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# ASIAN SPINE JOURNAL

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), and Korean Society of Spine Surgery (KSSS),  
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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## 12th Combined Meeting of Asia Pacific Spine Society & Asia Pacific Paediatric Orthopaedic Society

### The Surgical Strategies for Cervical Ossification of the Posterior Longitudinal Ligament

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**Purpose:** Various surgical approaches had been proposed effective in improving neurologic functions for managing cervical ossification of the posterior longitudinal ligament (OPLL). The surgical options for cervical OPLL are anterior-only approach, posterior-only, or combined posterior-and-anterior. However, to date, there is still a lack of consensus regarding the choice of the surgical approaches.

**Materials and Methods:** Twenty-five cases of cervical OPLL were enrolled on this study. Anterior approaches, anterior cervical discectomy and fusion (ACDF) five cases, ACCF 10 cases, posterior-only eight cases, combined posterior-and-anterior two cases were included. The Japanese Orthopaedic Association (JOA) score, Neck Disability Index (NDI), and 36-item Short-Form Health Survey (SF-36) were used to assess the clinical status of the patients before the operation and at the follow-up. The following time was at least 2 years.

**Results:** Anterior approaches include anterior cervical corpectomy and fusion (ACCF) or ACDF. If the ossification is localized to only one intervertebral disk space ACDF was selected; If the ossification is localized to only one segment (C4, C5, C6) and its disk space above and below ACCF was selected; For the flat, continuous (>3 segments) ossification of OPLL, or segmental OPLL of C2, C3, instrumented laminoplasty is recommended. Circumferential decompression in two stages is also an option for long-segment cervical (>3 segments) OPLL as well as with one or two beak type compression. Multilevel open-door laminoplasty was performed followed by anterior corpectomy at the most stenotic level. The laminoplasty was performed first to allow the spinal cord to drift back and

decrease the risk associated with anterior-based decompression. The JOA scores, NDI, and SF-36 significantly improved in the final follow-up, JOA from 10.5 to 14.8, NDI from 36.47 to 22.90, and SF-36 from 35.48 to 45.76.

**Conclusion:** Each of the approaches has its advantages as well as disadvantage and should be tailored to each individualized condition. Along with the clinical findings, radiologic findings are important in deciding the optimal surgical approach. Since the anterior approaches could directly decompress the spinal cord, one would.

### Selective Blocking Laminoplasty in Cervical Laminectomy and Fusion to Prevent Postoperative C5 Palsy

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**Purpose:** To compare the incidence of postoperative C5 palsy after performing selective blocking laminoplasty concurrently with cervical laminectomy and fusion (CLF) to those of conventional CLF.

**Materials and Methods:** We compared the occurrence of postoperative C5 palsy, as well as clinical, radiologic, and surgical outcomes, between the two groups at 1-year follow-up. Of 116 cervical myelopathy patients with degenerative cervical myelopathy, ossification of the posterior longitudinal ligament, and multilevel disc herniation, 93 patients (69 in group A [CLF group] and 24 in group B [selective blocking laminoplasty with CLF, CLF-S group]) were included in the study. The primary outcome measure was the occurrence of postoperative C5 palsy. Secondary end points included (1) clinical outcomes based on pain intensity, Neck Disability Index (NDI), Japanese Ortho-

paedic Association (JOA) score; (2) radiologic outcomes including cervical alignment and fusion rate at 1 year and hardware complications; and (3) perioperative data (hospital stay, blood loss, and operative times).

**Results:** The patients in both groups were statistically similar between the groups with respect to demographic characteristics such as age, sex, smoking status, body mass index, preoperative pathology, surgical segments, and the degree of the cervical lordosis. Postoperative C5 palsy developed in nine of 61 patients (14%) in group A and in 0 of 24 patients (0%) in group B (CLF-S group) ( $p=0.03$ ). Postoperative neck pain, NDI, and JOA improvement were not significantly different between the two groups ( $p=0.93$ ,  $0.90$ , and  $0.79$ , respectively). Perioperative data did not differ significantly between the two groups.

**Conclusion:** This study showed that performing selective blocking laminoplasty might lead to reducing the incidence of postoperative C5 palsy in CLF surgery.

## Evaluation about Lamina Closure after Double Door Laminoplasty without Bone Graft in Elderly Patients Preliminary Study

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**Purpose:** The purpose of this study was to clarify the incidence of lamina closure after laminoplasty without any devices. Our surgical procedure did suture between yellow ligaments and capsule of facet joints to keep opened lamina.

**Materials and Methods:** This was retrospective study. We recruited 16 cases which were diagnosed with cervical spondylotic myelopathy or ossification of posterior longitudinal ligament (OPLL) from February 2015 to December 2017. All cases had lordosis alignment. They were more than 70 years old. We excluded trauma, dialysis, infection, or kyphotic alignment cases. We measured lamina angle with computed tomography (CT) bilaterally from C3 to C7 and calculated ratio of opened lamina against preoperative lamina angle to standardize. We basically did CT scan at preoperative, postoperative 1 week, postoperative 3 months, and postoperative 6 months. We compared lamina angle and ratio of opened lamina among each time

points. We used analysis of variance and Turkey test as post hoc test.

**Results:** Our cases consisted 13 males and three females. The mean age was 79.7 years old. The mean preoperative cervical alignment was  $15.8^\circ$ . Regarding angle of opened lamina, there were no statistically significant differences from postoperative 1 week to postoperative 6 months. Also regarding ratio of opened lamina, there were no statistically significant differences from postoperative 1 week to postoperative 6 months.

**Conclusion:** Although our study had several limitations such as small number of cases, retrospective study design, and without evaluation in kyphotic alignment cases, we could not find statistically significant differences regarding lamina angle and ratio of opened lamina from postoperative 1 week to 6 months in our cases. We concluded that our surgical procedure had advantages for surgical cost and still had surgical indication for CSM and OPLL cases, especially they had lordotic cervical alignment.

## Is It Safe to Perform Anterior Foraminotomy Using a High Speed Burr during Anterior Cervical Discectomy and Fusion?: Evaluation on the Risk of Vertebral Artery Injury and the Safe Margin of the Foraminotomy

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**Purpose:** The objectives were to evaluate the risk of vertebral artery (VA) injury and propose a guideline for secure anterior foraminotomy (AF) using a high speed burr during anterior cervical discectomy and fusion (ACDF).

**Materials and Methods:** Angio-computed tomography (CT) images of the cervical spine preoperatively obtained from thirty patients were evaluated. Surgical simulation of AF with ACDF on the axial CT images was set as follows: mediolateral exposure between bilateral uncovertebral joints using a 40 mm self-retractor; longitudinal axis of burrs located 6.5 mm and 4 mm medial at the top of the retractor considering the radius of a hand-piece (10 mm and 5 mm, respectively) and a 3 mm burr tip; a burr tip targeting the lateral margin of the superior cortex of the pedicle. To assess the risk of VA injury, length from the anterior tip to drilling point on the uncinat process (TDL) and distance from VA to the burr tip (DVA) were mea-

sured. To assess the safe margin of the AF, length from the anterior tip to drilling point 3 mm away from the VA on the uncinat process (TD3L) was measured.

**Results:** The averages of TDs were 0.4, 1.7, and 2.9 mm in the simulation using a burr with 10 mm hand-piece (simulation1); 0.9, 2.1, and 3.1 mm in the simulation using a burr with 5 mm hand-piece (simulation 2) in C45, C56, and C67, respectively. The averages of DVAs were 1.8, 2.6, and 5.2 mm in simulation 1; 2.0, 2.8, and 5.5 mm in simulation 2 in C45, C56, and C67, respectively. The averages of TD3Ls were 2.2 and 2.8 mm in simulation 1; 2.4 and 2.9 mm in simulation 2 in C45 and C56, respectively. When a secure drilling point is set at 3 mm away from the uncinat tip based on the averages of TD3Ls, outliers (TD3L more than 3 mm) were 32% and 37% in simulation 1; 37% and 40% in simulation 2 in C45 and C56, respectively. Maximum TD3L were 4.1 mm in simulation 1 and 4.7 mm in simulation 2.

**Conclusion:** Considering high outlier rates and maximum of TD3Ls, this technique can be safely performed when drilling more than 5 mm away from the anterior uncinat tip.

## A New “C3 Dome-Hybrid Open-Door Laminoplasty” May Reduce Postoperative C5 Palsy: An Early Postoperative Magnetic Resonance Imaging Cord Migration Comparison with Traditional Techniques

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**Purpose:** Recent development of C3-dome hybrid open-door laminoplasty approach, consisting of C3-dome osteotomy, C4–6 laminoplasty and upper C7 laminectomy, to preserve posterior cervical musculature for reduction of postoperative axial neck pain and occurrence of C5 palsy had been reported by the author. The aim of this study was to compare the early postoperative dorsal cord migration in pts who underwent C3 dome-hybrid laminoplasty (HL), traditional laminoplasty (TL), and laminectomy with fusion (LF).

**Materials and Methods:** A retrospective review of patients with cervical myelopathy, who underwent C3 dome HL, C3–7 TL or C3–6/7 TL in a single university hospital was

performed. Patients' clinical, surgical, and radiological data, with attention to postoperative magnetic resonance imaging (MRI) dorsal cord migration, were analyzed.

**Results:** Five patients (HL:TL:LF=24:7:14) who had pre- and postoperative MRI were included in the study. Between the three groups, there were no statistically significant differences in age, gender, follow-up duration, and preoperative Japanese Orthopaedic Association (JOA) score. All three groups had improvement of JOA score postoperatively. There were two cases of postoperative C5 palsy in LF compared to none in HL and TL. A trend towards LF having a greater MRI dorsal cord migration at all levels from C2–7 as compared to HL and TL was seen. The mean dorsal cord migration of both LF and TL was greatest at the C4–5 level (LF:  $2.2 \pm 1.5$  mm, TL:  $1.9 \pm 0.8$  mm). By comparison, HL dorsal cord migration was greatest, one level caudal to LF, at C5–6 ( $1.6 \pm 0.8$  mm). Dorsal cord migration was significantly greater in the LF C5 palsy group as compared to the LF non-C5 palsy group at the levels of C4–5 (4.4 vs. 1.8 mm,  $p=0.036$ ) and C5–6 (4.8 mm vs. 1.3 mm,  $p=0.037$ ).

**Conclusion:** This was the first study to demonstrate the dorsal cord migration pattern of the new C3- dome hybrid laminoplasty technique. The controlled reduction of dorsal cord migration combined with a caudal shift of the maximal apical cord migration spinal level reduced C5 nerve root tension and has the potential to reduce occurrence of postoperative C5 palsy.

## Laminoplasty Instead of Laminectomy in Posterior Cervical Instrumented Fusion

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**Purpose:** Two major disadvantages of cervical laminectomy accompanied with posterior fusion are adhesion of the dural membrane with prominent disfiguring of cervical spine and narrow lateral mass fusion bed. Laminoplasty may protect dural membrane from adhesion through preservation of posterior bony elements. This study presents the surgical outcomes of laminoplasty, instead of laminectomy, as a decompression method applied in posterior instrumented fusion for degenerative cervical kyphosis with stenosis (DCKS).

**Materials and Methods:** A consecutive single center series of 20 cases between 2008 and 2011 were retrospectively reviewed. They were diagnosed as DCKS and received anterior cervical fusion followed by expansive open-door laminoplasty and lateral-mass or pedicle screw instrumented fusion. We collected the functional scores and radiographic parameters. Computed tomography (CT) scans and magnetic resonance imaging (MRI) were arranged to evaluate the status of fusion and decompression.

**Results:** The mean age was  $67.6 \pm 15.2$  years. Half of the patients were older than 75 years. All the functional scores and cervical lordosis markedly improved. No recurrence of spinal cord compression caused by closure of opened laminae, according to MRI study and no pseudarthrosis or hardware loosening according to CT scan at postoperative 60 months.

**Conclusion:** The surgical aims for DCKS are adequate decompression, correction of kyphosis, and solid instrumented fusion. Laminoplasty applied in cervical fusion as a decompression method seems to lead to a favorable functional recovery and reduces the complications of perineural adhesion that typically occur after laminectomy. In addition, laminoplasty affords an additional fusion bed at the hinge side and this advantage benefits solid fusion mass formation for the patients who suffered from DCKS.

## Long-Term Surgical Results from a Follow-up of Bilateral Open-Door Laminoplasty for Cervical Spondylosis Myelopathy for More than 15 Years after Operation

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**Purpose:** Cervical laminoplasty (LP) is generally performed as a surgical method for cervical spondylosis myelopathy. We report the long-term results we could track for more than 15 years after operation for the bilateral open-door LP in our department.

**Materials and Methods:** We targeted 49 patients (31 men and 18 women), who underwent LP for cervical spondylosis in our hospital from 1984 to 2006. The average patient age was  $53.5 \pm 11.5$  years old. The clinical results were evaluated using Japanese Orthopaedic Association

(JOA) scores of 1, 3, 5, 10, and 15 years before and after the operation. The image evaluation was performed by spinal column alignment measuring the C2–7 angle on the X-ray image of intermediate position, extension position and flexion position. For the analysis, a retrospective study was conducted using one-way analysis of variance.

**Results:** The mean value of JOA score was  $13.4 \pm 2.7$ ,  $13.2 \pm 2.9$ ,  $12.8 \pm 3.1$ ,  $12.3 \pm 3.1$ , and  $11.8 \pm 2.9$ , respectively. Compared with the preoperative mean JOA score  $9.9 \pm 2.6$ , postoperatively improvement was observed in all ( $p < 0.01$ ). But it was significantly worse in 3 years and 15 years after operation compared with 1 year ( $p < 0.01$ ,  $p < 0.05$ ). There was no significant difference in the extension and intermediate position alignment before and after the operation, but the flexion position alignment decreased significantly in the 1, 3, 5, and 15 years after the operation ( $p < 0.05$ ). In addition, the range of motion gradually got worse from 1 year postoperatively ( $p < 0.01$ ).

**Conclusion:** There are many reports stating that JOA score improve promptly after surgery, gradual decrease thereafter but maintain good result generally during more than 10 years after LP. In the present study of bilateral open-door LP after 15 years, we got the result similar to the past reports. Alignment evaluation using kinetic X-ray showed no significant change in extension position, but it decreased significantly at flexion position. The range of movement of cervical spine also decreased with long-term course.

## Paediatric Cranio-Cervical Deformities: Our Experience of 31 Cases

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**Purpose:** Pediatric cranio-cervical deformities are a major challenge with regards to diagnosis (because of multiple pathologies) and treatment.

**Materials and Methods:** This is retrospective study involving a single center. Data was retrieved from electronic medical record system. Medical and surgical records of 31 children who presented with deformity of head & neck and managed for cranio-cervical problems were scrutinized. Pre- and post-treatment clinical photographs, X-ray, computed tomography scan, magnetic resonance

imaging, and Visual Analog Scale (VAS) scores were evaluated. Final diagnosis, clinical features, neurological findings, radiological features, treatment given and outcome were studied in details.

**Results:** Thirty-one patients (age, 9 months–16 years) with cranio-cervical deformities were managed from 2005 to 2017. Various cranio-cervical aetiologies detected were Grisel's syndrome (n=9), trauma (n=7), sternocleidomastoid (SCM) contracture (n=5), congenital anomalies (n=5), tuberculosis (n=2), pyogenic abscess (n=1), spinal tumor (n=1), and neuromuscular disease (n=1). Grisel syndrome group were treated with halter traction as tolerated for 3 to 7 days with nonsteroidal anti-inflammatory drugs, antibiotics and ice-packs followed by molded cervical collar for 2 months. Those with traumatic aetiology were conserved with Halo Vest. The congenital group was either treated with surgical fusion or was followed up at regular intervals. Those with tuberculosis were either conserved or underwent fusion with complete course of anti tubercular drug therapy. Those with SCM contractures were managed conservatively with Halo Vest or surgically by uni or biopolar release. One patient with pyogenic abscess was managed conservatively with organism sensitive antibiotics. Patient with osteoid osteoma underwent surgical excision. Lastly one patient diagnosed to have dystonia was treated conservatively. All patients had significant reduction in clinical deformity as well as improvement in VAS score at 2-year follow-up.

**Conclusion:** Careful evaluation, proper diagnosis and evidence based treatment of cranio-cervical deformities in children can lead to good pain relief and correction of deformity.

## Cobalt Chrome versus Titanium Alloy Rods for Correction of Adolescent Idiopathic Scoliosis: A Multi-Center, Randomized Clinical Trial

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greater correctional force with lesser rod deformation in pedicle screw-based posterior spinal fusion. However, it is unknown whether rod stiffness can outperform the difference of individual surgeons, which utilizes variety of surgical techniques to maximize their surgical outcomes. The aim of this study was to conduct a prospective, multi-center, randomized clinical trial investigating on the use of cobalt chrome versus titanium alloy rods on correction of adolescent idiopathic scoliosis (AIS).

**Materials and Methods:** A total of 69 patients (age, 10 to 19 years) with AIS Lenke type 1, 2, and 3 and main thoracic curves to the right, ranging from 45° to 97°, were recruited from five institutions and followed for 12 months. Patients were automatically allocated using age, main thoracic Cobb angle, active bending, and Risser grade as stratified factors in a system equalizing groups using 6.0-mm diameter cobalt chrome (CoCr, n=32) or titanium alloy (Ti, n=37) rods. Changes in coronal (main Cobb, CCI), sagittal (thoracic kyphosis angle [TK, Th5–12], lumbar lordosis angle [LL, L1–S1]), and rotational (rib hump [RH], apical vertebral rotation [AVR]) profiles were compared by radiograph and computed tomography at final follow-up.

**Results:** Results showed that CoCr and Ti groups were adequately comparable after allocation (average age, 14.9 years, 14.2 years; main Cobb, 58.5°, 56.9°; and active bending, 36.8°, 34.7°). Both CoCr and Ti groups achieved significant correction after surgery in coronal (main Cobb, 19.1°, 18.2°; correction rate, 67.1, 68.4; CCI, 2.2, 2.2), sagittal (TK, 21.5°, 22.8°; LL, 54°, 51.1°) and rotational (RH: 6.9, 7.0, AVR: 14.8, 14.9) profiles at final follow-up.

