL) technique enables fast and accurate assessment of spinal parameters. Recent advances of spline sagittal curvature analysis for whole spine alignment, such as inflection points (IP) and apices, and their relationships between deformity correction prognosis had been recognized. The aim of this study was to develop a fully automatic system of whole spine sagittal alignment recognition and curvature analysis through DL technique.

Methods: From January 2018 to April 2020, a total of 1,500 consecutive whole spine lateral images were reviewed and 24 vertebral landmarks were annotated using costumed Matlab program. A two-staged Cascade Pyramid Network (CPN) DL model was trained for anatomical landmark detection, which enabling automatic recognition of all vertebral centers and their linear connections. The shape of sagittal alignment and Cobb angles represent lordotic

or kyphotic proportion of spine were approached by B-spline method. Inflection points of between kyphotic-lordotic junctions, and the apices of thoracic and lumbar area were generated by differentiation calculus. The reliability between DL model and traditional human annotations were assessed by intraclass correlation coefficient (ICC).

Results: A total of 300 images were randomly selected as testing data for model performance evaluation. The median localization errors from C2 to L5 of the CPN model were ranged from 1.81 to 3.07 mm. The whole spinal alignment curvature was automatically depicted in different categories of spine disease such as scoliosis, degeneration, vertebral fracture. The mean predicted C-T and T-L inflection point levels was located at C7±1 and L2±1. The mean predicted thoracic and lumbar apex levels was located at T8±2 and L4±1. Compared with the ground truth values, the predictions of CPN model showed excellent reliability in C-T, T-L inflection point and thoracic, lumbar apex (ICC=0.895, 0.952, 0.890, and 0.975, respectively). The ICC of Cobb angle represented the kyphotic and lordotic portion between two inflection points were 0.859 and 0.927, which also showed excellent reliability.

Conclusions: The deep learning framework was able to precisely predicted the position of vertebral centers, inflection points, apices and Cobb angles of the whole spine alignment with excellent accuracy. Future applications of surgical planning, database analysis, regular postoperative follow-up, and population-based screening could be explored for validations of the system and improve clinical efficiency.

PS-FP-13-19

Prognosis of Iatrogenic Spinal Cord Injury at a Major Rehabilitation Center in United Kingdom

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Purpose: The incidence of iatrogenic injury is more than what is quoted in the literature. Aim of our study was to determine the incidence and common etiologies responsible for iatrogenic spinal cord injury (SCI) in patients admitted at a dedicated spinal cord rehabilitation center.

This study aimed to study the prognosis of these patients in terms of neurological and functional outcomes for a period of 2 years.

Methods: This study analyzed all the SCI admissions to rehabilitation center over a duration of 4 years. These patients were followed at 6 weeks, 1 year, and at 2 years post the injury. The patients were assessed as per the American Spinal Cord Injury Association Scale for the neurological outcomes and as per the Spinal Cord Independence Measure version for the functional outcomes.

Results: Out of 528 admissions, 42 patients were reported to have iatrogenic SCI. The most leading cause of deterioration in our study was ischemic insult to the cord after vascular surgeries like aneurysm, arteriovenous (AV) malformation, aortic dissection, and AV fistula repair (eight cases), the 2nd most common cause was after an inadequate decompression (six cases), 3rd was mechanical pressure due to postoperative hematoma or a pseudomeningocele (five cases), 4th being implant related (three cases), and indirect cord manipulation as a result of deformity correction in scoliosis/kyphosis patients (three cases). One out of the three patients did show intraoperative signal loss on neuro-monitoring. Two patients had episodes of intraoperative and postoperative hypotension. Sixteen cases in our series didn't have an identifiable cause but a couple of cases showed postoperative high signals on T2 weighted magnetic resonance imaging scan, suggestive of a vascular insult as a result of sudden decompression and one patient deteriorated after postoperative infection; therefore, an infective embolus could well be attributed as a probable cause. At 2-year follow-up after rehabilitation, 17 patients started mobilizing, 22 were wheelchair bound and could not walk, and three died. Twenty-two patients were intact before they underwent the surgery and 16 patients were adolescent idiopathic scoliosis D preoperative. The Spinal Cord Independence Measure scores for these patients improved from a mean of 30.10 (standard deviation [SD]=19.56) to 59.09 (SD=23.62) at 2 years.

Conclusions: The incidence of iatrogenic SCI is higher than it is reported. There is a dire need of epidemiological studies to quantify these injuries and follow them up to see the prognosis of these patients in terms of neurological and functional outcomes.

PS-FP-13-23

Accelerated Recovery Protocol Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis Leading to Early Hospital Discharge

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Purpose: To determine if a standardized Accelerated Recovery Protocol (ARP) consisting of multimodal analgesia, early mobility exercises, and early patient feeding in adolescent idiopathic scoliosis (AIS) patients undergoing posterior spinal fusion (PSF) will lead to better pain control, lesser opioid usage, and related side effects, and early hospital discharge.