**Conclusion:** A multi-center, randomized clinical trial showed no difference in correction of coronal, sagittal, and rotational profiles between groups using CoCr or Ti rods. Findings suggest that rod stiffness profiles cannot overcome the effect of differences between surgeons in obtaining significant correction in posterior spinal fusion for AIS.

**Purpose:** It has been reported that stiffer rods can provide

## Analysis of Pelvic Compensation during Walking in Patients with Severe Positive Sagittal Imbalance Using Motion Analysis

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**Purpose:** To analyze pelvic compensation during walking in patients with severe sagittal plane deformity using motion analysis.

**Materials and Methods:** A total of 44 patients with kyphotic deformity who were scheduled to undergo surgery were included. Both clinical outcomes and sagittal spinopelvic parameters were measured. Three times of motion analysis were performed during walking consecutively. From motion analysis, the angle of anterior pelvic tilt (Ant-PT), center of gravity (CoG) from pelvic center of mass (CoM), thoracic kyphosis (TK) angle, and the angles of hip and knee joints during gait were estimated. The data of three trials were analyzed separately as well as averaged in order to obtain the trend of changes of the index variables. Depending on the change of Ant-PT angle, TK angle, and CoG distance from CoM of pelvic segment, Ant-PT+/Ant-PT- groups, TK+/TK- groups, and CoG+/CoG- groups were classified. '+' and '-' means that increase and decrease of values of a variable from 1st to 3rd trials, respectively.

**Results:** Kyphotic posture with anterior shifted-CoG and compensatory hip and knee joint flexion were demonstrated during walking. Mean Ant-PT angle, TK angle, and CoG distance from CoM of pelvic segment were increased progressively with trial, and the difference of values of these parameters between 1st and 3rd trials were statistically significant ( $p=0.042$ ,  $0.003$ , and  $0.003$  for Ant-PT angle, TK angle, and CoG distance from CoM of pelvic segment, respectively). From 1st to 3rd trials, 27/17 patients and 34/10 patients were classified into Ant-PT+/Ant-PT- groups and CoG+/CoG- groups, respectively. Older age and higher body mass index were significantly associated with the Ant-PT+ group. The CoG+ group demonstrated that significantly higher height and weight than the CoG- group.

**Conclusion:** Progressive worsening of sagittal balance and failure of pelvic compensation in the patients with severe sagittal plane deformity. Gait analysis can discriminate the patient with maintaining pelvic compensation from the

patients with pelvic failure during walking, which would be applicable to surgical planning for sagittal plane deformity.

## Is It Possible to Correct Congenital Spinal Deformity Associated with a Tethered Cord without Prophylactic Intradural Detethering?

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**Purpose:** Traditionally, congenital spinal deformity with tethered cord is treated with detethering followed by a second surgery to correct the deformity. However, the detethering procedure carries significant risk and morbidity. There is therefore significant benefit to establishing the efficacy of an alternative surgical strategy that avoids these complications.

**Materials and Methods:** Forty patients with congenital scoliosis and tethered cord from 2006 to 2016 were divided into three groups: a vertebral column resection (VCR) group, a pedicle-subtraction osteotomy (PSO) group, and a posterior fusion only group (PSF). All patients had >2-year follow-up. VCRs and PSOs were performed at the apical vertebra without a cage in order to shorten the spine and to indirectly relieve the tension of the spinal cord without an extra intradural detethering procedure.

**Results:** Forty patients had a mean age of 14.2 years and average follow-up of 49.8 months (range, 24–77 months). The conus ended at L3 in 13, L4 in 16, L5 in six, S1 in three, and S2 in two patients. Seventeen patients had other intraspinal anomalies. The preoperative Cobb angle was  $102.2^\circ \pm 24.9^\circ$  (VCR),  $71.2^\circ \pm 13.9^\circ$  (PSO) and  $69.7^\circ \pm 21.3^\circ$  (PSF). By 2 years, correction stabilized at  $44.6^\circ \pm 16.5^\circ$  (60.3%),  $20.6^\circ \pm 13.3^\circ$  (65.3%), and  $19.8^\circ \pm 8.9^\circ$  (67.8%), respectively. In the VCR group ( $n=21$ ), the mean spinal column shortening was 28.0 mm (range, 18–39 mm). Among 13 patients with preoperative neurological deficits, 11 pts were improved, while two patients did not change by final follow-up. In the PSO group ( $n=9$ ), the mean shortening was 20.0 mm (range, 15–23 mm). All nine patients had preoperative neurological deficits and by final follow-up, six patients had improved, while three patients did not change. The PSF group ( $n=10$ ) had no deficits. Five patients had complications. Other than one urinary tract infection in the PSF group, the other compli-

cations were all in the VCR group and included transient weakness ( $\times 2$ ), durotomy, and hemothorax.

**Conclusion:** Congenital spinal deformity with tethered cord may be safely and effectively treated without direct untethering, but the surgical strategy should be individualized.

## The Conformity of Radiological Shoulder Parameters in Scoliotic Patients after Corrective Surgery

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**Purpose:** To investigate the conformity of radiological shoulder balance parameters in scoliotic patients after corrective surgery.

**Materials and Methods:** Fifty patients who had corrective surgery were recruited. radiological shoulder height (RSH), clavicle angle (Cla-A), coracoid height difference (CHD), clavicle-rib intersection difference (CRID), cervical axis (CA) angle, and T1 tilt angle. These parameters were again measured postoperatively at 3-, 6-, 12-, and 24-month follow-up.

**Results:** There were 38 female patients and 12 male patients with the mean age of  $16.3 \pm 7.0$  years old. Majority of the patients were Lenke 1 ( $n=22$ , 44%) followed by Lenke 2 ( $n=11$ , 22%), Lenke 5 ( $n=8$ , 16%), Lenke 6 ( $n=5$ , 10%), Lenke 4 ( $n=1$ , 2%), and non-idiopathic patients ( $n=3$ , 6%). The RSH increased on the first follow-up ( $2.8 \pm 11.1$ ), and then reduced, shifting from positive to negative. The CHD was lower preoperatively ( $0.9 \pm 11.6$ ) and increased following the first follow-up. CRID gradually decreased upon follow-up ( $2.3 \pm 7.4$ ). The Cla-A was negative preoperatively ( $-0.8 \pm 3.8$ ). A slight decrease was noticed from the 1st follow-up ( $0.5 \pm 2.2$ ) till the 4th follow-up ( $0.04 \pm 2.1$ ). Interclass co-efficient correlation of the radiological parameters have a significant  $p$ -value with the strongest correlation at T1 tilt (0.78) and the weakest at Cla-A (0.13). We found that RSH and Cla-A had poor conformity with significant interclass correlation (ICC) values of less than 0.40 ( $p < 0.05$ ). The CHD, CRID, and CA angle had fair conformity with ICC between 0.40–0.59 ( $p < 0.05$ ). T1 tilt angle had excellent conformity with ICC of 0.78 ( $p < 0.05$ ).

**Conclusion:** RSH and Cla-A were poorer parameters to assess the shoulder balance postoperatively. T1 tilt angle was a better parameter to measure the postoperative shoulder balance and had excellent conformity on 3-, 6-, 12-, and 24-month follow-up.

## Proximal Junctional Kyphosis after Surgical Correction of Adult Spinal Deformity in Patients over 50 Years Old: Minimum 5-Year Follow-up

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**Purpose:** To report the incidence, risk factors, and clinical outcomes of proximal junctional kyphosis (PJK) after long instrumented fusion with a minimum 5-year follow-up.

**Materials and Methods:** This is a retrospective review of 76 patients with degenerative lumbar scoliosis or flatback deformity who underwent more than 4 level fusion to the sacrum/pelvis with a minimum 5-year follow-up. PJK was defined as the  $>10^\circ$  and  $>10^\circ$  increase of proximal junctional angle (PJA) without bony failure. Risk factors for PJK were analyzed according to patients' surgical and radiographic factors. Clinical outcome was evaluated using Oswestry Disability Index (ODI) and Scoliosis Research Society (SRS)-30 questionnaire. Presumed risk factors and clinical outcomes were compared between PJK and non-PJK groups.

**Results:** The age at the time of surgery was mean 66.7 years. Mean follow-up duration was 7.1 years. PJK developed 30 of a total of 76 patients (39.5%). PJK was found in 12 patients within 2 years and 18 patients after 2 years. Risk factors for PJK were older age, greater preoperative sagittal imbalance including larger pelvic tilt and sagittal vertical axis, greater postoperative pelvic incidence–lumbar lordosis mismatch, and greater sagittal vertical axis change. Clinical outcomes such as SRS-30 and ODI score were significantly worse in patients with PJK than non-PJK patients.

**Conclusion:** With long-term follow-up, PJK developed in almost 40% of patients and seemed to affect the clinical outcomes. Therefore, great care should be paid to prevent PJK especially in longer term follow-up considering the

presumed risk factors.

## Does Lumbar Stiffness Impact the Health-Related Quality of Life Following Adult Spinal Deformity Surgery?

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**Purpose:** The goal of adult spinal deformity (ASD) surgery is to improve the spinal alignment and reduce the disability. However, decreased spinal mobility may impair the health-related quality of life (HRQOL). The purpose of this study was to evaluate the HRQOL following ASD surgery and to determine the related factors.

**Materials and Methods:** Sixty-seven consecutive ASD patients underwent spinopelvic fixation (mean fused level, 9.9 segments) at our institute from 2010 to 2015. Four patients who underwent additional surgery and two patients who could not be followed for more than 2 years were excluded in this study. We identified 61 ASD patients (mean age at surgery, 66.9 years; average follow-up [FU] period, 48.4 months), and evaluated HRQOL with Scoliosis Research Society (SRS)-22 and 36-item Short-Form Health Survey (physical component summary [PCS] and mental component summary [MCS]) before surgery and at FU. We evaluated the trunk stiffness using Lumbar Stiffness Disability Index (LSDI).

**Results:** All domains of SRS-22, PCS, and MCS significantly improved at FU ( $p < 0.0001$ ). Each parameters (preoperative/FU) were as follows: total score of SRS-22 (2.0/3.8), PCS (20.5/37.1), and MCS (45.3/53.3). Key radiographic parameters (preoperative/postoperative/FU) were thoracic kyphosis (TK, 15.6°/27.6°/36.1°), thoracolumbar kyphosis (TLK, 16.9°/6.7°/11.5°), pelvic incidence–lumbar lordosis (PI–LL, 43.0°/3.1°/6.2°), pelvic tilt (PT, 35.0°/21.4°/23.4°), and C7 sagittal vertical axis (C7-SVA, 100.4/22.0/42.4 mm). Mean LSDI was calculated to 6.7 points. Statistical analysis indicated that PCS was significantly correlated with LSDI ( $r = -0.48$ ,  $p = 0.007$ ), TK ( $r = -0.49$ ,  $p = 0.002$ ), and TLK ( $r = -0.34$ ,  $p = 0.04$ ). Additionally, total score of SRS-22 was significantly influenced by age ( $r = -0.43$ ,  $p = 0.005$ ), LSDI ( $r = -0.36$ ,  $p = 0.05$ ), C7-SVA ( $r = -0.41$ ,  $p = 0.009$ ), PI–LL ( $r = -0.39$ ,  $p = 0.01$ ), and PT ( $r = -$

0.34,  $p = 0.04$ ).

**Conclusion:** HRQOL significantly improved after ASD surgery; however postoperative trunk stiffness and deterioration of sagittal spinal alignment due to PJK and reciprocal changes may impact HRQOL. Improving the trunk flexibility may be important for postoperative HRQOL in the ASD patients.

## Inserting C1 Lateral Mass Screw Using the Intersection between Lateral Mass and Posterior Arch as a Reference: Radiographic Study

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**Purpose:** Prior techniques for C1 lateral mass screw insertion have been proposed, but requires extensive dissection causing lethal bleeding. Purpose is to determine proper C1 lateral mass screw placement and trajectory by using the intersection between medial border of the posterior arch and the lateral mass as an isolated medial reference.

**Materials and Methods:** Ninety-three three-dimensional computerized tomography reconstruction images were simulated. Virtual placement of C1 lateral mass screws were performed in four entry points and two trajectory angle parameters by using VISI 17 software (VISI-Hexagon, Gloucester, UK). The safety during simulating screw insertion and the screw length were evaluated.

**Results:** C1 lateral mass screws could be safely placed bilaterally at 3 mm lateral from the reference point in both 0° and 15° medial screw angulation without cortex violation. The average screw length within the lateral mass in 3 mm and 5 mm lateral from the reference point was 16 mm in 0° medial angulation and 18 mm in 15° medial angulation, respectively.

**Conclusion:** C1 lateral mass screw is safely placed at 3 mm lateral from the intersection between medial border of the posterior arch at its junction with the lateral mass beneath the posterior arch in both 0° and 15° medial angulation.

## Ten-Year Longitudinal Follow-up Magnetic Resonance Imaging Study of Thoracic Intervertebral Discs in Asymptomatic Volunteers

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**Purpose:** There were some previous reports longitudinally investigating intervertebral disc degeneration in cervical or lumbar spine using magnetic resonance imaging (MRI), and no longitudinal study on thoracic spine was reported. This study was conducted to longitudinally evaluate change of intervertebral disc degeneration during 10 years in the thoracic spine in healthy asymptomatic subjects.

**Materials and Methods:** We assessed 103 healthy subjects (58 men and 45 women) among 223 volunteers who underwent MRI of the thoracic spine between 2005 to 2008 (follow-up rate of 46.2%). The mean age at the initial study was 45.0±11.5 years (range, 24–77 years). We compared initial MRIs and follow-up MRIs, conducted at an average of 10.0±0.6 years after the initial study, regarding (1) decreased signal intensity of the intervertebral discs (DSI), (2) posterior disc protrusion (PDP), (3) anterior compression of dual sac (AC), and (4) disc-space narrowing (DSN) from T1–2 to T12–L1. We assessed the association of MRI grading and the several factors, including age, gender, body mass index, smoking, sports habit, and disc degeneration of cervical spine.

**Results:** Progressive changes during a 10-year period occurred in 44.7% of the subjects in DSI, 18.4% in PDP, 21.4% in AC, and 0% in DSN, respectively. 63.1% of the subjects had progressive degeneration on MRI at least one grade. The prevalence of thoracic disc degeneration

increased with age. DSI was frequently observed in the upper thoracic spine (T1–4), PDP was frequently seen in the middle thoracic spine (T5–8), and progression of disc degeneration was relatively infrequent in the lower thoracic spine (T9–12). Significant association was observed between DSI and degeneration of the cervical spine ( $p=0.004$ ) and between AC and smoking ( $p=0.04$ ).

**Conclusion:** The progression of thoracic disc degeneration during 10 years were observed in 63.1% of the subjects. Factors significantly associated with degenerative changes in the thoracic spine included smoking and disc degeneration in the cervical spine.

## Defining Standardized Guidelines for Brace Weaning in Adolescent Idiopathic Scoliosis

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**Purpose:** Current brace weaning guidelines for adolescent idiopathic scoliosis (AIS) are not well-defined. Most consider Risser stage 4, 2-year post-menarche, and lack of height gain as justifiable reasons for brace weaning. However, curve progression is still observed. With more refined and standardized maturity parameters, brace weaning guidelines should be redefined. This study aims to assess the curve progression risk with Risser staging, bone age assessments via Sanders staging (SS), and the distal radius and ulna classification (DRU), as well as to redefine brace weaning criteria.

**Materials and Methods:** Consecutive AIS patients who underwent brace weaning from June 2014 to March 2016 were prospectively recruited and followed up for 2 years after weaning. Patients were referred for brace weaning based on the following criteria: Risser 4, no growth in the past 6 months of follow-up, and post-menarche of at least 2 years. Skeletal maturity was assessed by Risser staging, SS, and DRU. Statistical analyses included inter-group comparison of with/without curve progression, binomial stepwise logistic regression, odds ratio with their 95% confidence intervals, and risk ratio calculation.

**Results:** Patients (N=144) were recruited without dropouts. Up to 29.2% of patients experienced curve progression after brace weaning despite our standardized wean-

ing criteria. Large curves ( $\geq 45^\circ$ ) observed more curve progression ( $p=0.002$ ) as an independent risk factor. Patients weaned at SS7, radius grade (R) 9, and ulna grade (U) 7 were more likely to experience curve progression ( $p<0.001$ ). No progression was observed with R11 and U9. The earliest maturity indices with reasonable protective effect were SS8, and R10 with U9.

**Conclusion:** Brace weaning indications using Risser staging is inadequate. Curve progression is expected for large curves irrespective of maturity status due to its disease nature. Bone age measurement by either SS8 or DRU (R10/U9) provides earliest and clearer guidelines for brace weaning that result in least post-weaning curve progression.

## Radiologic Factors to Predict Injury of Transverse Atlantal Ligament in Unilateral Sagittally Split Fracture of C1 Lateral Mass

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**Purpose:** Unilateral sagittally split fracture (USSF) of C1 lateral mass (LM) is a variant type of C1 atlas fracture. The integrity of transverse atlantal ligament (TAL) is a key factor to determine whether to treat surgically or non-surgically in C1 atlas fracture. However, no information is available about which type of USSF of C1 LM is associated with injury of TAL.

**Materials and Methods:** Twenty-six consecutive cases of USSF of C1 LM were included. The fractures associated with other cervical spines, such as C2 and occiput, were excluded from the study. The mean age was 52 years old. Sixteen were male and 10 were female. Two radiologists determined presence of TAL injury in magnetic resonance imaging using Dickman's classification and divided into two groups: TAL injury and TAL intact. If the results of two judgements were not identical, the third radiologist re-evaluated. Three spine surgeons measured radiologic parameters and the averages were used as final

results: total LM displacement (LMD), unilateral LMD at fracture side, atlanto-dental interval (ADI), fracture gap, clivus canal angle (CCA), atlanto-occipital joint axis angle (AOJAA), and basion-dens interval (BDI). The radiologic results were compared between two groups. The incidence of associated other C1 fractures was also investigated and compared between two groups.

**Results:** Sixteen were TAL injury group (nine type I and seven type II) and 10 were TAL intact group. Total LMD and unilateral LMD at fracture side were higher in TAL injury group than TAL intact group, respectively. ADI and fracture gap were higher in TAL injury group than TAL intact group. However, CCA, AOJAA, and BDI were not statistically different between two groups. Total LMD was positively correlated to unilateral LMD at fracture side and fracture gap, but not CCA, AOJAA, and BDI. Incidence of associated other C1 fractures was higher in TAL injury group than TAL intact group.

**Conclusion:** Our results suggest that total LMD more than 5.9 mm and unilateral LMD at fracture side more than 4.3 mm are radiological factors to predict injury of TAL in USSF of C1 LM.

## Feasibility of Fat Degeneration of Lumbar Extensor Muscle as Additional Diagnostic Criteria of Sarcopenia

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**Purpose:** To analyze an association between fat degeneration of lumbar extensor muscle and sarcopenia criteria of Asian Working Group and to investigate the correlation in the risk of osteoporotic vertebral fractures

**Materials and Methods:** This study was enrolled in 33 patients with osteoporotic vertebral fractures (group 1) and 19 patients who did not have the vertebral fractures (group 2). Sarcopenia was diagnosed according to the Asian Working Group for Sarcopenia criteria, using extremity muscle mass assessed by dual-energy X-ray absorptiometry, grip strength, and gait speed. We investigated the bone mineral density (BMD) and fat degeneration of lumbar extensor muscle in magnetic resonance imaging.

**Results:** There was significant difference of fat degeneration of lumbar extensor muscle ( $p=0.02$ ), skeletal

muscle index ( $p=0.01$ ), BMD ( $p=0.01$ ), handgrip strength ( $p=0.01$ ), and gait speed test ( $p=0.01$ ) between two groups. The analysis between sarcopenia criteria and fat degeneration of lumbar extensor muscle revealed a negative correlation with gait speed test ( $r=-0.42$ ,  $p=0.01$ ) and handgrip strength ( $r=-0.44$ ,  $p=0.01$ ). There was a positive correlation between fat degeneration of lumbar extensor muscle and osteoporotic vertebral fractures ( $r=0.33$ ,  $p=0.02$ ). Receiver operating characteristic curve analysis between fat degeneration of lumbar extensor muscle and osteoporotic vertebral fractures showed that the cut-off value of the fat degeneration was 32.50% (sensitivity, 0.61; specificity, 0.63). There was a positive correlation between sarcopenia defined by Asian Working Group and sarcopenia defined by 32.50%, cut-off value of fat degeneration of lumbar extensor muscle instead of extremity muscle mass ( $r=0.574$ ,  $p=0.01$ ).

**Conclusion:** These results suggest that there is a feasibility of the fat degeneration of lumbar extensor muscle as additional diagnostic criteria of sarcopenia for osteoporotic vertebral fractures. The cut-off value of lumbar extensor muscle for osteoporotic vertebral fractures showed 32.50% of the fat degeneration.

## The Impact of Lower Limb-Truncal Proportion on Spinal Angles and Other Sagittal Radiographic Parameters

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**Purpose:** The lordotic realignment of the lumbar spine established but its ideal target is not yet fully established. Similar to pelvic incidence which correlates with lumbar lordosis, the unique lower limb-truncal proportion of individuals may impact sagittal alignment of the spine. We investigate the possible influence of lower limb-truncal proportions on sagittal radiographic parameters.

**Materials and Methods:** A retrospective radiographic comparative study was conducted on 100 patients. Measurements of C7 sagittal vertical axis (C7-SVA), global cervical angle, global thoracic angle (GTA), Scheuer-

mann's kyphosis (SK), thoracolumbar angle, global lumbar angle (GLA), segmental lordosis (SL), T1-slope, pelvic incidence (PI), pelvic tilt, sacral slope, femoral alignment angle, knee adduction angles, as well as apical and end vertebrae were performed using whole body lateral EOS imaging (Paris, France) in the standing posture. Univariate analyses were performed to compare radiographic parameters between groups with different lower limb-truncal proportions. Multivariate analysis was performed to identify the associations of lower limb-truncal ratio, GLA and GTA with various other radiographic parameters.

**Results:** The mean C7-SVA of  $-10.2$  mm, PI of  $50.9^\circ$ , lumbar lordosis (LL) of  $-47.7^\circ$ , PI-LL discrepancy of  $3.2^\circ$ , and mean total lower limb/C1-hip length ratio of 1.38. Regardless of lower limb-truncal proportion, GLA differed from SL ( $p=0.002$ ), with the absolute means of GLA and SL larger and smaller than PI, respectively. Patients with proportionately longer lower limbs (lower limb-truncal proportion  $>1.38$ ) are more likely to have larger mean T1-slope ( $20.92^\circ$  vs.  $17.33^\circ$ ,  $p=0.006$ ), GTA ( $36.33^\circ$  vs.  $32.23^\circ$ ,  $p=0.018$ ), SK ( $41.26^\circ$  vs.  $35.19^\circ$ ,  $p=0.001$ ), GLA ( $-50.53^\circ$  vs.  $-45.63^\circ$ ,  $p=0.006$ ) and SL ( $-56.01^\circ$  vs.  $-51.09^\circ$ ,  $p=0.004$ ). Multivariate analysis showed that a larger total lower limb length/C1-hip length ratio  $>1.38$  is predictive of larger GLA  $<-47.69^\circ$  (odds ratio [OR], 2.660;  $p=0.026$ ), and larger T1-slope of  $>18.84^\circ$  (OR, 3.695;  $p=0.012$ ).

**Conclusion:** Larger lower limb-truncal proportion results in naturally accentuated spinal curves which needs to be considered in spinal realignment surgeries. These patients require a larger lumbar lordosis that is closer to the PI. A larger lower limb-truncal proportion is also predictive of a high T1-slope.

## Does Sarcopenia Increase the Risk of Fresh Vertebral Fragility Fractures?: A Case Control Study

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**Purpose:** Sarcopenia is a known risk factor for falls in elderly and is associated with osteoporosis and fragility

fractures. Previous studies have relied on the measurement of muscle mass alone and have not considered the role of preexisting fractures. We aimed to investigate whether sarcopenia increased the risk of vertebral fragility fractures.

**Materials and Methods:** A prospective, matched, case-control study involving 51 consecutive patients with fresh vertebral fragility fractures and 51 age- and sex-matched controls without fracture was done. Sarcopenia, T-score, presence of preexisting fractures, and body mass index (BMI) were compared between groups. Sarcopenia was diagnosed as decreased total psoas cross-sectional area (TPA) calculated on axial MRI sections (2 standard deviations below normative value obtained from a historical cohort of normal young adults) and decreased hand grip strength measured by dynamometer (26 kg for men and 18 kg for women). Univariate and multivariate analysis of these variables was done with the occurrence of fresh fracture as dependent variable.

**Results:** Normative TPA values were 1,576 and 2,723 mm<sup>2</sup>, and cut-off values were 86 and 1,641 mm<sup>2</sup> for women and men, respectively. 29.4% of cases and 7.8% of controls had sarcopenia ( $p=0.005$ ). 56.8% cases and 13.7% controls had previous vertebral fractures. Sarcopenia was more prevalent in those with previous fractures (38% vs. 7.6%; odds ratio, 7.76;  $p<0.001$ ). TPA was higher in the control group (1,569 vs. 1,278 mm<sup>2</sup>,  $p=0.001$ ) and also in those without previous fractures (1,563 vs. 1,168 mm<sup>2</sup>,  $p<0.001$ ). Handgrip strength was higher in those without old fractures (19.6 vs. 16.3 kg,  $p=0.05$ ). In a multivariate model using conditional logistic regression, with the covariates of sarcopenia, BMI, T-score, and old fractures, sarcopenia was not found to be a significant predictor, with only old fractures and T-score being predictive of fresh fracture.

**Conclusion:** Sarcopenia is not an independent risk factor for fresh vertebral fragility fractures whereas old fractures and lower T-score are risk factors.

## Magnetic Resonance Imaging Evaluation of Postoperative Fatty Infiltration in Paraspinal Muscle and Dural Sac Cross-Sectional Area after Posterior Lumbar Surgery: Comparison between Conventional Open and Minimal Invasive Approaches

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**Purpose:** The main purpose of this prospective study was to determine the degree of postoperative fatty infiltration in paraspinal muscle and the degree of spinal decompression between conventional open surgery (COS) and minimal invasive surgery (MIS) based on magnetic resonance imaging (MRI).

**Materials and Methods:** From February 2016 to January 2017, 46 patients underwent posterior lumbar interbody fusion using two different approaches: COS in 21 and MIS in 25. Lumbar MRI scan were obtained within 3 months before surgery and about 1 year after surgery. The postoperative muscle fat index (MFI) change of paraspinal muscles along lumbosacral spine and the dural sac cross-sectional area (DSCAS) change at index segment was measured and compared between the two surgery methods.

**Results:** The average MFI change at L2–S1 was more prominent in COS than MIS groups of both multifidus muscle and erector spinae muscle, but statistical significance is only noted at erector spinae muscle ( $27.37\%\pm 21.37\%$  vs.  $14.13\%\pm 19.19\%$ ,  $p=0.044$ ). Significant MFI change difference between COS and MIS groups was found at caudal adjacent level ( $54.47\%\pm 37.95\%$  vs.  $23.60\%\pm 31.58\%$ ,  $p=0.016$ ). No significant difference at operative and cranial adjacent level of multifidus and erector spinae muscles. The change of DSCSA at index segment after operation is more prominent in COS than MIS groups ( $128.23\pm 40.75$  mm vs.  $72.28\pm 40.79$  mm,  $p<0.001$ ).

**Conclusion:** The minimal invasive surgery caused less postoperative paraspinal muscle fatty atrophy than conventional open surgery, especially at caudal adjacent level of erector spinae muscle. The improvement of spinal canal stenosis at index segment was more prominent in conventional open surgery than minimal invasive surgery.

## Can Selective Nerve Root Block Avoids Surgery for Lumbar Radiculopathy?

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**Purpose:** There is still controversy regarding the treatment of lumbar radiculopathy. Common modalities include anti-inflammatory agent, bed rest, physical therapy, and surgery. Present study was done to determine the clinical effectiveness of selective nerve block for lumbar radiculopathy with a mild neurological deficit.

**Materials and Methods:** Eighty-six patients with a minor sensory/motor deficit and a unequivocal magnetic resonance imaging finding (68 disc herniation, 18 foraminal stenosis) were treated with selective nerve root block from June 2014 to August 2018. All the patients were evaluated by Oswestry Disability Index of Fairbank at pre- and post-injection period with a regular interval. Methylprednisolone (80 mg) with 0.5 mL 2% lidocaine was administered in all cases under C-arm and confirmed by radioculogram.

**Results:** From the total of 86 patients, 77 patients (89.53%) showed improvement in their symptoms in 1st week. Out of these 77 patients, 63 patients (81.81%) had long-term improvement and 14 patients (18.18%) showed short-term relief. Statistically significant improvement at every stage of assessment was observed.

**Conclusion:** Selective nerve root block is very effective & safe procedure for relief of severe radicular pain unresponsive to conservative patients. It can help, delay, or avoid more invasive surgical procedure and has role in significant improvement of quality of life.

## Relationship between Bone Mineral Density and Paraspinal Muscle in Postmenopausal Compression Fracture Patients

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**Purpose:** The loss of skeletal muscle and strength is known to be a predictor of bone mineral density (BMD) reduction and induces increasing risk of fall and fractures. Pre-

vious studies have reported that the cross-sectional area (CSA) and the degree of fatty infiltration of the paraspinal muscles were related to BMD. The risk of spinal compression fracture can be increased by reduction of back extensor strength. The purpose of this study is to analyze the effect of paraspinal muscle condition in patients with spinal compression fractures.

**Materials and Methods:** Between June 2010 and October 2017, BMD of femur and lumbar spine was measured in 402 patients who were diagnosed as compression fracture over 60 years of age postmenopausal women. CSA of psoas muscle and paraspinal muscle were measured on magnetic resonance imaging axial image of the L3/4 disc level. The degree of fat infiltration in the paraspinal muscle was also estimated semi-quantitatively with three visual scale grades at the same level. The number of osteoporotic vertebral fractures including the old fractures was investigated.

**Results:** Correlation analysis revealed that BMD of lumbar spine was positively correlated with the CSA of psoas muscle ( $r=0.279$ ,  $p<0.01$ ) and paraspinal muscle ( $r=0.319$ ,  $p<0.01$ ). BMD of femur was also correlated with CSA of psoas muscle ( $r=0.275$ ,  $p<0.01$ ) and paraspinal muscle ( $r=0.319$ ,  $p<0.01$ ). The number of compression fractures had positive correlation with fatty infiltration grades of paraspinal muscle ( $r=0.376$ ,  $p<0.01$ ) and had negative correlation with the CSA of paraspinal muscle ( $r=-0.299$ ,  $p<0.01$ ). Comparison between lumbar osteoporotic and non-osteoporotic group was performed. It showed statistical difference in paraspinal, psoas muscle area ( $p<0.01$ ), and the number of vertebral fractures ( $p<0.01$ ), but not in grades of fatty infiltration ( $p=0.331$ ).

**Conclusion:** In the postmenopausal patients with compression fracture, the cross sectional area and condition of the psoas and paraspinal muscles are significantly correlated with the BMD and the number of compression fractures.

## Remaining of Endplate Is a Risk Factor of Delayed Osseous Union after Posterior Lumbar Interbody Fusion: A Multicenter, Prospective, Randomized Study

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**Purpose:** Posterior lumbar interbody fusion (PLIF) is usually performed to treat lumbar degenerative diseases in elderly patients. Some patients exhibit intervertebral pseudo-arthritis. The purpose of our study is to investigate independent predictors of osseous union after PLIF.

**Materials and Methods:** We analyzed 66 elderly patients with osteoporosis after PLIF from 2011 to 2014 (all females; mean age, 71 years; follow-up period, at least 6 months). Patients were randomly allocated to treatment with weekly teriparatide, starting at 1 week postoperatively; others received no teriparatide. Postoperative lumbar computed tomography 2 months postoperatively were obtained and examined for remaining of endplate (more than 50% of vertebral diameter), and autograft position with bone bridging (anterior, center, or posterior). Osseous union was assessed by using computed tomography 6 months postoperatively.

**Results:** Thirty-three patients (50%) showed complete osseous union, while 33 did not. Postoperative remaining of endplate was observed in nine patients (27%) of the union group and in 23 (70%) of the non-union group ( $p<0.01$ ). Autograft position with bone bridging 2 months postoperatively were anterior in 17 (52%), center in 30 (91%), and posterior in 20 patients (61%) of union group, and anterior in 12 (36%), center in 20 (61%), and posterior in seven patients (21%) of non-union group ( $p=0.22$ ,  $p<0.01$ , and  $p<0.01$ ), respectively. Multivariate logistic regression analysis showed that remaining of endplate (odds ratio, 0.1; 95% confidence interval, 0.026–0.398;  $p<0.01$ ) and teriparatide administration (odds ratio, 8.8; 95% confidence interval, 2.222–34.936;  $p<0.01$ ) were independently

associated with osseous union within 6 months after PLIF.

**Conclusion:** Remaining of endplate and weekly teriparatide administration were independent predictors of osseous union 6 months after PLIF. It is important to remove the hyaline cartilage of endplates possibly and pack the autogenous bone behind the spacer for osseous union enhancement after PLIF.

## Comparison of Complications and Clinical Outcomes of Primary and Revision Surgery in Patients with Adult Spinal Deformity with Sagittal Imbalance Using Combined Anterior and Posterior Procedure

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**Purpose:** Revision surgery seems intuitive, with increased risk of complications and poor clinical outcomes. Previous studies comparing primary versus revision surgery included data for a wide variety of disease entities and age; however, literature comparing primary and revision surgery in patients with adult spinal deformity (ASD) with sagittal imbalance undergoing anterior and posterior combined surgery is less. We aimed to compare complications and clinical outcomes of primary and revision surgery in patients with ASD accompanied by sagittal imbalance.

**Materials and Methods:** We retrospectively reviewed 54 consecutive patients of ASD with sagittal imbalance who underwent primary ( $n=30$ ) versus revision ( $n=24$ ) surgery with a minimum 2-year follow-up.

**Results:** Patient characteristics, including prevalence of sarcopenia, were similar between the two groups. Pedicle subtraction osteotomy was performed more frequently in the revision group, although there was no statistical significance. The primary group had more proximal junctional problems, whereas the revision group had more rod breakage ( $p<0.05$ ). There were significant improvements between the preoperative and 2-year postoperative clinical outcomes in both groups. The Oswestry Disability Index, Visual Analog Scale score, and assessment activities of daily living for sedentary Asian culture were similar in both groups 2 years postoperatively. Additionally, sarco-

penia did not affect the clinical outcome.

**Conclusion:** Patients who underwent revision surgery for ASD with sagittal imbalance showed similar general and surgical characteristics as those who underwent primary surgery. However, the revision group achieved relatively more benefit from surgery at 2-year follow-up than did the primary group. This is probably because they had greater pain and disability at the time of the revision procedure. Therefore, the revision status of the patient should not be an obstacle to the treatment of ASD with sagittal imbalance.

### The Risk of Venous Thrombolism after Lumbar Spine Surgery: A Population-based Cohort Study

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**Purpose:** Venous thromboembolism (VTE) including deep vein thrombosis (DVT) and pulmonary embolism (PE) are never the least rare complication after spine operation, but currently, no study has yet investigated the risks of these fatal consequences following lumbar spine surgery (LSS).