Methods: All subjects with AIS who underwent posterior spinal fusion surgery by a single attending surgeon were included in the project. Phase 1 is a retrospective cohort study from January 2015 to December 2016. We divided the cohort into two: baseline group (B) patients prescribed with patient-controlled analgesia (PCA) morphine and phase 1 group (P1) patients prescribed with PCA morphine plus ketamine 1:1 concentration. Our physiotherapists provided once-a-day exercise sessions on weekdays but not weekends and holidays. Surgeons started soft diet on postoperative day (POD) 3. Phase 2 is a prospective interventional audit that followed ARP from June 2017 to July 2020. Pain treatment included PCA Morphine plus Ketamine 1:1 concentration. Paracetamol, Ibuprofen or Etoricoxib, and Diazepam or Orphenadrine were given to all groups, while Clonidine was only prescribed for P2 patients. All parental pain treatments in this project were converted to oral when a patient tolerated a soft diet. Our physiotherapists increased visits to twice a day during weekdays and once on weekends and holidays. Soft diet initiated on POD 1, then full meals on POD 2. We conducted a post implementation (PI) audit from August 2020 to January 2021. The primary outcomes were mean daily pain scores and mean daily opioid usage (intravenous

Morphine equivalent mg/kg/day). Secondary outcomes included hospital stay and frequency of opioid-related side effects requiring intervention.

Results: The number of subjects per group was; 15 in B, 16 in P1, 25 in P2, and 11 in PI. The frequency of subjects who reported pain scores of more than 6 in groups P1, P2, and PI was significantly less when compared to group B on POD1 ($p=0.004$), POD2 ($p=0.022$), and POD3 ($p=0.000$). Morphine usage was significantly lower in P1, P2, and PI than B (POD1: $p=0.041$, POD2: $p=0.000$, POD3: $p=0.002$). The PI subjects were discharged home 38.4% earlier. Fewer patients in groups P1, P2, and PI, reported nausea and vomiting requiring additional ondansetron (30% less). Nil reported readmission due to uncontrolled pain.

Conclusions: The standardized ARP implementation leads to lower pain scores, lesser opioid usage, reduced frequency of nausea and vomiting, and early hospital discharge.

PS-FP-13-24

How Much Experience Is Required to Acquire the Skills for Spinal Surgery? Results of a Survey of Spine Surgeons

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Purpose: Surgical experience is essential to master the skills required in spinal surgery. Practical training on actual patients is indispensable when learning proper techniques. However, no report has evaluated the number of spinal operations that a surgeon needs to acquire the skills required for each surgical technique before being able to perform the procedure independently.

Methods: This study was aimed at conducting an e-mail survey. We asked 70 spine surgeons about 12 types of spinal surgery, namely upper cervical surgery, anterior cervical fusion, posterior cervical decompression/fusion, anterior lumbar fusion, posterior lumbar decompression, endoscopic posterior lumbar decompression, posterior lumbar decompression and fixation, lumbar disk hernia-

tion, endoscopic lumbar disk herniation, spinal tumor resection, spinal kyphosis surgery, and percutaneous vertebroplasty. For each procedure, they were asked to identify whether they could (A) not perform the procedure at all, (B) perform the procedure with the help of a senior surgeon, or (C) perform the procedure independently. If the participants chose A or B for any of the procedures, they were asked how many cases they felt they needed to acquire the necessary skills to perform the procedures independently. Those who chose C for any procedure were asked to state the number of cases they actually performed to acquire the required skills. The participants also responded to questions on 10 items regarding surgical training. They were asked to rate the usefulness of the surgical training methods on a 5-point scale.

Results: In total, 55 surgeons completed the survey. The participants who reported an inability to perform the following surgeries (group A) required significantly more cases than those who reported complete independence (group C): upper cervical spine surgery (A/C: 19.3/7.3), anterior cervical decompression/fusion (28.8/6.7), posterior cervical decompression/fusion (27.3/9.5), lumbar disk herniation (26.7/12.6), endoscopic lumbar disk herniation (24.2/10.2), spinal tumor resection (37.2/6.5), and spinal kyphosis surgery (32.3/10.3). More than 80% of the participants responded that operations with assistance from a senior surgeon; lectures and self-education with surgery manuals, articles, and textbooks; and surgical videos were effective training resources. By contrast, >50% of the participants responded that surgical training on animals was ineffective.

Conclusions: We conducted a survey of 55 spine surgeons to determine the number of cases required to achieve autonomy for 12 different spinal surgeries. Surgeons who could not yet independently perform a specific surgery needed more cases than those who could perform the procedures independently.