**Materials and Methods:** After excluding those who have received any kind of arthroplasty and spine surgery in previous 6 months, 8,697 patients over the age of 20 years old under through LSS between 2000 and 2013 were identified from the Taiwan National Health Insurance claims data. Each patients was randomly selected and frequency-matched with four individuals not receiving LSS by age, sex and index year.

**Results:** The incidence rates of VTE in LSS group and the control group were 1.84 and 0.69 per 1,000 person-years, respectively. The LSS group had a higher risk of VTE (adjusted hazard ratio [HR], 2.13; 95% confidence interval [CI], 1.41–3.21), DVT (adjusted subdistribution HR [aSHR], 2.20; 95% CI, 1.40–3.46), and PE (aSHR, 1.60; 95% CI, 0.68–3.78). The other correlated risk factors included older age (50–64 years old: aSHR, 2.16; 95% CI, 1.14–4.09; >65 years old: aSHR, 3.18; 95% CI, 1.65–6.13), cancer history (aSHR, 2.96; 95% CI, 1.58–5.54), heart failure (aSHR, 2.19; 95% CI, 1.27–3.78), chronic kidney disease (aSHR, 1.83; 95% CI, 1.18–2.83), and admission

longer than 9 days (aSHR, 1.92; 95% CI, 1.22–3.04).

**Conclusion:** The overall risk of venous thromboembolism following lumbar spine surgery is less than 2% but correlated with curtain risk factors. The spine physician should be aware of the prophylactic prevention according to the heterogeneity with higher risks.

### Unilateral Posterior Lumbar Interbody Fusion for Coronal Balance Correction in Patients with Degenerative Lumbar Scoliosis

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**Purpose:** Sagittal imbalance have been extensively described in the literature whereas there was paucity of literature paying attention to coronal imbalance. The unilateral posterior interbody fusion (PLIF) was performed at the most tilting region on concave side of the curve. This study reports radiological outcomes in patients with degenerative lumbar scoliosis (DLS) undergoing multilevel instrumented fusion and unilateral PLIF.

**Materials and Methods:** The study included 24 consecutive patients with DLS who underwent instrumentation and unilateral PLIF. All eligible patients meeting a minimum 2-year follow-up criteria were included. The radiological parameters, measured on the pre- and postoperative anteroposterior and lateral radiographs, were analyzed. Patients were classified into three groups (group A, B, and C) according to coronal balance (shifting of C7 plumb line) and the convex of curvature. In group C (convex type), we inserted PLIF cage unilaterally on concave side of the curve paying attention to the fractional curve to correct tilting of L4 vertebral body. The primary outcome was postoperative improvements in radiological parameters at 6-week and last follow-up, assessed using the paired *t*-test to compare the differences. A  $p < 0.05$  was considered statistically significant.

**Results:** Differences of the radiological parameters between pre- and postoperation concerning Cobb angles both the main curve and fractional curve, thoracic kyphosis, lumbar lordosis, sacral slope, pelvic tilt, and sagittal vertical axis, were significant improved ( $p < 0.05$ ). Main thoraco-lumbar/lumbar Cobbs was improved from 25.51° to 15.70° ( $p < 0.05$ ). Fractional curve (L4–S1) Cobb was

improve from 17.40° to 3.70° ( $p<0.05$ ). Coronal imbalance was improved from 4.15 to 2.60 cm ( $p<0.05$ ). In our cohort, we found the group C was also improved in curve correction, coronal and sagittal balance after surgery.

**Conclusion:** The posterior instrumented fusion and unilateral PLIF might provide the improvement of coronal balance in DLS. Although interbody cage was inserted unilaterally, the sagittal parameters were also improved effectively.

## The Risk Factors of Non-traumatic Vertebral Fracture in Hemodialysis Patients

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**Purpose:** From the previous studies, chronic kidney disease (CKD) patients have an extremely increased risk of fragility fractures. Dr. Ball and his colleagues reported that kidney transplant recipients hip and spine fracture risks are more than 4- and 23-fold higher than in the general population. Renal osteodystrophy is a bone disorder that occurs in chronic kidney disease patients and is associated with 2- to 14-fold increased fracture risk compared to the general population.

**Materials and Methods:** A total of 120 patients, who visited Kangbuk Samsung Hospital, with back pain and on hemodialysis, were assessed for eligibility between 2011 and 2018. We excluded 37 patients with trauma history, six patients who have already undergone surgery, and 22 patients with no lumbar plane radiograph. Among them, 24 patients with vertebral fracture were allocated into the vertebral fracture group and 31 patients without vertebral fracture were allocated into the non-fracture group. Age, duration of hemodialysis, bone mineral density (BMD), and serum alkaline phosphatase (ALP) level were evaluated for correlation with prevalence of fracture.

**Results:** On simple comparison of variables, age ( $p=0.042$ ), duration of hemodialysis ( $p=0.044$ ) and serum ALP level ( $p=0.049$ ) were related with prevalence of vertebral fracture. On comparison of crude OR, age ( $p=0.050$ ; OR, 1.069; and 95% confidence interval [CI], 1.000–1.142) and serum ALP level ( $p=0.020$ ; OR, 4.167; 95% CI, 1.258–13.800) are related with vertebral fracture.

**Conclusion:** It is necessary to prevent and diagnose high

risk group in chronic renal disease and hemodialysis patients to prevent and treat osteoporosis and vertebral body fracture. Because of the possibility of non-traumatic fractures in long-term dialysis patients, periodic confirmation by simple radiography and BMD are important to treat osteoporosis. We confirmed serum ALP level associated with non-traumatic vertebral fracture in hemodialysis patients. Therefore, it is important to trace serum ALP level carefully to prevent non-traumatic vertebral fracture in hemodialysis patients.

## Comparison of Radiographic Results of L5–S1 Anterior Lumbar Interbody Fusion, Minimally Invasive Oblique Lumbar Interbody Fusion, and Conventional Open Posterior Lumbar Interbody Fusion

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**Purpose:** There are three representative techniques for interbody fusion: anterior lumbar interbody fusion (ALIF), oblique lumbar interbody fusion (OLIF), and posterior lumbar interbody fusion (PLIF). The purpose of this study is to compare which is effective in indirect decompression and lumbar lordosis restoration in radiographic parameters.

**Materials and Methods:** This retrospective comparative study based on the patients with degenerative spinal diseases underwent L5–S1 interbody (41 males and 91 females). ALIF group ( $n=13$ ), OLIF group ( $n=56$ ), and PLIF group ( $n=63$ ) were included. We evaluated the demographics, preoperative, and postoperative 3 months radiographic parameters of L5–S1 segment. These parameters included disc height, lumbar lordosis, segmental lordosis and foraminal height in computed tomography (CT) image or plain radiograph.

**Results:** There was no difference in demographics ( $p>0.05$ ). Postoperative disc height increase ratio (ALIF 62.3% vs. OLIF 93.4% vs. PLIF 37.7% in plain radiograph,  $p=0.007$  and ALIF 50.2% vs. 93.2% vs. 23.5% in CT image,  $p=0.017$ ) and lumbar lordosis increase ratio (ALIF 301.7%

vs OLIF 121.3% vs. PLIF 45.0%,  $p=0.001$ ) in radiographs, ALIF and OLIF showed significantly larger increment than PLIF. ALIF and OLIF showed more foraminal height restoration (ALIF 21.7% vs. OLIF 19.0% vs. PLIF 14.8%,  $p=0.076$ ) in CT images and more segmental lordosis increment in both plain radiograph (ALIF 239.0%, 327.5%, 148.9%,  $p=0.179$ ) and CT images (ALIF 73.6%, OLIF 159.4%, PLIF 52.7%,  $p=0.257$ ) but there was no difference.

**Conclusions:** Disc height and lumbar lordosis restoration is more efficient in ALIF and OLIF than PLIF which can also affect indirect decompression. But in terms of segmental lordosis restoration and foraminal height, all techniques we evaluated can be considered as comparable techniques.

## Predictors of Needing Laminectomy after Indirect Decompression Via Initial Anterior or Lateral Lumbar Interbody Fusion

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**Purpose:** To evaluate factors are associated with the need for additional posterior direct decompressive surgery after anterior (ALIF) or lateral (LLIF) lumbar interbody fusion.

**Materials and Methods:** Eighty-six adult patients who underwent ALIF or LLIF for degenerative spondylolisthesis and foraminal stenosis were enrolled. Prior lumbar surgery, deformity, tumor, trauma, and infection patients were excluded. Patient factors (age, sex, number of surgery levels, and Visual Analog Scale [VAS] of leg and back pain), procedure related factors (cage height and lordosis), and radiographic measurements (disc height [DH], foraminal height [FH] and area [FA], central canal diameter [CCD], and facet joint degeneration [FD]) were analyzed. All patients underwent staged surgery on two different days, with the anterior portion first followed by the posterior portion. Posterior instrumentation with or without additional decompression was recorded.

**Results:** Out of 86 patients, 62 patients also underwent posterior decompression, and 24 patients had no posterior decompression. There were no significant differences between groups with regards to age, sex, preoperative VAS of back pain, cage height, cage angulation, preoperative DH, FH, FA, CCD, and FD ( $p>0.05$ ). The group that underwent posterior decompression showed statistically dif-

ferent numbers of treated segments (1.92 vs. 1.21,  $p<0.01$ ), preoperative VAS leg (7.9 vs. 6.3), postoperative DH improvement (61.3% vs. 96.2%), postoperative FH improvement (21.5% vs. 32.1%), postoperative FA improvement (24.1% vs. 36.9%), and cage height minus preoperative DH (5.3 mm vs. 7.5 mm) compared with the no decompression group.

**Conclusion:** There appears to be some correlation between the need for posterior decompression and the foraminal height, foraminal area, difference between the cage height and preoperative disc height, duration of symptoms, and VAS leg scores. In selected patients undergoing staged surgery, indirect decompression without direct decompression may be a reasonable option in treating degenerative spinal conditions.

## Clinical Adjacent Segment Pathology Following Instrumented Lumbar Spine Fusion: Minimum of 2-Year Follow-up

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**Purpose:** To evaluate incidence, characteristics, risk factors and type of management (surgical/conservative) needed for clinical adjacent segment pathology (CASP) in patients who underwent instrumented lumbar spine fusion.

**Materials and Methods:** From 2001 to 2016, 1,111 patients who had instrumented lumbar fusion with at least 2-year follow-up were included. After thorough evaluation of clinical and radiological records, patient characteristics, surgical variables, radiographic parameters, and bone-mineral-density were evaluated for patients who developed CASP.

**Results:** Fifty-one patients (28 males and 23 females) out of 1111 developed CASP (incidence=4.59%) with mean age of 61 years and 46 patients being aged >50 years. Single-level fusion was done in 36 patients, two level fusions in 14, and three level fusion in one. Thirty-seven patients (73%) had floating fusions and 14 (27%) non-floating fusions. Mean asymptomatic period for development of CASP was 5.5 years. CASP at proximal adjacent segment was seen in 45 patients (88%), at distal adjacent segment in three (6%), and at both segments in three (6%). Thirty-

three out of 51 patients underwent surgery for CASP. Osteoporosis (T score <-2.5) was seen in 15 patients.

**Conclusion:** Incidence of CASP in our study was 4.59%. Age>50 years, single level fusion, floating fusion, and osteoporosis were risk factors for CASP. Majority of CASP affected proximal segment. Canal stenosis was the most common pathology of CASP. Majority of patients required second surgery for CASP.

## Necessity of Instrumentation for Decompression of Ossification of Yellow Ligament in Thoracolumbar Spine

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**Purpose:** Ossification of yellow ligament (OYL) in thoracolumbar spine is not common, but it is necessary to perform surgical treatment in patients who have severe neurologic symptoms or pain. We retrospectively reviewed the result of surgical treatment in OYL in thoracolumbar spine. The aim of this study is to compare result of surgical treatment depending on methods of surgery (decompression and fusion).

**Materials and Methods:** We reviewed 39 patients with minimum 1-year follow-up who underwent surgery for OYL in thoracolumbar spine from 2000 to 2011. The mean age of patients was 62 years (range, 36–62 years). There were 11 in men and 28 in women. Surgery was performed, if neurologic symptom progressed, or pain was not improved by medical therapy. Surgical techniques was divided into two groups: posterior decompression (18 cases) and posterolateral fusion after decompression (21 cases). We compared improvement of muscle power, gait disturbance, and pain estimated by MI score, JOA score, MI score, Japanese Orthopaedic Association (JOA) score, Visual Analog Scale (VAS) score preoperatively, and at last follow-up. Subjective of satisfaction by Macnab criteria was compared between decompression group and fusion group, also compared between gait disturbance and pain of chief complaint.

**Results:** OYL shows multiple development, which was 30 cases in T11–12, 21 in T10–11, 19 in T12–L1, 11 in T9–10, six in L1–2, and four in T8–9. Clinical results improved, 83 to 90 in MI score, 10 to 14 in JOA score, 7

to 4 in VAS score. Comparing degree of satisfaction by surgical method, satisfaction more than good was occupied 50% in decompression group, 67% in fusion group. In symptoms, gait disturbance was satisfied after surgical treatment in 75%, symptoms of pain in 43%.

**Conclusion:** The results of surgical treatment of OYL in thoracolumbar spine showed more improvement of subjective symptom in fusion group rather than decompression group. Authors believe instrumentation for stability after decompression of OYL guarantee more improvement of clinical satisfaction because one of causes of OYL is mechanical stress in thoracolumbar spine.

## The Study of Operative Window in Performing Oblique Lumbar Interbody Fusion: Feasibility in Southern Chinese and Comparison between Magnetic Resonance Imaging and Computed Tomography

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**Purpose:** The advantages of oblique lumbar interbody fusion (OLIF) using anterior to psoas approach included better correction of scoliosis, larger area of fusion, and better indirect decompression. However, risk of injuries to retroperitoneal structures can cause significant bleeding or even mortality. Currently, there are only scanty reports about the size of this operative windows.

**Materials and Method:** This is a retrospective study about the operative window from left side using both magnetic resonance imaging (MRI) and computed tomography (CT) scan. The sizes of windows in axial cut (distance between lateral border of the aorta and medial border of the psoas muscle), any intervening structures, difference in size between CT and MRI, and any retroperitoneal structures that can only be seen in only one of the imaging were assessed. Using SPSS software, we also compare the size in both imaging, in different levels in MRI and any difference in frequency of obstruction free levels.

**Results:** Both MRI and CT were available in 73 patients. Two hundred and forty-seven levels were assessed. The mean horizontal widths (mm) of the operative windows were as follows (CT/MRI measurement): L1/2 (19.87/20.32), L2/3 (19.87/20.32), L3/4 (18.43/18.56), and L4/5

(18.22/17.15). There was no statistical difference between the CT and MRI measurements. There was no retroperitoneal structure that can only be seen in only one imaging. No significant size difference between different levels was found using analysis of covariance ( $p=0.132$ ). The percentages of free windows were significantly different ( $p=0.000$ ): 98% in L1/2, 91.5% in L2/3, and 59.4% in both L3/4 and L4/5 levels.

**Conclusion:** In our study, the mean horizontal width of operative window in Southern Chinese population allow insertion of a sizable cage but the actual size could be highly variable (e.g., from 0.89 to 40.34 cm in L2/3 levels). MRI alone should be good enough in assessing the operative windows in OLIF.

## Inflammaging Is the Key Factor Dissecting the Molecular Mechanisms between Biological Ageing and Disc Degeneration

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**Purpose:** The true understanding of ageing and disc degeneration (DD) is still elusive. Reliance on magnetic resonance imaging (MRI) imaging has led to a mechanistic understanding of DD with mechanistic solutions and poor results. Understanding degeneration at molecular level through proteomics will allow differentiation from normal ageing and also allow development of biomarkers for early diagnosis and preventive therapies. We did an experimental analysis to utilize proteomics and understand the molecular basis of healthy, ageing and degenerating discs and conclusively differentiate normal ageing and degeneration.

**Materials and Methods:** L4–L5 disc samples from MRI normal, healthy brain dead voluntary organ donors of 6 decades, and five degenerated discs were subjected to proteomic analysis. Discs from donors <40 years were considered as control; >40 years as aged; and those from fusion surgery as degenerated. The entire proteome map and alteration in protein expressions were further analyzed using Gene Functional Classification tool in DAVID

and STRING database.

**Results:** There were 84 common proteins with specific proteins being 225 in A, 315 in B, and 283 in C. By the Gene Ontology biological process identification, group A predominated with extracellular matrix organization, cytoskeletal structural, and normal metabolic proteins. Group B differed in having additionally basal expression of immune response, complement inhibitors, and senescence proteins. Group C was completely different with upregulation of proteins associated with oxidative stress response, positive regulators of apoptosis, innate immune response, complement activation, and defense response to gram-positive bacteria indicating ongoing inflammaging.

**Conclusion:** Our study documented entirely different proteome signatures between young, ageing, and degenerating discs and inflammaging being the main basis of DD. Multiple inflammatory molecules unique to DD were identified, allowing the possibility of developing specific biomarkers for early diagnosis and thereby provide evidence based metrics for preventive intervention and monitoring progress.

## Does Discectomy Improve Radiculopathy as Well as Low Back Pain in Patients with Lumbar Herniated Intervertebral Disc

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**Purpose:** To evaluate the effectiveness of reducing the low back pain (LBP) within 1 year after discectomy.

**Materials and Methods:** Among 183 patients who underwent discectomy by a single surgeon from January 2010 to December 2016, 106 patients who met the inclusion and exclusion criteria were enrolled. Three types of spine-related pain in 106 patients who have underwent lumbar discectomy, was assessed preoperatively, and at 3, 6, 12 months after surgery, retrospectively. Functional outcomes were evaluated and quality of life was assessed using the 36-item Short-Form Health Survey which was subdivided into mental components and physical components at 12 months after surgery.

**Results:** LBP showed both statistical and clinical improvement during the first 3 months but did not maintain until after 12 months. Referred buttock pain and lumbar radiculopathy showed both statistical and clinical improvement

during the first 3 months and consistently showed statistical improvement, those were not improved clinically. LBP improved clinically only until after 3 months regardless of herniation type.

**Conclusion:** LBP showed improvement during the first 3 months and showed plateau afterwards, and referred buttock pain and radiculopathy showed consistent improvement until after 12 months. This may explain why patients of over than 12 months of follow-up may show improvement in referred buttock pain and radiculopathy but rather not in LBP.

### Multivariate and Survival Analysis of Prediction Factors That Influence the Clinical Outcome of Oswestry Disability Index in Patients with Hernia Nucleus Pulposus at Lumbar Vertebra Post Microendoscopic Discectomy

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**Purpose:** Nucleus pulposus hernia (HNP) is a condition of protrusion of the nucleus pulposus through the annulus fibrosus in the intervertebral disc that presses towards the spinal canal. Minimal invasive surgery is one of the management of HNP with minimal intervention. The Oswestry Disability Index (ODI) is a clinical outcome for evaluating the success of treating low back pain. This study was conducted to assess the factors that influence ODI clinical outcomes in patients with nucleus pulposus herniation after microendoscopic discectomy (MED).

**Materials and Methods:** This study was an observational analytic cohort method in 102 patients by analyzing the factors of age, sex, body mass index, cigarette consumption, alcohol consumption, occupation, pain onset, Visual Analog Scale (VAS) pain score, radicular pain, neurological deficit, duration and conservative management, herniation zone, herniation grading length of operation, duration of treatment, recurrence of herniation, complications, and duration of postoperative healing.

**Results:** Some factors influence ODI outcome in the sample as resulted by statistical analysis. From linear regression calculation, ODI 12-month postoperative formula =  $21.967 + -1.54 \times (\text{VAS preoperative}) + 0.697 \times (\text{ODI}$

preoperative) +  $-0.104 \times (\text{age}) + 0.794 \times (\text{grading herniation})$ . There was no statistical significance found in the survival analysis of pain recurrence. However, the pain recurrence happened before 3 months postoperative was found in two patients having sequestration grade and body mass index (BMI) more than 25 kg/m<sup>2</sup>.

**Conclusion:** Factors influencing clinical outcomes by ODI in patients with nucleus pulposus herniation after MED were preoperative ODI, preoperative VAS, pain onset, BMI, age, sport history, herniation grading, and pain recurrence. Only four of them are able to predict postoperative ODI, preoperative ODI, preoperative VAS, age, and herniation grading.

### Quantitative Assessment of Paraspinal Muscle Damage after Posterior Lumbar Spinal Fusion Surgery: Triple Incision versus Conventional Posterior Lumbar Interbody Fusion versus Minimally Invasive Transforaminal Lumbar Interbody Fusion

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**Purpose:** Paraspinal muscles (PSM) are related to the surgical outcomes of degenerative lumbar fusion. In conventional open technique, postoperative magnetic resonance imaging shows significantly increased high signal intensity in PSM. The purpose of this study is to evaluate and compare the perioperative PSM change using Photoshop-based image analysis according to various lumbar fusion techniques.

**Results:** We used three types of surgical techniques: (1) conventional open posterior lumbar interbody fusion (PLIF) (n=57), (2) triple incision (laminectomy and interbody fusion via midline spinous splitting approach supplemented with instrumentation using Wiltse approach) (n=45), and (3) minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) followed by percutaneous instrumentation (n=36). We evaluated the intramuscular high-signal ratio (IHR, %) using pixel values in Adobe Photoshop image program applied to PSM on MR axial images. Perioperative changes of IHR were defined as postoperative IHR divided by preoperative IHR. We also

compared the clinical outcomes Visual Analog Scale and Oswestry Disability Index among three groups.

**Conclusion:** From the Photoshop-based image analysis, MIS TLIF and triple incision techniques showed a significant preventive effect for paraspinal muscle damage compared to conventional PLIF in the degenerative lumbar fusion surgery.

## The Use of Non-traumatic Adhesive Patient Tracker in Computerized Navigated Pedicle Screws Insertion

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**Purpose:** Secure placement of patient tracker on patient's bony surface was required for navigated screw insertion. Recently, there was a newly developed adhesive skin tracker (SpineMask from Stryker) available but the literature about its accuracy were lacking. Besides, the use of skin tracker can avoid another skin incision when performing minimal invasive spine surgery using Wiltse approach. This is a retrospective study about the accuracy and clinical result in using this patient tracker.

**Materials and Methods:** Adhesive patient trackers were used in patients requiring pedicle screws insertion over lumbar or thoracic region. Exclusion criteria included patient with significant spinal deformity or requiring midline posterior open approach. The operations were performed in prone position. Before the skin incision, the tracker was applied to the skin. It was followed by intra-operative computed tomography (CT) scanning. After matching of preoperative with intra-operative imaging, pedicle screw tracts were prepared with navigated instruments using Wiltse approach. Positions of guide wires and final position of screws were checked using intra-operative fluoroscopy. Patient's demographics, any complications, and X-rays alignment were recorded after the operation. Postoperative CTs were performed to check the accuracy of the pedicle screws and classified using 2-mm classification system.

**Results:** From January 2018 to December 2018, 15 patients were recruited. The mean age of the patient was 61.5 years old and 10 of them were male. Seventy-six pedicle screws were inserted. The percentages of screws at differ-

ent levels were as follows: 26.3% in L4, 21.1% in L5, 13.2% in L3, 7.9% in L2 and T12, 5.3% in S1, SAI, and 2.6% in L1, T10 and T8. No neurological complication was noted after the operation. For those with CT scan available after the operation, 100% of the screws belong to grade A.

**Conclusion:** Adhesive skin tracker allowed accurate pedicle screws insertion during computerized navigated spine surgery.

## How Do Beginners Who Do Biportal Endoscopic Spinal Surgery Overcome Trial and Error?

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**Purpose:** To introduce biportal endoscopic spinal surgery (BESS) for lumbar spinal diseases (LSDs) and to inform technical strategies to overcome pitfalls associated with early learning periods in mastering the technique.

**Materials and Methods:** This study evaluated 63 patients (mean age,  $63.3 \pm 7.6$  years) with LSDs who underwent BESS from March to December 2018. To evaluate the learning curve for BESS, the procedures for various LSDs by one surgeon were analyzed in the view of shortening of the operating times and reduction of complications. Operation time, intra- and postoperative complication, and pre- and postoperative magnetic resonance imaging were measured. Reviewing of recorded procedures helped in finding the reasons and the implemented solutions.

**Results:** The 70 cases included 48 for lumbar spinal stenosis (LSS), 12 for degenerative lumbar spondylolisthesis, and eight for lumbar disc herniation (LDH). The operation time for the total cases averaged  $87.7 \pm 33.6$  minutes. It took  $102.4 \pm 32.4$  minutes before 15 cases, but  $47.3 \pm 18.6$  minutes afterwards. According to diagnosis, it was  $68.2 \pm 23.7$  minutes for one level of LSS. It took  $120.2 \pm 40.5$  minutes before 15 cases, but  $50 \pm 13.2$  minutes afterward. For the LDH it changed from  $47.1 \pm 12.1$  to  $24.3 \pm 8.3$  minutes. Since the 15th cases of BESS, it was nearly constant and close to the average time. Prolonged operation times even in some later cases of LSS were mainly from struggling against blurred vision due to epidural bleeding. There were 12 cases of complications (17.1%) including seven cases of dural tear, one case of root injury, two cases of symptomatic hematoma, and two incomplete decom-

pression on postoperative magnetic resonance imaging. Most of the complications occurred before the 20th cases (9/12).

**Conclusion:** Despite being a beginner, BESS is a relatively short learning curve period. The overall complication rate in early learning period was 17.1%. These could be avoided by establishing precise treatment goals before surgery, early adaptation to magnified regional views on an endoscope, and a clear surgical field by controlling epidural bleeding.

### Combination of Minimally Invasive Spinal Surgery: Oblique Lumbar Interbody Fusion and Biportal Endoscopic Spinal Surgery for Lumbar Spinal Stenosis: Pilot Study

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**Purpose:** Oblique lumbar interbody fusion (OLIF) procedure is one of the minimally invasive spine surgeries and is being frequently attempted recently to treat lumbar degenerative disease. It effectively decompresses foraminal stenotic lesions indirectly by inserting a large cage anteriorly, which reduces spondylolisthesis and widens the disc space. However, OLIF has limited effect for severe central canal stenosis, since it cannot achieve direct decompression. Therefore, authors report a new minimally invasive technique of OLIF combined with direct central decompression using biportal endoscopic spinal surgery (BESS) for severe central stenosis along with its clinical results as a pilot study. We report the new minimally invasive technique and its clinical results of OLIF combined with central decompression using BESS.

**Materials and Methods:** For patients who were candidate for fusion surgery due to spondylolisthesis (more than one segment) or foraminal stenosis, authors performed OLIF and central decompression using BESS simultaneously, when the patients had concomitant severe central canal stenosis. From June to December, 2017, eight patients (16 levels) were enrolled, and the operative time, blood loss, complications, and clinical results have been evaluated. The clinical results were analyzed by Visual Analog Scale (VAS) scores, Oswestry Disability Index (ODI),

and Roland Morris Disability Questionnaire (RMDQ) of preoperative, 1-month, 3-month postoperative, and final follow-up.

**Results:** Mean operative time and blood loss were 238.4 minutes and 173.3 mL, respectively. In all cases, there were no operative complications, and mean follow-up period was 7.1 months. The mean back VAS, lower extremity VAS, ODI, and RMDQ at the final follow-up were improved from  $5.4 \pm 2.4$  to  $2.0 \pm 0.9$ ,  $7.0 \pm 1.1$  to  $1.6 \pm 1.7$ ,  $64.2 \pm 11.8$  to  $44.2 \pm 10.6$ , and from  $17.5 \pm 4.2$  to  $12.9 \pm 4.0$ .

**Conclusion:** A new combination technique of OLIF and BESS for direct decompression can be regarded as effective alternative procedure to treat the foraminal and central stenotic lesions of lumbar degenerative disease.

### Efficacy and Safety of Vertebroplasty and Kyphoplasty in Osteoporotic Vertebral Compression Fracture with Posterior Cortical Bone Injury: Evaluated by Magnetic Resonance Imaging and Computed Tomography

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**Purpose:** Kyphoplasty and vertebroplasty are useful treatment option for painful osteoporotic vertebral compression fractures (OVCF). The purpose of this study was to evaluate the clinical effect of vertebroplasty and kyphoplasty in osteoporotic compression fractures and evaluate the cement leakage in patients with posterior cortical bone injuries using computed tomography (CT).

**Materials and Methods:** The present study retrospectively analyzed patients who underwent vertebroplasty or balloon kyphoplasty for OVCF between July 2011 and October 2016. The patients were divided into two groups according to the presence of posterior cortical bone injuries. Pain Visual Analog Scale evaluation was performed prior to the operation, at immediate postoperatively, and 1-year follow-ups. Simple radiography were taken preoperatively, immediate postoperatively, and 1-year follow-ups. Anterior and posterior vertebral height and kyphotic angle were measured in lateral radiographs. Immediate postoperative radiographs and CT were also reviewed for cement leakage and canal encroachment

**Results:** In 446 patients, total of 647 vertebroplasty or

kyphoplasty were performed. Among 647 vertebral bodies, 291 were compression fractures and 356 were burst fractures. The overall leakage rate was 33.14% in the compression fracture and 31.95% in the burst fracture, respectively ( $p=0.842$ ). Compression fracture group and stable burst fracture group showed no difference in total leakage rate regardless of the procedure. Both vertebroplasty and kyphoplasty in the vertebral body with osteoporotic burst fracture showed improvement in anterior vertebral height ratio and kyphotic angle after the operation, and kyphoplasty showed better result than vertebroplasty. The degree of canal encroachment was improved both vertebroplasty and kyphoplasty group in burst fractures.

**Conclusion:** Vertebroplasty and kyphoplasty in burst fractures showed no clinically important difference in cement leakage rate compared with compression fracture and showed clinical and radiologic improvement.

## Uniportal Endoscopic Interlaminar Decompression

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**Purpose:** To describe surgical technique of percutaneous endoscopic decompression by a uniportal and unilateral approach for lumbar central or lateral recess stenosis and to report the postoperative results.

**Materials and Methods:** In this retrospective study, the procedure was performed with full-endoscopic technique in the same way as conventional microscopic laminotomy and flavectomy in 97 patients between June 2016 and December 2017. We analysed the clinical outcomes using the Visual Analog Scale (VAS), Oswestry Disability Index (ODI), and modified MacNab criteria. And the surgical outcomes including operation time and complications were recorded

**Results:** Mean follow-up period was 13.5 months (range, 12–18 months). Mean age was 64.2 years and sex ratio was 6 (male):4 (female). The operation level were 43 (44.3%) at L4–5, 27(27.8%) at L3–4, 15 (15.5%) at L2–3, 6(6.2%) at L1–2, and 6 (6.2%) at L5–S1. Mean operation time was 51.2 minutes/level. VAS leg score improved from 7.8 to 1.7, and ODI improved from 67.4 to 20.3. According to the modified MacNab criteria, excellent or good results were obtained in 92 cases (94.8%). There were seven cases of

transient postoperative dysesthesia, two cases of transient cauda-equina syndrome due to postoperative hematoma, two cases of medial facet fracture, two cases of dural tear, and one case of revision surgery for incomplete decompression.

**Conclusion:** Percutaneous uniportal endoscopic interlaminar decompression technique is a safe, clinically feasible, and effective surgical technique for treatment of lumbar canal or lateral recess stenosis.

## Identification of Plasma microRNA Signature to Predict Curve Progression in Adolescent Idiopathic Scoliosis: A 6-Year Longitudinal Follow-Up Study

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**Purpose:** Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional spinal deformity without clear etiopathogenesis. The outstanding research question is to improve the sensitivity and specificity of prognosticating curve progression in the early diagnosis stage for timely treatment and to avoid unnecessary over treatment. We recently proved association of miRNA to bone quality of AIS with miR-145 impairing osteoblast to osteocyte differentiation in AIS. We hypothesized that circulating miRNA(s) could be a new biomarker to reflect disease severity and in predicting curve progression in AIS.

**Materials and Methods:** This study consists of a case-control cohort (100 AIS girls vs. 52 healthy control) and a longitudinal cohort with 6-year follow-up (120 AIS girls). Cobb angle and bone qualities were measured with posteroanterior X-ray and HR-pQCT, respectively. In the longitudinal cohort, blood was taken at first visit, and the progressive or non-progressive group was defined according to Scoliosis Research Society criteria ( $>6^\circ$  or  $<6^\circ$  annually). Plasma levels of miRNAs were determined by quantitative polymerase chain reaction. Mann-Whitney, Student *t*-test, Spearman's rank correlation, logistic regres-

sion model, and area under the receiver operating characteristic test were used for statistical analysis.

**Results:** In case-control cohort, AIS has significantly higher plasma level of miRNA-145, miR-224, and miR-96 than control. Logistic model showed miRNA-145, miR-224, and miR-96 could distinguish AIS from control. In the longitudinal cohort, we established a model composing of identified plasma miRNAs level and bone qualities showed predicting power of curve progression with high sensitivity and specificity.

**Conclusion:** This study demonstrates circulating miRNAs prognosticate the curve progression in AIS. Result of the study shed light on potential of novel biomarkers to improve timely treatment of AIS. This study was supported by HMRF (04152176), RGC (project no., 463113), and NSFC/RGC (project no., N\_CUHK416/16; project no., 81661168013).

## Telomerase Activity after Spinal Cord Injury

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**Purpose:** The purpose of this study is to investigate the interaction of telomerase activity and telomere length on the effect of neuro-protection or neuro-degeneration after spinal cord injury (SCI).

**Materials and Methods:** Contusive SCI was made using 56 Sprague-Dawley rats, and each seven rats were allocated into the acute phase (1, 3, 8, 24, and 48 hours), and the subacute, and chronic phase (1, 2, and 4 weeks). Telomerase activity were assessed by telomerase reverse transcriptase (TERT) and telomeric-repeat binding protein (TERF) 1 and 2. Differentiation of the activated neural stem cells was also investigated by coexpression of neuronal/glial cell markers (GFAP, Neu N, and CC-1). Expression of apoptosis were also investigated by caspase-3, -8, and -9 using terminal dioxynucleodidyl transferase dUTP nicked-end labeling staining. Immunofluorescence staining and western blotting were performed for quantitative analyses, and these results were compared with those in the control group.

**Results:** Expression of TERT increased gradually until post-injury 24 hours, and decreased following SCI. How-

ever, the overall expression of TERT was not significantly higher than that of the normal spinal cord. TERF 2 also showed gradual increase following SCI until post-injury 24 hours and decreased with time. And these TERF 2 expression was significantly higher than that of the normal spinal cord. Apoptosis analysis showed persistent high expression of caspases-3, -9, and -8 during the observation period compared with control group.

**Conclusion:** Increased activity of TERT and TERF 2 was noted in the acute phase of SCI. These findings suggest that increased telomeric activity may also be related to neuro-protective mechanisms for subsequent apoptosis (via the inhibition of apoptosis) resulting from the DNA damage after acute SCI.

## Comparison of Insertion Time, Pullout Strength, and Screw: Media Interface Area of Indonesian Customized Pedicle Screw with Different Core and Thread Design with Commercially Available Pedicle Screw

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**Purpose:** Indonesian vertebral morphology has been shown to have difference with the western population. Developing customized pedicle screw based on previous study of Indonesian vertebral morphometry will give better outcome related to the anatomical similarity.

**Materials and Methods:** This was an experimental study. We have developed three different types of pedicle screws (v-thread cylinder-core, square-thread cylinder-core, and square-thread conical-core). The thread diameter was calculated from pedicle width of Indonesian population (6 mm). We used commercially available pedicle screw as control group (6.2 mm). The insertion time were recorded, the pullout strength test were performed, the interface area were calculated, and the results were analyzed statistically.