PS-FP-13-25**Novel In Vivo Imaging System of Grafted Human Induced Pluripotent Cells-Derived Neuron Activity after Spinal Cord Injury**

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Purpose: Spinal cord injury (SCI) is a devastating and incurable disease. NS/PCs (neural stem/progenitor cells) transplantation is one of the most promising therapies for SCI. NS/PCs integrate into spinal injury lesion and enhance motor function recovery. The grafted cells can mainly differentiate into neurons, but only a little has been reported if grafted neurons actually show action potential in vivo. The aim of this project is to establish a novel in vivo imaging system of neural activity of grafted neurons, and to reveal the connectivity between host circuit neurons projecting to the lesion and grafted neurons.

Methods: First, dorsal column lesions to the C4 spinal cord and subacute grafting on immunodeficient mice were performed. We transplanted NS/PCs derived from human induced pluripotent cells (iPSCs) that has AkaBLI system expressed understream immediate early gene (IEGs; an indirect marker of neuronal activity) promotor. AkaBLI system is a bioluminescence in vivo imaging system that produces bright emissions so that we can detect the weak expression of IEGs. Second, we also introduced excitatory designer receptors exclusively activated by designer drugs (DREADD) transgene, hM3Dq, into corticospinal neurons injecting AAV vector into host sensorimotor cortex at six weeks after transplantation. Three to four weeks after corticospinal tract labeling when viral vector permits efficient anterograde access to the C4 lesion, we assessed the genuine effect of corticospinal neurons' activation on grafted cells measuring their photoncounts. We can activate DREADD system administering clozapine-N-oxide (CNO) that is the prototypical DREADD activator.

Results: Because of corticospinal neurons' activation caused by excitatory DREADD system in vivo, the photoncount of grafted cells with CNO administration increased indirectly, reached 1.5 times as high as that without CNO on average. As the positive control, grafted cells' direct activation caused by excitatory DREADD system led to more than 3 times higher photoncounts of grafted

cells in another mouse. Immunohistochemistry showed the luminescence and Venus fluorescence that makes fusional protein with AkaLuc were related to positive correlation, that is consistent with in vitro data.

Conclusions: Grafted neurons were indirectly activated after corticospinal neurons' activation via DREADD system. That implies that synaptic connectivity between host corticospinal neurons and grafted neurons had been formed in vivo. We confirmed this active synaptic connection occurred in free moving animals applying this novel in vivo imaging system. In the future, we can assess the effect of all kinds of synaptic organizers, or even cell-type associated differences regarding graft-host synaptic differentiation.

PS-FP-13-27**Comparison of the Global Sagittal Alignment and Surgical Outcomes for Osteoporotic Vertebral Body Fracture Between Lower Lumbar and Thoracolumbar Area**

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Purpose: There are few papers evaluated sagittal alignment of the patients who underwent surgery for the osteoporotic vertebral fracture (OVF) because of the difficulty in standing due to late-onset paralysis. The purpose of this study is to evaluate the global spinal parameters and to compare the surgical outcomes of lower lumbar fractures with that of the thoracolumbar fracture.

Methods: Retrospective study at a single center. Thirty-three patients of the 123 patients who underwent surgery for OVF with a minimum follow-up of 2 years after surgery were identified. These patients were divided into two groups. Fractures in the 10th to 2nd lumbar vertebrae were defined as the thoracolumbar group (group TL: 27 cases), and fractures in the 3rd to 5th lumbar vertebrae were defined as the lower lumbar group (group LL: six cases). The average number of fixed intervertebral discs (group TL, LL) was 5.9 ± 0.4 and 7.8 ± 2.8 ($p=0.20$). The numbers of patients who underwent posterior fusion down to the pelvis are 4 (14.8%) in the group TL and 3 (50%) in group LL, respectively ($p=0.06$).

Results: Preoperative spinal parameters (group TL, LL)

are sagittal vertical axis (SVA): 81.8 ± 10.4 mm, 144.2 ± 32.9 mm ($p < 0.05$), pelvic tilt: $27.7^\circ \pm 2.1^\circ$, $44.4^\circ \pm 3.5^\circ$ ($p < 0.05$), pelvic incidence: $49.7^\circ \pm 1.8^\circ$, $64^\circ \pm 2.2^\circ$ ($p < 0.05$), lumbar lordosis: $26.1^\circ \pm 3.9^\circ$, $7.6^\circ \pm 4^\circ$ ($p < 0.05$). The amount of SVA change from postoperative to final observation (group TL, LL) was 28.7 ± 9.7 mm, 90 ± 13.2 mm ($p < 0.05$), and the increase in local kyphosis after surgery (group TL, LL) was $4.9^\circ \pm 1.4^\circ$, $14.4^\circ \pm 8.0^\circ$ ($p < 0.05$). By the time of the final observation, proximal junctional kyphosis incidence (group TL, LL) was 25.9%, 50% ($p = 0.25$). The reoperation rate (group TL, LL) was 7.4%, 16.7% ($p = 0.48$). The Japanese Orthopaedic Association score (group TL, LL) was evaluated on a scale of 15 points, preoperatively 7.7 ± 0.4 , 6.6 ± 1.4 points ($p = 0.30$), postoperatively 10.6 ± 0.4 , 11.0 ± 0.8 points ($p = 0.68$).

Conclusions: There were not significant differences in radiographical and clinical outcomes between two groups. In group LL, the longer fixation than previous reported may cause less complication rate compared with group TL.

PS-FP-13-28

Comparison of the Stability and Osseointegration of Different Intravertebral Fixators

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Study Design: Clinical animal studies.

Purpose: To determine the safety and utility of a novel modular spine block (VeroPlaGo, VPG) before its use in human subjects.

Overview of Literature: It is an intuitive notion that reducing the use of bone cement while maintaining the correction of the vertebral compression fracture would contribute to a decrease in the occurrence of the above-mentioned complications. The theoretical advantages of modular spinal blocks (VeroPlaGo, VPG) include its ability to support and maintain vertebral height, without incurring the complications related to the use of bone cement.

Methods: VPG was designed to provide intravertebral

fixation at the compressed thoracolumbar segments. Four pigs were implanted at each of the six lumbar segments with the following five type of constructs: (1) solid (VPG-0), (2) perforated (VPG-1), (3) hollow (VPG-2), (4) three-dimensional printed (VPG-3), and (5) intravertebral expandable pillar (I-VEP). All subject pigs received X-ray, computed tomography (CT), micro-CT and histomorphometry evaluation.

Results: All implants were implanted securely without any occurrence of major complications. Decent levels of alignment of the implants were shown in the series of X-ray and CT inspections. High levels of bone ingrowth and bone ongrowth are observed in the results of the micro-CT and histomorphometric evaluations. The average results of bone volume/tissue volume ratio (BV/TV), bone surface/tissue volume ratio (BS/TV), trabecular bone thickness (TBT), and trabecular bone number (TBN) were highest in group VGP-2 while the values of trabecular bone separation (TBS) were the lowest. However, no statistically significant differences were found between the various VGP groups and commercialized I-VEP group in terms of BV/TV, BS/TV, TBT, TBS, and TBN results.

Conclusions: Similar levels of osteointegration were observed to different VPG construct each with different rates of hollow/solid ratio in microstructure analysis in in-vivo porcine models. All the different VPG constructs showed similar levels of stability and implant-bone contact in comparison with the commercially available I-VEP.

PS-FP-13-29

Do Ovariectomy and Calcium-Restricted Diets Create Osteoporosis in Porcine Model?

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Study Design: Clinical animal studies.

Purpose: To evaluate the mid-term changes in bone mineral density (BMD) with calcium-restricted and ovariectomized miniature porcine models as a large animal model in osteoporosis.

Overview of Literature: Compared to canines, dairy goats or sheep, the vertebral anatomies of pigs resemble that of humans the most. The physiological characteristics of pigs are very similar to those of humans. Pigs are relatively easy to obtain at a reasonable price, which is why they are normally preferred over other types of animal models.

Methods: Four 6-month-old (T0), female ovariectomized miniature pigs that had been fed low calcium diets were enrolled in this study. The body weight of each pig was recorded. Ovariectomy were operated on each pig at the age of 1 year and 3 months (T1). The pigs were fed a normal diet prior to the ovariectomy, but switched to a diet with restricted calcium content afterwards. Each of the pigs received dual-energy X-ray absorptiometry once before ovariectomy, and once every three months (T2, T3, T4) after the ovariectomy to evaluate the changes in BMD. All the BMD readings were checked 3 times.

Results: The body weight of all four subject pigs increased significantly during this study ($p < 0.05$). The initial changes in both the BMC and BMD levels (T1/T2) were found to be statistically insignificant ($p = 0.325$ and $p = 0.137$, respectively). However, upon comparison of later BMC and BMD changes (T3/T4, T1/T3 and T1/T4), statistically significant elevations were found ($p < 0.05$ for all three comparisons). Between the time stages T2 and T3, BMC showed a statistical increase ($p < 0.05$) while the BMD did not ($p > 0.05$).

Conclusions: Ovariectomy and calcium-restricted diets are ineffective in achieving an osteoporotic porcine model based on BMD assessments. BMD levels of the subject pigs continued to rise until the point at which body growth had stopped.

PS-FP-13-30

Consideration of Cryopreservation Solutions and Methods of Nucleus Pulposus Cells for Industrialization

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Purpose: We previously reported that nucleus pulposus cells (NPC) showed no significant difference in their viability, differentiation ability, and extracellular matrix production before or after cell cryopreservation. This suggested that activated NPC could be used as a commercial, mass-produced, off-the-shelf regenerative therapeutic product, but still, there is a large difference between the clinical application and the laboratory-based reports. For example, the time required for cryopreservation is rarely taken into consideration, and the cytotoxicity of animal serum and dimethyl sulfoxide (DMSO) may present safety concerns for clinical applications. Therefore, we investigated the effects of the cryopreservation solutions within real-world mass-production time circumstances.