**Results:** We evaluated four groups of pedicle screws that consist of 15 customized pedicle screws and five commercially available pedicle screws. The insertion time were significantly difference between v-thread cylinder-core pedicle screw (22.94 seconds) with commercially available pedicle screw (15.86 seconds) ( $p < 0.05$ ). The pullout

strength were significantly difference between commercially available pedicle screw (408.60 N) with square-thread conical pedicle screw (836.60 N) ( $p < 0.05$ ). The square-thread conical-core group have the highest interface area ((1,486.21 mm<sup>2</sup>).

**Conclusion:** This study showed that our institution has been able to develop customized pedicle screws that have smaller diameter than commercially available pedicle screw. The data comparison showed that the square-thread conical-core customized pedicle screw group has comparable insertion time and has better pullout strength than commercially available pedicle screw.

## The Thickness of Ligamentum Flavum Was Affected by Different Lumbar Postures: A Computed Tomography Study

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**Purpose:** Different lumbar postures may cause bulking of ligamentum flavum (LF) which can cause the symptoms of spinal stenosis. Therefore, we conducted a quantitative computed tomography (CT) study of cadaveric specimens to investigate the influence of different lumbar postures on the change of LF thickness.

**Materials and Methods:** Eleven fresh frozen cadaveric specimens of lumbar spine were used in this study. We obtained the CT images of these specimens from four v extension, flexion, right lateral bending (RLB), and right axial rotation (RAR). The LF was measured the thickness by BoneJ and in-house programs developed with MATLAB. We then analyzed the LF thickness from L1 to L5 in different postures.

**Results:** The thickness of LF in extension was significantly larger than flexion from L1/L2 to L4/L5 ( $p < 0.05$ ). In RLB posture, the LF thickness of L1/L2 was thicker than that in neural position, while it was thicker in neural position than in RLB in L4/L5 level ( $p < 0.05$ ). In RAR posture, the LF thickness of L1/L2 and L2/L3 was significantly in-

creased than that in neutral posture ( $p < 0.05$ ).

**Conclusion:** The extension posture increased LF thickness compared to flexion posture in lumbar spine which may aggravate spinal stenosis. Lateral bending or axial rotation posture also increased the LF thickness in upper lumbar spine.

## Outcome of Spinal Decompression in Cauda Equina Syndrome

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**Purpose:** To study the outcome of spinal decompression in cauda equina syndrome (CES) with delay presentation.

**Materials and Methods:** This study was prospective descriptive clinical study. Thirty-one patients with evidence of cauda equina symptoms due to lumbar disc herniation who underwent urgent surgery were identified and invited to follow-up. Duration of delay presentation after onset was 1 to 12 weeks. All patients were operated within 1 week after admission and reexamined at 3-, 6-, and 9-month follow-up. The outcome measures comprised history and physical examination, several validated self-assessment questionnaires (Visual Analog Scale, Oswestry Disability Index [ODI], and 36-item Short-Form Health Survey [SF-36]), and urodynamic study preoperatively and at follow-up.

**Results:** Mean SF-36 score of CES with retention (CESR) was significantly better than incomplete CES (CESI) at 9-month ( $p$ -value=0.02) follow-up but not significantly different at 3-month ( $p$ -value=0.16) and 6-month ( $p$ -value=0.1) follow-up. CESR patients got minimal disability (i.e., 0%–20% ODI) and CESI patients got moderate disability (i.e., 20%–40% ODI) at 9-month follow-up. In urodynamic study, CESR type improved bladder function (postvoid residual urine, voiding volume, and maximal flow rate) significantly and got recovery of bladder function faster than CESI type at follow-up. Four patients who had areflexic bladder did not get satisfactory bladder function at 9-month follow-up.

**Conclusion:** Patients who have had CES can get clinical improvement and patient's specific functional outcome after decompression at 9-month follow-up even delay presentation between 1 week and 3 months.

## The Anatomic Feasibility of C7 Pedicle

## Morphology for Optimal Entry Points and Trajectories for Pedicle Screw Fixation

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**Purpose:** The author of this study will review the cervical computed tomography (CT) images of patients to delineate the anatomic details of the C7 vertebrae and pedicles to identify a suitable entry point and trajectories for pedicle screw fixation. The objective is to evaluate quantitatively the anatomy of C7 vertebra and pedicles using the multi slice axial CT scanner with sagittal, coronal, and three-dimensional reconstruction to determine the optimal entry points and trajectories for pedicle screw fixation.

**Materials and Methods:** This is a retrospective study. The study will involve all cervical CT scans from 2013 to 2014 in Davao Doctors Hospital radiology department database. The inclusion criteria are as follows: all patients 18 to 60 years old and normal complete study. The exclusion criteria are as follows: degenerative disease, cervical spine fracture, congenital or developmental spinal malformation, and infectious or neoplastic disease of the cervical spine. Using the multi-slice axial CT scanner with sagittal, coronal, and three-dimensional reconstruction, measurements will be performed/supervised by an experienced radiologist. The accuracy of measurements and the collected data will be verified by the authors. Statistical analysis will be used to calculate the average and standard deviation.

**Results:** A total of ninety patients with cervical CT scans were included in the study where seven pairs of measurements were obtained from each C7 vertebra.

**Conclusion:** The optimal entry point of the right C7 pedicle is 2.47 mm caudal to the inferior border of the C7 superior facet and 2.57 mm medial from the lateral edge of the lateral mass. It is 2.42 and 2.62 mm, respectively for the left C7 pedicle. There's no significant difference when compared between age groups and gender. The combined vertical orientation measurement is  $2.44 \pm 0.94$  mm caudal to the C7 superior facet while the horizontal orientation is  $2.59 \pm 0.75$  mm from the lateral border of the lateral mass.

## Three-Dimensional Pedicle Morphometry in Patient with Severe Adolescent Idiopathic Scoliosis

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**Purpose:** Knowledge of morphometry of the deformed vertebral including inner diameter (ID), outer diameter (OD), transverse pedicle angle (TPA), chord length (CL), and pedicle height is important for safe pedicle screw instrumentation and correction of deformities.

**Materials and Methods:** A descriptive cross-sectional study was conducted to five patient with severe adolescent idiopathic scoliosis underwent three-dimensional (3D) computed tomography (CT) scan and measure all the parameter and statistical analyzed it.

**Results:** A total of 425 measurements were performed from five patients and an average of 85 pedicles were assessed for each set of the measurements made. All samples are female and youngest age is 14 years old and the oldest age is 25 years old. With various apex and main curve, vertebral level and cobb angle range from  $70^{\circ}$ – $88^{\circ}$ . On the morphometry, each parameter showed that convex is slightly higher than concave side. Inner diameter parameter have significant result at 2nd thoracal vertebral ( $p=0.025$ ). Chord length parameter have significant result at 4th, 5th, and 7th thoracal vertebral ( $p=0.007$ ,  $p=0.032$ , and  $p=0.004$ ). From comparing between main curve and adjacent curve the result is significant in one sample from chord length parameter ( $p=0.001$  and  $p=0.03$ ).

**Conclusion:** Convex side vertebral has bigger morphometry comparing to concave side vertebral. Apex vertebral morphometry has relatively same dimension comparing to adjacent vertebral level. Scoliosis is a 3D deformity in which vertebral morphometry can be different from each patient. To perform safe pedicle screw instrumentation vertebral morphometry of every patient should be evaluated. CT is the ideal imaging modality for detailed analysis of bone structure.

## Surgical Treatment for Lumbopelvic Instability Caused by Complex Sacral Fractures: A Report of Three Rare and Difficult Cases

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**Purpose:** To report three cases of complex unstable sacral fractures treated with spinopelvic stabilization.

**Materials and Methods:** Combination of popular classifications, treatment of severe unstable sacral fractures with internal reduction, and spinopelvic stabilization applying triangular osteosynthesis concept were performed.

**Results:** Patients recovered spinopelvic stability and neurologic functions with good weight bearing to move and walk early after surgery.

**Conclusion:** Triangular osteosynthesis spinopelvic fixation is effective in restoring lumbopelvic stability and allows early postoperative mobilization with good weight bearing, and good neurological recovery can be hope with decompression.

## Thoracolumbar Burst Fractures: Results of Decompression Surgery and Its Correlation with Surgical Tactic

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**Purpose:** Thoracolumbar junction is the most common site of burst fractures. Current study was done to assess anterior and posterior approaches and to analyze outcomes.

**Materials and Methods:** It was a retrospective study at tertiary level center. Data was retrieved from hospital records. Forty-eight patients were included. Inclusion criteria were- patients presenting within 3 weeks of injury to DL spine with incomplete neurological deficit and aged between 18–65 years. Group 1 included anterior surgical approach (n=18) and group 2 had posterior surgical approach (n=30). Assessment was done with regard to blood loss, duration of surgery, hospital stay, and complications. Radiological outcomes were analyzed: kyphosis correction and improvement in canal decompression. American

Spinal Injury Association scoring was done to evaluate neurology. Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) were used for functional outcome analysis.

**Results:** Group 1: Mean age in anterior group was 29.3 years (T12 [n=8], L1 [n=10]). In our series, mean blood loss was 350 mL and duration of surgery was 160 minutes. Mean Cobb's angle of 28° improved to 4.8° ( $p<0.05$ ). The preoperative VAS of 7.4 improved to 0.5 ( $p<0.05$ ) at the end of 2 weeks. ODI score of 75.84 decreased to 17.60 ( $p<0.05$ ) at the last follow-up. Group 2: Mean age in posterior group was 27.8 years (T12 [n=16], L1 [n=11], L2 [n=3]). Mean blood loss was 160 mL and duration of surgery was 115 minutes. Mean Cobb's angle was 26° improved to 3.5 ( $p<0.05$ ). Average canal compromise was 56% which improved to 8% ( $p<0.05$ ). Preoperative VAS score of 8.1 improved to 0.25 at the end of 2 weeks ( $p<0.05$ ). ODI score of 48.6 improved to 14.7 at final follow-up which was statistically significant. Canal clearance in anterior decompression group (group 1) was statistically significant when compared to group 2.

**Conclusions:** Decompression by anterior approach is significantly superior to posterior approach. However, canal clearance and decompression did not translate to significantly better functional outcomes. There was no significant difference in kyphosis correction. Anterior approach takes significantly longer time and involves more blood loss than posterior approach.

## Clinical and Radiologic Features of Osteoporotic Spine Fracture with Delayed Neurologic Compromises

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**Purpose:** Osteoporotic spine fractures (OSFs) with delayed neurologic compromises (NC) have been increasingly reported. Although several studies have addressed that the pathologic mechanism of NC involves nonunion and segmental instability, the risk factors remain unclear. Therefore, the purpose of this study is to assess the radiologic and clinical features of OSFs with delayed NC.

**Materials and Methods:** Thirty patients with delayed

NC (group I) were matched in a 1-to-1 format with 30 patients without delayed NC (group II) by age, bone mineral density, body mass index, and medical treatment for osteoporosis. Clinical and radiologic parameters were assessed to determine the risk factors related to delayed NC. Clinical outcomes were also compared between the two groups.

**Results:** Neurologic compromises were presented as myelopathy in 20 patients and radiculopathy in 10 patients. Initial kyphotic angle (KA) and height loss (HL) were significantly greater in group I ( $21.6^{\circ} \pm 12.9^{\circ}$  vs.  $10.5^{\circ} \pm 8.6^{\circ}$ ,  $p=0.0001$  for KA;  $55.8\% \pm 15.2\%$  vs.  $19.9\% \pm 10.9\%$ ,  $p=0.0001$  for HL). Fracture instability with intravertebral cleft, posterior wall involvement, mid-portion type of magnetic resonance classification, thoracolumbar level, and aortic calcification were significantly correlated with delayed NC. In multivariate analysis, initial HL (hazard ratio, 1.24;  $p=0.012$ ) and mid-portion type fracture (hazard ratio, 14.9;  $p=0.03$ ) were the independent risk factors related to delayed NC. In addition, clinical outcomes at last follow-up were significantly better in the group II.

**Conclusion:** Initial HL and mid-portion type fracture were correlated with delayed NC following OSFs. Moreover, pre-existing stenotic lesions may be also associated with delayed NC.

## Outcome of Pedicle Screw and Rod Fixation in Thoracic and Lumbar Spine Fractured Patients Admitted to Yangon General Hospital

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**Purpose:** To study outcome of pedicle screw/rod fixation in thoracic and lumbar spine fractured patients

**Materials and Methods:** In a prospective study in level 1 trauma center, Yangon General Hospital, patients with thoracic and lumbar spine injuries were studied between September 2013 and August 2014. Twenty-seven skeletally mature patients, who sustained fractures within 1 week without any prior treatment, were evaluated. Twenty-four cases were included in the study after excluding associated injury, all of which were assessed for patient characters, mechanisms and fracture patterns. Outcomes were recorded and healing, stability, and recovery pattern observed. The studies which consisted of subjective and

objective evaluations were correlated with outcomes.

**Results:** Among 24 patients, background characteristics were comparable, with male predominance, the mean age ( $33.67 \pm 10.53$  years). Main mechanisms of injuries were identified fall from height representing three fourth. Whereas most common type observed was wedge flexion compression 11 cases (45.8%) followed by unstable burst fracture nine cases (37.5%), and unstable rotational translational fracture four cases (16.7%), most fractures were seen at lumbar spine. The anterior height loss was much improved ( $p<0.001$ ). The mean posterior height loss was 19.17% in preoperative measurement and 6.16% in postoperative 3rd week. There was an improvement in regional angle from  $18.33^{\circ}$  to  $4.80^{\circ}$  ( $p<0.001$ ). Twenty-one out of 24 patients had neurological deficit. Five out of six patients with grade A showed no improvement. Majority were improved either American Spinal Injury Association grade 1 or 2 higher.

**Conclusion:** Analysis revealed that the commonest cause was fall from height, compressive fractures being most common type which leads to deformity, and neurological compromise. The radiological and neurological evaluations were the parameters to assess instability and indication for surgery and recovery. We found that posterior instrumentation resulted in reasonable correction of deformity with a significant reduction in recumbency-associated complications; limiting factor being the small study group and short follow-up period.

## Closed Reduction for Pelvic Fractures with Real-Time Navigation

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**Purpose:** Many procedures were developed for unstable pelvic fracture. Now we start to closed reduction with pedicle screws to fix anterior and posterior unstable pelvic ring. This study aims to investigate the safeness and benefit of this procedure.

**Materials and Methods:** A total of five patients (four men and a woman; mean age, 73.6 years; range, 62–88 years) who underwent triangular osteosynthesis and anterior subcutaneous (closed) internal pelvic fixation with navigation via O-arm II were evaluated. The mean follow-up

period was 8.8 months (range, 4–27 months). For after surgical treatment, all patients were allowed full weight bearing.

**Results:** Evaluated the fracture type with the AO Foundation and Orthopaedic Trauma Association classification, two cases were B2.1, and a case was B2.3, B3.3, and C3.3. The average of the total operative time was 239 minutes (range, 182–275 minutes), the average time of triangular osteosynthesis was 124 minutes (range, 79–150 minutes), and the average time of anterior subcutaneous internal pelvic fixation was 84 minutes (range, 67–100 minutes). The average amount of bleeding was 173 mL (range, 30–245 mL).

**Conclusion:** Using navigation via O-arm II, we can get almost real-time images. The value of real-time navigation is that triangular osteosynthesis and anterior subcutaneous internal pelvic fixation could be used together with adequate screw size and without interference of the screw. Total operative time was less than 4 hours but it is long or not we cannot evaluate. However the amount of bleeding was 200 mL or less and was small quantity. These procedures provided adequate stability to unstable pelvic ring and facilitated intensive care, nursing care, and rehabilitation.

## Penetrating Spine Injury Bisecting Thoracic Spinal Canal with No Significant Neurological Deficits: The Midline Cord Syndrome

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**Purpose:** In India, the incidence of penetrating spine injury (PSI) is increasing because of the increased use of advanced ballistics (missile PSI) among military personnel and sophisticated tools and construction instruments like nail-guns or drills (non-missile PSI) among civilians. These injuries are associated with a risk of neurological damage, central nervous system infections, vascular injury, dural tear followed by cerebrospinal fluid (CSF) leakage, and spinal instability.

**Materials and Methods:** A 35-year-old male presented with a non-missile PSI with retained iron nail bisecting his dorsal spinal cord, without any motor deficits. The patient presented with only left lower limb proprioceptive loss and L1–L3 paresthesia. Nail removal was done on

emergent basis without any further neurological damage.

**Results:** Exposing the T8–T9 spinous process using a dorsal midline approach the nail was found passing through the interlaminar space along the right margin of the D9 spinous process. A lower T8 and upper T9 partial laminectomy was done preserving the facet joints. The nail was found penetrating through the dura. The intact nail (foreign body) of size 5.7 cm in length and 0.5 cm in diameter was carefully removed and the dural rent was repaired with 6-0 prolene and then sealed off using TISSEEL (Baxter Healthcare, Deerfield, IL, USA). The seal was augmented using autologous fascial graft and no CSF leak was confirmed using an intra-operative Valsalva maneuver under anesthesia. The facet joints were disturbed; therefore, any further consideration for posterior stabilization was aborted. His postoperative stay in the hospital was uneventful and the patient was discharged on day 12. A repeated neurological examination was conducted every 6 to 8 weeks and complete sensory recovery was seen at around 12-month follow-up.

**Conclusion:** To the best of our knowledge, this presentation of a non-missile PSI is rare and has not been previously reported. The specific clinical presentation of this distinct type of injury to the midline structures of the spinal cord is hence named “midline cord syndrome”.

## Single Anterior Approach for Subaxial Cervical Spine Injury: A Proposed Algorithm with Its Efficacy, Safety, and Reliability

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**Purpose:** Acute injury to the cervical spine and spinal cord is one of the most common causes of severe disability and death after trauma. Though treatment of cervical spine injury is controversial but anterior cervical surgery has still a better outcome than any other method. Aim of the study is to see the safety and efficacy of single anterior approach for subaxial cervical spine injury with development of treatment algorithm.