Methods: Primary human NPC were collected from young disc hernia patients ($n = 5$; mean age, 20.4 years) after consent, and isolated according to previous report. The samples were kept at room temperature or on ice for 0.5, 1, 2, 3, 4, and 5 hours, within one of six cryopreservation solutions (i.e., CELLBANKER 1 [CB1], STEM-CELLBANKER GMP grade [SCB], STEM-CELLBANKER DMSO Free GMP grade [SCBD-Free], CryoStor CS10 [CS10], CP-1, and Pro Freeze-CDM [PF]). After these defined incubation times, cell viability was either directly analyzed or analyzed following cryo-storage at -80°C for 1 day. Additionally, thawed cells were cultured for 5-7 days and analyzed on their proliferation- and Tie2-positivity rate.

Results: Comparing the CELLBANKER series, only CB1 showed satisfactory cell viability after 3 hours (CB1: mean, $95.8 \pm 3.7\%$; SCB: mean, $64.6 \pm 2.1\%$; SCBD-Free: mean, $51.3 \pm 2.2\%$; $p = 0.021$). Most cryopreservation solutions resulted in rapid cell viability loss over time, while CB1 and CS10 showed limited viability loss. If the incuba-

tion time was limited to 3 hours, both solutions resulted in 90% or more cell viability after thawing. Also, CB1 and CS10 incubated cells showed higher proliferation rates (CB1: 93.3, CS10: 43.3-fold increase) after thawing, compared to other cryopreservation solutions (SCB: 24.0, SCBD-Free: 16.0, CP-1: 29.2, PF: 28.3-fold increase). Furthermore, CS10 had a highest Tie2 positive rate of 12.6% after culturing for 5 days after thawing, compared to other cryopreservation solutions (CB1: 6.6%, SCB: 5.1%, SCBD-Free: 5.1%, CP-1: 4.3%, PF: 2.5%).

Conclusions: CB1 had the highest cell viability and cell proliferation rate after thawing, although CS10 showed comparable performance and higher Tie2 positive rates. It proved difficult to maintain cell viability without DMSO for human NPC; however, animal serum could be removed by using CS10.

PS-FP-13-31

Clinical Efficacy of Ultrasound Guided Bilateral Erector Spinae Block for Single Level Lumbar Fusion Surgery: A Prospective, Randomized, Case-Control Study

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Purpose: Post-operative experience plays a vital role in recovery of a patient and does not depend on the type and quality of the surgical procedure alone. Non-opioid therapies have become part of the multimodal analgesic regimen for better pain control and reduced opioid related side effects. Most recently evolved among these are the regional anesthetic techniques, such as the thoracolumbar interfascial plane (TLIP) block and the erector spinae (ESP) block. The aim of this study is to assess the efficacy of ultrasound guided (US) ESP block for postoperative analgesia after a single level lumbar spine fusion surgery compared with conventional (opioid-based) multimodal postoperative analgesia.

Methods: This is a prospective randomized controlled double blinded study including 100 patients requiring single level lumbar fusion surgery. Patients were randomly

allocated into block (multimodal analgesia with US-ESP) and control groups (only multimodal analgesia). Patients were assessed intra-operatively for blood loss, duration of surgery, opioid usage and amount of muscle relaxants used. Postoperatively the parameters studied included Numeric Pain Intensity (NRS) score, modified observer's alertness/sedation score (MOASS), satisfaction score, and total amount of opioids consumed in the initial 24 hours. Continuous variables were analyzed using Student t-test and categorical variables were analyzed using either the chi-square test or Fisher's exact test. A p-value <0.05 was considered as statistically significant.

Results: Total opioid consumption (TOC) in the 24 hours from the start of surgery was significantly lower in the block group than the control group (105.0 ± 15.15 mcg vs. 158.00 ± 23.38 mcg, $p < 0.001$). The total muscle relaxant consumption during surgery was also significantly less in the block group as compared to the control group (51.90 ± 3.17 vs. 57.70 ± 5.90 , $p < 0.0001$). The intra-operative blood loss was significantly less ($p < 0.0001$) in the block group (303.00 ± 86.55 mL) as compared to the control group (437.00 ± 116.85 mL). Compared to the block group, the control group's pain score (NRS) was significantly higher in the first 48 hours following surgery. The MOASS score was significantly less in control group compared to block group in the immediate postoperative period (0–4 hours). The satisfaction score was significantly higher in the block group as compared to the control group (9.52 ± 0.65 vs. 8.22 ± 0.79 , $p < 0.0001$).