**Materials and Methods:** It was a prospective study from July 2009 to August 2018. Discectomy or corpectomy was done for decompression, and tricortical bone graft or cage

with bone graft was used for fusion. Cervical plate was used in all cases.

**Results:** Total operated cases were 98 and mean follow-up time was 56 months. Out of 98 patients, in preoperative period 10 patients had the American Spinal Injury Association (ASIA) scale A, 43 patients had ASIA scale B, 42 patients had ASIA scale C, and three patients had ASIA scale D. At follow-up, 39 patients of ASIA scale B changed to ASIA scale D, four patients of ASIA scale B changed to ASIA scale E, 26 patients of ASIA scale C changed to ASIA scale D, 16 patients of ASIA scale C changed to ASIA scale E, three patients of ASIA scale D changed to ASIA scale E, and 10 patients of ASIA scale A remain unchanged. In the current series none of the patients had worsening of neurological deficit.

**Conclusion:** Single anterior approach is a safe, effective procedure with a good neurological, radiological, and functional outcome. It definitely reduces hospital stay and postoperative morbidity.

## Reducible Nonunited Odontoid Type II Fracture with Myelopathy: Treatment with Two Different Fixation Techniques

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**Purpose:** Displaced nonunited odontoid type II fracture results in C1–C2 instability, causing delayed cervical myelopathy. Among the posterior atlantoaxial fusion, both transarticular screw fixation and segmental fixation are the effective techniques to create stability. Purpose is to compare the results of two surgical fixation techniques for treatment of reducible nonunited odontoid type II fracture with atlantoaxial instability.

**Materials and Methods:** Fifteen patients who have reducible nonunited type II odontoid fracture were collected during April 2007 to October 2015. Magerl's C1–C2 transarticular screw fixation (group 1) and C1–C2 segmental fixation (group 2) were treated. Fusion rate, fusion period, operative time, blood loss, postoperative hospital stay, and complications were compared.

**Results:** Nine patients were treated by C1–C2 transarticular screw technique and six were treated by C1–C2 segmental fixation. Two treatment groups had no statistically

significant difference in fusion rate. C1–C2 transarticular screw fixation had slightly better outcome than those with C1–C2 segmental fixation regarding to amount of blood loss ( $p=0.31$ ) and fusion period ( $p=0.16$ ).

**Conclusion:** Displaced nonunited odontoid type II fracture with myelopathy should be treated by surgery. Both fixation techniques provide substantial construct stability and enhance similar fusion rate. C1–C2 transarticular fixation is superior to segmental fixation in aspect of blood loss, fusion period, and implant cost without significant difference.

## Subdivision of C2 Odontoid Type III Fracture Classification

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**Purpose:** In this study, we aimed to suggest a new classification method for odontoid process type III fractures.

**Materials and Methods:** Patients with odontoid fractures who visited the different centers involved in this study were retrospectively analyzed. One hundred and ninety-eight patients were identified. All fractures that separated odontoid process from body of axis were reclassified as type III, and 34 cases were confirmed. We subdivided odontoid process type III fractures into groups A, B, and C (A, similar to Anderson & D'Alonzo's definition; B, similar to Grauer's definition; and C, fractures that could not be classified using traditional methods). Four independent observers analyzed the cases at 2-month intervals. Each observation was followed by intra- and inter-observer reliability tests with determination of kappa value.

**Results:** Each case was reclassified into the group with the highest agreement. Group A included 15 cases; group B, 10 cases; and group C, eight cases. One case could not be classified (the evaluation result was equivocal between group A and B). The mean kappa value of the inter-observer reliability was 0.7385. Meanwhile, the kappa value of intra-observer reliability was 0.9195. In morphological analysis in group C, six of eight cases showed the same fracture type. The fracture line did not involve the facet joint and started from the odontoid process base to the C2 body in a coronal oblique direction.

**Conclusion:** We classified group A as IIIa, B as IIIb, and C as IIIc. Type IIIa was defined as odontoid base fractures

without C1–2 facet involvement. Type IIb was defined as odontoid base fractures with C1–2 facet involvement. Type IIc was defined as odontoid base fractures run in coronal oblique direction.

## Anterior Approach to Cervical Spine Fracture-Dislocations: A Case Series

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**Purpose:** Treatment of choice in cervical fracture-dislocation is an area of contention between anterior cervical discectomy/corpectomy and fusion (ACDF/ACCF) or posterior instrumentation and fusion. Anterior approach permits the introduction of a large graft surface area placed under compression with associated disc herniation removal and fusion. Posterior approach is indispensable in cases associated with laminar and facet fractures. The aim of this article is to analyse outcomes in patients undergoing ACDF/ACCF for cervical fracture dislocations.

**Materials and Methods:** Twenty-one patients (15 males and six females) average age 46.8 years who underwent (ACDF/ACCF) with bone graft/metallic cage indicated for traumatic fracture dislocation from January 2016 to July 2018 were included in the study. All patients with radiology proven fracture dislocation included in the study were managed with planned closed reduction followed by ACDF/ACCF. All patients were followed up monthly for first 3 months and then 6 monthly till their last follow-up visit and were evaluated on basis of radiological, clinical, and patient-reported outcomes with average follow-up of 11.3 months (min 4 months, max 29 months).

**Results:** Out of 21 patients (20 ACDF, one ACCF) 15 had complete spinal cord injury while six had incomplete spinal cord injury (American Spinal Injury Association scale B, C, and D). At their final follow-up all showed clinical improvements in pain with patient reported outcomes showing significant improvements: Visual Analog Scale (VAS, 6.8 to 1.1), Oswestry Disability Index (ODI) score (56.7 to 23), modified Japanese Orthopedics Association (mJOA) score (11.5 to 17.3), and Nurick's grading (4.8 to 3.4). There were no severe intra-operative complications; however average blood loss was 253.1 mL. 1 patient of ACDF needed secondary posterior fixation.

**Conclusion:** Anterior approach to cervical spine in cervical fracture dislocation is an effective treatment of choice showing optimal recovery rate in terms of patient-reported outcomes and structural stability with added advantages of less blood loss and less instrumentation.

## Clinical Outcomes of Acute Cervical Spinal Cord Injury Depending on the Timing of Surgery

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**Purpose:** There have been lots of prior studies that show optimal surgical time for acute spinal cord injury (SCI). Most studies reported that early surgery had better results than late surgery. However, the timing of surgery remains controversial. We tried to evaluate the clinical outcomes of acute cervical SCI depending on the timing of surgery.

**Materials and Methods:** We analyzed patients whose surgery was performed for acute cervical SCI from 2007 to 2017. We analyzed change in the American Spinal Injury Association Impairment Scale (AIS) and ASIA motor subscore depending on the timing of surgery and analyzed the relation of clinical outcomes and age, gender, neurological level of injury (NLI), and type of spinal cord syndrome by multivariate analysis. Secondary outcomes were analyzed with complication and mortality.

**Results:** A total of 154 patients with acute cervical SCI were enrolled. Of these, 49 patients (group A) underwent early surgery ( $\leq 24$  hours), 54 patients (group B) underwent intermediate surgery (24–72 hours) and 48 patients (group C) underwent delayed surgery ( $\geq 72$  hours). AIS improvement was shown as 44.8% in group A, 31% and 24.1% in group B and C, respectively (A vs. B and C,  $p=0.041$ ). In the multivariate analysis, with steroid administration, the rate of AIS improvement were 33% in early surgery group and 16% in the other group (odds ratio, 2.6;  $p=0.061$ ). Age, gender, and NLI had no relation with AIS statistically. Mortality during hospitalized period was 2 in group A and 1 in group B. The complication rate was 34.6% in group A, 28.5% and 24.4 % in group B and C, respectively.

**Conclusion:** Surgery prior to 24 hours after acute cervical SCI could improve clinical outcome.

## Comparison of the Results after Posterior Fixation by Monoaxial Pedicle Screws and Polyaxial Pedicle Screws in Thoracolumbar Burst Fractures

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**Purpose:** The biomechanical study suggests that the monoaxial pedicle screw can significantly increase the stiffness in axial direction compared with polyaxial pedicle screws, and reduce the risks of correction loss. The purpose of this study was to compare the clinical and radiological results after posterior fixation by monoaxial pedicle screws and polyaxial pedicle screws in thoracolumbar burst fractures.

**Materials and Methods:** We analyzed 50 patients retrospectively who had an unstable burst-compression injury at T12–L1 without a neurological deficit. Patients were divided into two groups: monoaxial pedicle screw fixation group (n=25) and polyaxial pedicle screw fixation group (n=25). Follow-up times ranged from 18 to 68 months. The mean age was 49.3 years in the mono group and 52.9.0 years in the poly group. Posterior fusion involved a mean of 3.3 levels in the mono group and a mean of 3.6 levels in the poly group. We collected clinical data (Visual Analog Scale [VAS] score for back pain) and included radiographic measurements. The latter were used to calculate the sagittal plane kyphosis (SPK).

**Results:** For the mono group, the preoperative mean SPK was 21.56° and the postoperative mean SPK was 8.13°. The mean correction angle was 13.43°. The SPK angle decreased from 8.13° to 11.18° in late follow-up. For the poly group, the preoperative mean SPK was 23.18° and the postoperative mean SPK was 11.09°. The mean correction angle was 12.09° (correction rate=52.17%). The SPK angle decreased from 11.09° to 18.83° in late follow-up. The monoaxial pedicle screw group had good correction rate, and reduced the risks of correction loss. The mean VAS scores for back pain improve.

**Conclusion:** There was significant difference in degree of radiographic correction between groups. Then, the mono-

axial pedicle screw is a better optional instrumentation to treat thoracolumbar vertebral fractures.

## Water Sport-Related Spine Injury in Bali: A Review and Preliminary Study

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**Purpose:** This study aims to evaluate the water sport-related spine injury (WS-RSI) which is occurred in Bali during 2017 as a preliminary study at BROS General Hospital.

**Materials and Methods:** A cross-sectional study was conducted retrospectively among 55 patients who got an injury during water-sport activity in 2017 and admitted to BROS General Hospital, Denpasar, Bali by medical records. There was 28 patient-related spine injury. Demographic status regarding age, sex, length of stays, hemoglobin (Hb), random blood glucose, nationality, country origin, treatment, patient's status, history of alcohol intake, type of water sport, and the location of spine injury were recorded. Data were analyzed using IBM SPSS ver. 25.0 for Windows (IBM Corp., Armonk, NY, USA) in mean±standard deviation (SD), percentage, and odds ratio (OR) as well as statistically significant if *p*-value less than 0.05.

**Results:** Indonesian travelers were predominant in WS-RSI (53.6%), followed by China and Australia (17.9%), India, Japan, and European countries (3.6%, respectively). The average age of patients was higher in spine injury (47.89±15.98 years, *p*=0.047). Both sexes were equal (50%). There were no significant difference in Hb (11.08±1.30 g/dL) and random blood glucose (100.65±21.37 mg/dL) (*p*>0.05) levels. However, there was a significant difference among nationality, type of treatment, patient's status, and type of WS-RSI compared with non-spine injury (*p*<0.05). Based on variables, banana boat, foreign travelers, conservative treatment, and outpatient status were having a higher risk in WS-RSI (OR, 4.275, 5.143, 5.014, 7.389; *p*<0.05, respectively)

**Conclusion:** As a preliminary study, recent findings at

BROS Hospital, Denpasar, Bali suggest that several factors are having a higher risk towards water sport-related spine injuries such as older age, banana boat, foreign travelers, conservative treatment, and outpatient status.

## Surgical Outcomes of Transpedicular Intra-vertebral Cage Augmentation in Patient with Neurologic Deficits Following Severely Collapsed Osteoporotic Vertebra: A Minimum 1-Year Follow-up Study

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**Purpose:** To introduce a surgical option for anterior column support through only the posterior approach, the intra-vertebral cage augmentation technique, in patients who had delayed neurologic deficit due to severely collapsed osteoporotic vertebrae and to evaluate the clinical and radiographic outcomes.

**Materials and Methods:** Ten consecutive patients who underwent intra-vertebral cage augmentation were included, with at least 1-year postoperative follow-up and were divided into two groups (group I: fractured index vertebra at the thoracolumbar junction; group II: at the lower lumbar spine). Radiographic analyses include restored ratio of anterior vertebral height (RAVH), local kyphotic angle (LKA), thoracolumbar kyphosis (TLK), and lumbar lordosis (LL) for evaluation of regional deformity, and clinical results include modified Frankel grade in group I, ambulatory status, and Oswestry Disability Index (ODI) in preoperative, postoperative, and last follow-up periods.

**Results:** Compared to preoperative measures, average RAVH were 2.98 and 2.35 times greater, and the LKA were corrected from an average of 20.3° and 14.8° to an average of 3.0° and 0.2° at the last follow-up periods in both groups I and II, respectively. The TLK in group I was corrected from an average of 32.9° to 19.7° and the LL in group II were improved from an average of -15.8° to -32.3° at the last follow-up. All corrected angles and heights in both groups showed some decrease in most cases at the last follow-up in comparison with their postoperative measures. All patients who could not independently ambulate became able to walk except for two patients who needed a cane, and patients showed significant improvement in ODI scores from an average of 38.2 to

12.8 (standard deviation [SD]±1.72) in group I and 37.3 (SD±1.70) to 19.3 (SD±9.87) in group II.

**Conclusion:** The introduced technique is a valuable surgical option to obtain support of the anterior column in osteoporotic patients with a severely collapsed vertebra who require decompression and stabilization procedures using only the posterior approach.

## Comparison of Results between Conservative and Operative Treatment in Pyogenic Spondylitis

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**Purpose:** With advancements in antibiotics, the ability to treat pyogenic spondylitis is increasing. This study aimed to compare and analyze the outcomes between conservative and operative treatments.

**Materials and Methods:** Sixty patients (28 males and 32 females) with pyogenic spondylitis, who were hospitalized and treated between February 2008 and June 2016, were enrolled. Patients were divided according to the following: type of treatment—conservative or operative treatment, method of surgery, radiographic parameters, and location of the affected spine. Clinical parameters as durations of hospital stay, intravenous antibiotics use, normalization in laboratory findings, and residual symptoms were analyzed. For statistical evaluation, independent-sample *t*-test, Mann-Whitney *U*-test, Pearson's chi-square test, one-way analysis of variance, and Spearman correlation analysis were performed retrospectively.

**Results:** There was no significant difference in the duration of hospital stay, intravenous antibiotics use, normalization in laboratory findings, and residual symptoms between the conservative and operative treatment groups.

**Conclusion:** In treating pyogenic spondylitis, conservative treatment can be considered as the first choice, and operative treatment can be chosen in refractory cases.

## Differentiating Cervical Pyogenic Spondylodiscitis and Tuberculosis: A Cross-Sectional Observational Analysis of 35 Patients

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**Purpose:** Cervical spine infections constitute only around 3% to 6% of all vertebral infections. Unlike other locations of infection, they often rapidly deteriorate, leading to neurological complications. There is a paucity of literature on epidemiology, clinical presentation, management, and surgical strategies of infective lesions of cervical spine.

**Materials and Methods:** A cross-sectional analysis of all patients who were diagnosed with clinical and radiological features of cervical spine infection and managed in a single center over 5 years from 2011 to 2016 was done. All patients who were evaluated by complete blood count, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and biopsy were included. The presence of constitutional features and neurological status were recorded. The time lag between onset of clinical symptom and diagnosis was compared between tuberculosis (Tb) and pyogenic infection (PI). In addition Tb-polymerase chain reaction, blood, urine, and tissue culture which were performed routinely were analyzed for their positivity rate.

**Results:** Seventy-one percent (25/35) were Tb and 29% were PI. The mean age at presentation in Tb was 35 years vs. 48 years in PI. The mean time lag to diagnosis was 120 days in Tb vs. 44 days in PI. Multifocal involvement was 24% in Tb and 10% in PI. Contiguous involvement of more than two vertebra in Tb was 56% compared to 10% in PI. C1–C2 involvement was seen only in Tb group in 32% (8/25). The commonest level of infection was C5–C6. The mean ESR and CRP in Tb were 74 mm/hr and 23 mg/L compared to 90 and 40 in PI. Forty percent (14/35) of all patients had neurological deficits.

**Conclusion:** Cervical spine infections in contrary to other locations behave in a much more fulminant manner with high chances of neurological deficit. Tb constitutes majority of the cervical spine infections. Most patients require anterior procedure alone. Multilevel epidural abscess formation warrants posterior decompression as well. Collapse of vertebra with instability, deformity, and neural deficits require combined approach. Despite the early complications associated with cervical spine infection, they generally have good outcomes.

## Pott's Disease: 10-Year Experience in a Single Tertiary Centre in Malaysia

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**Purpose:** The incidence of tuberculosis remains high despite multiple measures taken. Pott's disease not only becomes a burden to the particular individual patient, but to the community as a whole in terms of healthcare and economy. Despite the devastation that may be caused by spinal tuberculosis, national level study and data regarding management is disappointingly scarce.

**Materials and Methods:** A retrospective study of patients with spinal TB over a 10-year period in Pusat Perubatan Universiti Kebangsaan Malaysia was conducted. Demographic data, clinical features, underlying diseases, laboratory results, imaging findings, therapy, treatment given, and outcomes were analysed.

**Results:** Seventy-seven confirmed spinal tuberculosis patients were included and analysed. The mean age was 43.9 years with more female than male. The most common presenting symptoms were backache and neurological deficits. The most common vertebral area involved was thoracic spine (53.2%) with most having two or more vertebra involved. Surgery was carried out on 21 patients (27.3%). All patients received a minimum mandatory 6-month anti-tuberculosis chemotherapy. There was significant improvement in terms of kyphosis deformity correction for patients who had surgery done ( $p < 0.01$ ). There was significant improvement in functional outcome at 2-year follow-up for all patients, either treated surgically or with chemotherapy alone ( $p < 0.001$ ).

**Conclusion:** Chemotherapy prescribed in line with current guidelines is the pillar of therapy. Radical debridement and construct surgery have significantly reduced kyphotic angle. Functional outcome is good after 2-year follow-up for all patients. Our principle follows the currently accepted management worldwide by adopting the 'middle path regime'.