Conclusions: Ultrasound guided ESP block for single level lumbar fusion surgery is an excellent component of multimodal analgesia for alleviating the perioperative pain.

PS-FP-13-32

The Effect of Anti-Receptor Activator of Nuclear Factor- κ B Ligand Monoclonal Antibody on Spinal Fusion in a Mouse Spinal Fusion Model

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Purpose: Spinal fusion surgery is commonly used to treat unstable spinal condition. The purpose of fusion surgery is to gain a solid union and bony fusion. However, bone fusion sometimes delays or fails and pseudarthrosis is well described complication of fusion surgery. Anti-receptor activator of nuclear factor- κ B ligand (RANKL) monoclonal antibody is widely used for osteoporosis patient. However, the effect of anti-RANKL monoclonal antibody in spinal surgery is unknown. Therefore, we investigated whether anti-RANKL monoclonal antibody accelerate bone fusion in a mouse spinal fusion model.

Methods: A total of 24 male, 8-week-old, C57BL/6J mice underwent posterior spinal arthrodesis surgery using collagen sponge. The animals were randomly assigned to one of the following groups: saline containing collagen and saline injection (group 1); BMP-2 containing collagen (containing 1.0 μ g in each sponge) and saline injection (group 2); saline containing collagen and anti-mouse RANKL-neutralizing monoclonal antibody injection (OYC1: 5 mg/kg) (group 3); BMP-2 containing collagen and OYC-1 injection (group 4). OYC1 or saline were injected the day after surgery. The quantitative evaluation of bone fusion was performed by direct palpation, computed tomography (CT), and micro-CT.

Results: Newly formed bone were visualized in treated with BMP-2 (group 2 and group 4), whereas no bone formation were observed in treated without BMP-2. Bone fusion was accelerated in group 4 compared to group 2 (group 2: 4 weeks, group 4: 3 weeks). Furthermore, in mi-

cro-CT analysis, group 4 showed the superior results than the group 3 (volumetric bone mineral density [151.5 mg/cm³ vs. 488.2 mg/cm³], BV/TV [16.8% vs. 71.8%], trabecular thickness [9.4 μ m vs. 55.5 μ m], trabecular separation [51.6 μ m vs. 19.7 μ m]; group 3 vs. group 4, all $p < 0.05$).

Conclusions: Postoperative administration of anti-RANKL monoclonal antibody significantly increase fusion rate and improve the quality of newly formed bone. Our result suggests that anti-RANKL monoclonal antibody might be a good option in management of spinal fusion surgery.

PS-FP-13-34

Efficacy of Human Induced Pluripotent Stem Cell-Derived-Gliogenic NS/PCs for Transplantation in the Chronic Phase of Spinal Cord Injury

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Purpose: One of the main pathologies in spinal cord injury (SCI) is demyelination of neuronal axons, thus remyelination of host axons by grafting glial cell including oligodendrocyte progenitor cells is considered as a promising strategy to restore function in damaged spinal cord. We have reported efficient remyelination by transplanting human induced pluripotent stem cell-derived gliogenic NS/PCs (hiPSCs-gNS/PCs) for SCI mice in the subacute phase. However, demographically, most patients with SCI are in the chronic phase, and therapeutic development would be imperative for the patients. Therefore, the purpose of the present study was to investigate the efficacy of the hiPSCs-gNS/PCs for the rodent model of SCI in the chronic phase.

Methods: Contusive SCI was induced at the Th10 level in immunodeficiency rat, and the hiPSCs-gNS/PCs were transplanted into 2 points around lesion epicenter 42 days after the injury. An equal volume of phosphate buffered saline was injected for the control group. Motor function of injured rat was assessed by the Basso, Beattie, Bresna-

han Locomotor Rating score, and DigiGait analysis. Histological analyses were performed to examine the survival and differentiation of the grafted cells.

Results: Histological analyses revealed that the transplanted cells well survived and migrated far into the host spinal cord without any tumor formation. The transplanted cells differentiated into three neural lineages including neurons, astrocytes and oligodendrocytes. The area with regenerative fibers (pGAP43+ area) in the transplanted group were significantly larger than that in the control group. The active remyelination on damaged axon in injured spinal cord was observed in the transplanted group by immunoelectron microscopy. Importantly, hindlimb motor function named BBB score was significantly improved in the transplanted group. Rotarod tests revealed a significant motor functional improvement in the transplanted group at 12 weeks after transplantation.

Conclusions: The past studies of cell transplantation in the chronic phase reported the limited efficacy. This study has proven that the transplanted cells contributed to the improvement of motor function with robust remyelination for the demyelinated axon and the regenerative fibers. Our laboratory is planning clinical application for spinal cord injury in the future, and the result of this study is expected to be a promising cell source for treating SCI even in the chronic phase.

PS-FP-13-36

A Retrospective Audit of Effectiveness and Reliability of Telemedicine Consultations in Patients with Spinal Ailments

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Purpose: In view of the ongoing pandemic, telemedicine has been increasingly adopted worldwide. This retrospective cohort study was planned to evaluate the effectiveness of telemedicine for patients with spine ailments; and to assess the satisfaction rates and concerns of spine surgeons and patients regarding telemedicine consultations in Indian scenario.

Methods: Telemedicine appointments for spine patients were conducted through “Zoom-Healthcare” online plat-

form between April and November 2020 in a tertiary-care spine center. Questionnaires (including nine and five questions, respectively) were filled by patients and doctors after their consultations. The questionnaire included questions on overall satisfaction, time consumption, ease of setting-up appointment, ease of communication, influence on decision making and patient preference.

Results: Overall, 70.1%, 23.6%, and 6.3% of patients replied that they were “very satisfied”, “satisfied”, and “dissatisfied” with their telemedicine appointments. Among post-operative follow-up patients, 69%, 30.2%, and 0.8% expressed that they were “very satisfied”, “satisfied”, and “dissatisfied”, respectively with telemedicine. At the end of the session, 88.5% of patients opined that they would still prefer a telemedicine appointment for the completed consultation; and 93.4% were happy to use telemedicine for future visits. The doctor’s responses were “very satisfied” or “satisfied” on 96.5% of occasions overall. The doctors required approximately 24.1 minutes for conducting a telemedicine appointment. Three major concerns for doctors included difficulty in procuring good-quality magnetic resonance imaging (17%), problems with connectivity (14.6%), and difficulty in eliciting certain physical findings (13.2%).

Conclusions: Telemedicine is an effective alternative to in-person visits for the assessment of patients with spine ailments. A majority of the post-operative follow-up patients were satisfied with their remote consultations. In specific situations, these remote visits may need to be complemented by in-person visits for thorough evaluation.

PS-FP-14-1

Intradiscal and Epidural Platelet-Rich Plasma Injection for the Treatment of Chronic Discogenic Low Back Pain

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Purpose: Platelet-rich plasma (PRP) has been found to be effective for a variety of musculoskeletal conditions. The treatment of discogenic pain with PRP is under investigation. This study to explore the clinical effects and safety of PRP in treating chronic discogenic low back pain.

Methods: The clinical data of 21 patients (22 disc) from June 2017 to December 2018 were diagnosed with discogenic low back pain by clinical means, imaging. Inclusion criteria for this study included chronic low back pain without leg pain for more than 3 months; one or more lumbar discs degeneration, as indicated via magnetic resonance imaging; and at least one symptomatic disc, confirmed using standardized provocative discography and exclusion of other structures included discitis and tumor. Patients underwent treatment of intradiscal and epidural injection of PRP at one or multiple levels. Outcome measures included the use of a Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) score. Patients were followed up at intervals of preoperative, postoperative 1 month, 3 months, and last follow-up.

Results: Data were analyzed from 21 patients (11 men and 10 women; mean age, 37.8 years). Following treatment, no patient experienced adverse events or significant narrowing of disc height. The mean preoperative low back pain VAS scores decreased from 6.81 ± 0.83 to 1.44 ± 0.58 at 1 months after surgery, 1.38 ± 0.51 at 3 months after surgery, 1.02 ± 0.58 at final follow-up after surgery. The mean preoperative ODI scores decreased from 75.2 ± 13.3 to

33.4 ± 10.8 at 1 months after surgery, 25.2 ± 3.2 at 3 months after surgery, 20.2 ± 1.2 at final follow-up after surgery ($p < 0.01$).

Conclusions: This study demonstrated that intradiscal and epidural injection of autologous PRP in patients with low back pain was safe, with no adverse events observed during follow-up. Intradiscal and epidural PRP injection is a safe and a possibly effective treatment for discogenic low back pain. Randomized placebo-controlled trials are needed to further evaluate the efficacy of this treatment.

PS-FP-14-2

One-Year Clinical Result of Condoliase for Lumbar Disc Hernia

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Purpose: Condoliase is a minimally invasive treatment of lumbar disc hernia (LDH), started in August 2018 and is becoming popular in Japan. However only short-term results have been reported, and there have been no reports on clinical results for more than 1 year. The purpose of this study was to evaluate 1-year clinical results of condoliase for lumbar disc hernia.

Methods: A total of 18 patients with LDH (12 males, six females; mean age, 31.5 years) who underwent injection of condoliase between August 2018 and September 2020 were followed for 1 year after administration. All patients had a subligamentous type hernia at L3/4, L4/5, L5/6, or L5/S1 verified on magnetic resonance imaging. We examined the Visual Analog Scale (VAS), complications, imaging parameters, before, and 3 weeks, 3 months, and 1 year after administration.

Results: Condoliase improved VAS score (back pain, leg pain, leg numbness) after 3 weeks administration, and significantly improved after 3 months. The mean VAS scores at baseline and 3 months were 51 mm and 22 mm in back pain, and 72 mm and 23 mm in leg pain, and 53 mm and 16 mm in leg numbness. The improvements of symptoms were maintained until 1 year. Condoliase did not cause clinically important adverse events, but allergy-like symptoms (rash) were observed one patient. One patient underwent surgery because of no improvement symptoms after administration. In the imaging analysis, a significant

decrease in disc height were observed after 3 weeks, but after that no significant decrease after 3 months and 1 year. Disc height decreased from 9 to 7 mm 3 weeks after administration, and 6.5 mm and 6.0 mm in 3 months and 1 year.

Conclusions: In this report, the effectiveness of condoliase at 3 months after administration could be maintained even after 1 year. The decrease in disc height, which is concern with condoliase, was observed in the early stage up to 3 months after administration, but no significant progression was observed up to 1 year after that. Condoliase is a safe and effective treatment for LDH. Further studies needed to confirm effectiveness of condoliase for recurrent LDH after surgery.

PS-FP-14-3

The Effectiveness of Chemonucleolysis with Condoliase for Treatment of Painful Lumbar Disc Herniation

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Purpose: Chemonucleolysis with condoliase, which degrades chondroitin sulfate, could be a new, minimally invasive therapeutic option for patients with lumbar disc herniation (LDH). The purpose of this study was to analyze prognostic factors for clinical outcomes in LDH patients subjected to chemonucleolysis with condoliase.

Methods: Inclusion criteria for this procedure were (1) 18–70 years of age; (2) unilateral leg pain and positive straight leg raise (SLR) (<70°) or femoral nerve stretching test; (3) subligamentous extrusion verified on magnetic resonance imaging; (4) neurological symptoms consistent with a compressed nerve root on magnetic resonance imaging images; and (5) minimum 6 months of follow-up. In total, 82 patients (55 men, 27 women; mean age, 47.2±15.5 years; mean follow-up, 9.1±3.0 months) who underwent chemonucleolysis with condoliase for painful LDH were included. An improvement of 50% or more in

the Visual Analog Scale (VAS) of leg pain was classified as effective.

Results: Seventy patients (85.4%) were classified into the effective (E) group and 12 patients (14.6%) into the less-effective (L) group. Surgical treatment was required in four patients. No severe adverse complications were reported; 41.3% of the patients developed disc degeneration of Pfirrmann grade 1 or more at the injected disc level. Univariate analysis revealed that young age ($p=0.036$), without history of epidural or nerve root block ($p=0.024$), and injection into the central portion of the intervertebral disc ($p=0.014$) were significantly associated with clinical effectiveness. A logistic regression analysis revealed that injection into the central portion of the intervertebral disc ($p=0.049$; odds ratio, 4.913; 95% confidence interval, 1.006–26.204) was significantly associated with clinical effectiveness.

Conclusions: Chemonucleolysis with condoliase is a safe and effective treatment for painful LDH; 85.4% of the patients showed improvement after the treatment without severe adverse events. To obtain the best outcome, condoliase should be injected into the center of the intervertebral disc.

PS-FP-14-4

Transforaminal Full Endoscopic Discectomy and Thermal Annuloplasty for High Signal Intensity Zone Radiculopathy

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Purpose: High signal intensity zone (HIZ), presented in 1992, is a high signal change on the posterior site of intervertebral disc in T2 weighted magnetic resonance imaging. It is said that HIZ means the fibrous tears after degeneration of the disc and the secondary inflammation causes for the pain source of the chronic low back pain. We sometimes see the patients who suffer radicular pain and numbness of their buttock and leg without the compression to the nerve root. We named this new pathology as “HIZ radiculopathy” and have performed transforaminal full endoscopic spine surgery (TF-FESS) under local anesthesia if the conservative treatment was not effective.

Methods: In this retrospective study, 21 patients (male 12, female nine; average age, 48 years old) underwent TF-FESS due to HIZ radiculopathy in our hospital. Intraoperative findings, surgical time, blood loss, radicular pain (MacNab's criteria), low back pain (VAS), and the period for return to job were investigated using medical record.

Results: Average surgical time was 64 minutes; blood loss was uncountable in all cases. MacNab's criteria accepted excellent 18, good 2, and fair 1. The average perioperative

VAS was improved from 8 to 2. There is no complication intra- and postoperatively in all cases and the average period for return to job was 11 days. In some cases, vessels and bleeding were seen endoscopically at anulus fibrosus.

Conclusions: It may occur the radicular pain with the inflammation around the nerve root even if the compression to the nerve root is not severe. TF-FESS might be good indication and effective for HIZ radiculopathy if the patients would like to return to job earlier.