## Changing Trends in Spinal Tuberculosis

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**Purpose:** To study disease distribution, morphology, and demographic profile of spine tuberculosis (TB) patients.

**Materials and Methods:** Prospective observational cohort study was conducted from December 2016 to May 2018. Outcome measures were as follows: socioeconomic status as per modified Kuppaswamy scale; family structure; presence or absence of overcrowded living conditions; residing in hills, plains, urban, and rural area; and age and gender.

**Results:** Out of 206 patients, 53.9% were females and 46.1% were males. Mean age was  $39.09 \pm 17.13$  years (range, 3–81 years). Max patients were in younger age group (range, 20–40 years). Sixty-three point one percent patients were from nuclear families while 36.9% were from joint families. Sixty-three point one percent of patients were living in overcrowded conditions but 36.9% did not. Sixty-three point nine percent patients were from rural areas while 63.6% from urban. Most patients belonged to lower middle class socioeconomic (41.29%) strata followed by 30.32% patients from upper lower class. Max patients (88.8%) were from plains while 11.2% patients from mountains. Sixty-three point five percent had single segment disease while 36.5% patients had multifocal TB spine. Out of patients having single segment disease, 32.3% patients had involvement of lumbar spine, 27.2% patients had dorsolumbar TB spine, and 24.2% patients had dorsal spine TB. Out of patients having multifocal TB spine, 68.4% patients had contagious while 31.5% patients had non contagious TB spine. In overall disease distribution, 27.2% patients had multifocal contagious TB spine, 22.4% patients had lumbar, 18.4% patients dorsolumbar, and 14.4% had dorsal TB.

**Conclusion:** Significant change in today's era is involvement of lumbar spine to be most common followed by dorsolumbar and then dorsal spine. Another major difference is that overall incidence of both multifocal contagious and non-contagious Pott's spine is also increasing. This provides an alarming signal because rising trend of multifocal contagious TB has implication that need for surgery in TB spine may increase in future. However other factors like residing in overcrowded families, lower

middle, and lower socioeconomic status still continue to be important association for TB spine.

## Costovertebral Joint: A Rare Localisation for Tubercular Arthritis

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**Purpose:** Tubercular arthropathy can affect any joint but the most common form of articular tuberculosis is spondylitis followed by arthritis of weight bearing joints especially hip and knee. To the best of our knowledge, tuberculosis of the costovertebral joint has only been reported twice in the literature.

**Materials and Methods:** A 18-year-old girl was admitted with 3-month history of left sided dorsal spinal pain. There were no constitutional symptoms. Magnetic resonance imaging was suggestive of enhancing perarticular erosive lesions and marrow oedema in the medial portion of the 7th rib and left posterolateral portion of the vertebral body and lateral portion of the left 7th pedicle with thickening and enhancement of the synovium of the 7th costovertebral joint with enhancing soft tissue elevating the overlying pleura and abutting the descending aorta. Computed tomography-guided biopsy on cytology showed caseous necrosis with epithelioid and langerhans giant cells suggestive of tuberculosis.

**Results:** Patient was treated with anti-tubercular drugs. At 1-year follow-up, patient showed clinical as well as radiological improvement.

**Conclusion:** Tubercular arthritis of the costovertebral joint is extremely rare and can occur as an isolated lesion in the absence of the disease elsewhere. Diagnosis of such cases can be prolonged unless a strong suspicion is kept and appropriate diagnostic studies are obtained as early as possible to avoid neurological complications.

## Role of Local Streptomycin in Prevention of Surgical Site Infection in Tuberculosis Spine

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**Purpose:** Patients with tuberculosis (TB) of spine undergoing surgery are at a high risk of developing surgical site infection (SSI) due to a number of reasons. Poor nutritional status, low immunity, poor patient compliance to anti-tubercular therapy and intraoperative spillage of tubercular debris, and pus and necrotic material make these patients prone to secondary infections and SSIs. The aim of this study was to investigate the role of local streptomycin in preventing SSI in patients undergoing surgical management of spinal TB.

**Materials and Methods:** Fifty-six patients who underwent surgical management for radiologically proven TB spine from January 2016 to November 2018 were included in the study. Patients were analysed retrospectively and were divided into two groups on the basis of intraoperative local streptomycin administration. Group A included 30 patients operated before December 2017 with no local streptomycin administered intraoperatively while group B included 26 patients operated in the later part of study after December 2017 with the use of local streptomycin intraoperatively. The two groups were compared with each other and the following outcome criteria were analyzed: SSI rate, length of hospital stay, duration of postoperative antibiotics, and need for debridement.

**Results:** Mean duration of hospital stay and mean duration of antibiotics in postoperative period in group A was significantly higher than in group B. Although SSI rate and need for debridement was higher in group A as compared to B but the difference was not statistically significant.

**Conclusion:** Using powder streptomycin locally in surgical site may significantly reduce the rate of surgical site infections in patients of TB spine undergoing surgical management; thus, significantly reducing the morbidity and economic burden for the patients

## Does the Sagittal Alignment of the Cervical Spine Have an Impact on Disc Degeneration?: 20-Year Follow-up of Asymptomatic Volunteers

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**Purpose:** To longitudinally evaluate the association between sagittal alignment of the cervical spine and progression of degenerative changes of intervertebral discs and development of clinical symptoms in healthy subjects.

**Materials and Methods:** Ninety volunteers (30 males and 60 females) who had undergone magnetic resonance imaging (MRI) and plain radiography of the cervical spine between 1994 and 1996 and had been originally asymptomatic were enrolled in this 20-year follow-up study. All subjects underwent second MRI at an average of 21.6 years after the initial study. The mean age at the time of the initial study was 35.5 years. The items assessed on MRI were (1) decrease in signal intensity of the intervertebral discs, (2) posterior disc protrusion, and (3) disc space narrowing from C2–3 to C7–T1. The subjects were divided into groups according to the age and sagittal alignment of the spine at baseline, i.e., subjects under or over the age of 40 years, and subjects with the lordosis type or the non-lordosis type of sagittal alignment of the cervical spine.

**Results:** During the 20-year period, progression of decrease in signal intensity of the disc, posterior disc protrusion, and disc space narrowing were observed in 84.4%, 86.7%, and 17.8% of the subjects, respectively. No significant associations were observed between sagittal alignment and progression of decrease in signal intensity, posterior disc protrusion, or progression of disc space narrowing. Progression of the degenerative change at C7–

T1 was significantly more frequent in the non-lordosis over 40 years group (90.9%) than those in older the lordosis group (54.2%) ( $p=0.032$ ). No significant differences were observed between sagittal alignment and the onset of clinical symptom at follow-up.

**Discussions:** The present 20-year follow-up study showed that non-lordotic cervical alignment may be related to progression of disc degeneration. However, cervical alignment had no impact on development of the clinical symptom in healthy subjects.

### Outcome Study of Posterior Lumbar-Interbody Fusion with Instrumentation for Tuberculous Lumbosacral Spine

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**Purpose:** To evaluate the clinical, radiological, and functional outcomes in patients who underwent posterior lumbar-interbody fusion (PLIF) with instrumentation for tuberculous lumbosacral spine.

**Materials and Methods:** This is a prospective study of clinical and radiographic outcomes in 43 patients who underwent PLIF with instrumentation for tuberculous lumbosacral spine. All cases were operated between January 2014 and June 2016 were assessed with radiography, magnetic resonance imaging, and laboratory parameters before operation. All the cases had instability with kyphotic deformity or loss of lordosis. Clinical outcomes measured included Visual Analog Scale (VAS), modified MacNab criteria at 6 months, neurological status, and radiographic outcomes (segmental kyphotic angle and total lumbar lordotic [TLL] angle) only up to 6 months.

**Results:** Mean operative time was 105.5 minutes. Mean VAS back scores decreased from 6.7 to 2.85 at 3-week follow-up. After 3 months, mean VAS back scores decreased to 1.24, and after 6 months, the mean VAS back scores decreased to 0.5. Mean segmental kyphotic angle was reduced from 23.5° to 0° after operations, it was maintained up to 6 months, and mean TLL angle improved from 23.9° to 41.5°. At 3 months, the mean value was 40 with no change at 6 months. Neurological examinations revealed that 37 patients became Frankle E and only six patients were D after 6 months, from 14 patients with Frankle C, and 21 patients with Frankle D. Modified MacNab criteria

was used to evaluate the clinical results after 6 months of surgery. Overall, 26 cases had excellent results, 16 cases were good, and one was fair.

**Conclusion:** Radical debridement and reconstruction using posterior instrumentation are an acceptable surgical option for the treatment of lumbosacral spinal TB because it provides maximum contact surface to promote solid bony fusion.

### Role of Additional Coronal Magnetic Resonance Imaging in Decompression and Reconstruction with or without Segment Salvage in Tuberculosis of the Dorsal Spine

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**Purpose:** The aim of the present study was to develop guidelines for segment salvage or sacrifice on the basis of coronal magnetic resonance imaging (MRI) imaging in addition to sagittal and axial images in tuberculosis of the spine.

**Materials and Methods:** Sixty-five patients with dorsal Koch were divided into two groups (segment salvage and sacrifice) on the basis of thickness of subchondral bone and the endplate morphology of the vertebra as seen on MRI. Operative procedure in the form of instrumentation with sublaminar wire and Hartshill using the versatile approach was done. Patients were analyzed for postoperative fusion and improvement in kyphosis angle and followed up for development of complications.

**Results:** This method of deciding the level of fixation and segment salvage on the basis of the coronal MRI in addition to the sagittal and axial images gave good result with graft buckling and resultant kyphosis in a single patient out of 65 in the second group where the segment was sacrificed.

**Conclusion:** For segment salvage it is important to have a three-dimensional clear idea about the viable remnant bone. Viable saved segment reduces the morbidity of the procedure, length of the construct, and unnecessary debridement without compromising on the neural recovery and the rate of fusion. Hence, it is important to ask for additional cone down coronal cuts when one suggests MRI for tuberculosis of the spine as it will help in the decision making.

## Surgical Management of Tuberculosis of the Spine: A Retrospective Analysis of 127 Cases in a Tertiary Care Hospital of Bangladesh

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**Purpose:** Tuberculosis was a leading cause of mortality in the beginning of the 20th century. Improvement in the socio-economic status led to a major decline in the prevalence even before the introduction of anti-tubercular drugs. However, it continues to be a major public health problem in developing countries like Bangladesh. The objective of current study is to observe the results of surgical treatment of tuberculosis of the spine.

**Materials and Methods:** This is a retrospective study. This was carried out in the department of neurosurgery, National Institute of Neurosciences & Hospital, Dhaka, Bangladesh during the period of January 2013 to December 2017. The patients were divided into two groups. One group was treated by surgery without instrumentation and other group was treated by surgery with instrumentation. All patients received anti-tubercular drugs for 18 months. Outcomes of treatment were recorded and analyzed.

**Results:** Total number 127 cases were treated during the study period with the diagnosis of tuberculosis of the spine. The mean age of the patient was 32 years. Among them in 72 cases only surgical decompression done and other 55 cases were treated by surgical decompression and stabilization. Significant neurological improvement observed in the both groups of patients. Only one patient failed to improve neurologically. Two patients developed resistant to first line anti-tubercular drugs and one patient showed hardware failure.

**Conclusion:** Early surgical intervention is optimum mode of treatment. Surgery without instrumentation is the preferred option in developing country like Bangladesh.

## Prevalence and Risk Factors for Positive Nasal Methicillin-Resistant *Staphylococcus aureus* Carriage among Orthopedic Patients

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**Purpose:** Recent guidelines recommend screening for

methicillin-resistant *Staphylococcus aureus* (MRSA) at the time of admission. However, studies conducted to determine the prevalence and risk factors for colonization at the time of admission are limited. This study aimed to investigate the prevalence and associated risk factors for MRSA colonization in orthopedic patients.

**Materials and Methods:** MRSA screening tests were performed through nasal swabs among patients enrolled between January 2017 and July 2018. Demographic data, socio-economic data, medical comorbidities, and other risk factors for MRSA carriage were evaluated based on the results.

**Results:** There were 1,577 patients enrolled in the study. Ultimate prevalence of MRSA nasal carriage was 7.2%. Univariate regression analysis showed that the colonization with MRSA at the time of hospital admission was significantly related to patient age, body mass index (BMI), smoking, disease, recent antibiotic use, and type of hospital admission. Multiple logistic regression analysis for the risk factors for positive MRSA nasal carriage showed that BMI lower than 18.5 kg/m<sup>2</sup>, trauma, recent antibiotic use 1 month prior to admission, and admission through the emergency department were related to MRSA colonization.

**Conclusion:** Present study focused on prevalence of positive MRSA carriage and associated risk factors among patients admitted to the orthopedic surgery department. Relatively high prevalence of MRSA in this study highlights the importance of preoperative screening test for patients scheduled for surgery involving implant insertion, particularly those at risk for MRSA

## Risk Factors of Increased Length of Stay in the Treatment of Postoperative Spine Surgical Site Infection

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**Purpose:** Postoperative surgical site infection (SSI) is a serious complication of spinal surgery, and SSI is known to be associated with increased length of stay (LOS) and additional cost. Although many risk factors are known to

contribute to the development of SSI, little is known regarding risk factors of increased LOS in the management of SSI. The aim of this study was to identify specific risk factors for increased LOS in the management of SSI.

**Materials and Methods:** This is a retrospective observation study. Patients experiencing SSI following spinal surgery at two institutions between January 2009 and December 2016 were identified. The patients were divided into two groups depending upon the median LOS attributable to SSI. The effect of patient characteristics, comorbidities, disease history, and invasion of the elective surgery on the risk of increased LOS was determined using univariate analyses and multivariate logistic regression.

**Results:** Of the 1,656 cases included in this study, 40 cases (2.4%) experienced deep SSI. The median LOS was 74.5 days. Multivariate logistic regression testing revealed that serum albumin level during hospitalization is associated with LOS (odds ratio, 0.042; 95% confidence interval, 0.005–0.342;  $p=0.003$ ). We determined the appropriate diagnostic cutoffs of hypoalbuminemia during hospitalization using the receiver operating characteristic (ROC) curves. The cutoff of serum albumin level was less than 3.1 g/dL (sensitivity, 86.4%; specificity, 75.0%; area under the ROC curve, 0.84).

**Conclusion:** Serum albumin level during hospitalization were independent risk factors of increased LOS in the management of SSI following spinal surgery. If serum albumin level is less than 3.1 g/dL in the treatment of SSI, we should consider methods of correcting malnutrition.

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## Over 20 Years of Experience of a Multidisciplinary Programme for Rehabilitation of Chronic Low Back Pain: Factors Predicting Successful Reintegration and Return to Work

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**Purpose:** Low back pain (LBP) is highly disabling with significant health cost worldwide. Since 1996, we have adopted a 14-week intensive multidisciplinary programme targeting patients with chronic LBP, providing functional rehabilitation and reintegration back to the society. This

study aims to identify factors predicting successful return to work.

**Materials and Methods:** This is an assessment of a prospectively collected cohort of chronic LBP patients consecutively enrolled into the programme from 1996–2014. Rigorous pre-admission assessment was performed to identify patients with functional deficits while excluding patients with surgically treatable diseases or psychological disorders. All recruited patients failed to return to work previously despite a prolonged period of conservative treatment. Assessments were performed at baseline, 8 weeks and 14 weeks for standing, standing and walking tolerance, straight leg raise test, Oswestry Disability Index (ODI), and Spinal Function Sort Score (SFSS).

**Results:** One hundred and ninety-one patients were recruited. Significant improvement was found in ODI (46.9 to 43.9,  $p<0.05$ ) and SFSS (98.3 to 108.1,  $p<0.05$ ). Sitting, standing, walking tolerance, and performance in straight leg raising test all improved significantly ( $p<0.01$ ). After training, 41.9% of the patients met their work demand. Multivariate logistic regression model showed gender and initial job demand (by Physical Demands Classification) correlated with meeting work demand level ( $R^2=62.4\%$ ). Male patients were 5.92 times ( $p<0.05$ ) more likely to meet work demand level.

**Conclusion:** This programme is effective in improving outcomes of patients with chronic LBP. There was significant improvement in physical tolerance of daily activities despite persistent negative cognition and low mood. However, they were more accepting towards chronic LBP, and enjoyed better general well-being. Male patients with higher job demand were more likely to return to their work. From our data, we have constructed a viable tool to determine patients most suitable for this intensive rehabilitation programme.

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## The Efficacy and Persistence of Selective Nerve Root Block under Fluoroscopic Guidance for Cervical Radiculopathy

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**Purpose:** Cervical selective nerve root block (SNRB) may be considered as alternative treatment when patients suf-

fering from painful cervical radiculopathy have not benefited from conservative therapy. The aim of current study is to evaluate the demographic factor (gender, age, symptom duration, etiology) affecting the efficacy of SNRB with mid-term follow-up period.

**Materials and Methods:** We present result of retrospective 1-year follow-up study of 72 patients with radiculopathy due to cervical disc disease and spondylosis. Patients with myelopathy, gross motor weakness, or any other pathology were excluded. Cervical nerve root blocks were administered up to 3 times every 2 weeks. The clinical outcomes including Visual Analog Scale scores, Neck Disability Index, and patient satisfaction were assessed before the procedure with those at 1-, 3-, 6-month, and last follow-up after the procedure.

**Results:** At follow-up, the clinical outcomes showed no significant differences between old age (age  $\geq 60$  years) and young age group (age  $< 60$  years). Also, there were no significant differences between male and female group. However, acute group (symptom duration  $\leq 3$  months) and disc herniation group showed statistically better than chronic group (symptom duration  $> 3$  months) and cervical spondylosis group on the clinical outcomes ( $p < 0.05$ ).

**Conclusion:** Among multiple demographic factors, the symptom duration and etiology was most significant variable affecting the effect of cervical selective nerve root block.

## Scoliosis in Osteogenesis Imperfecta: A Single Centre Cross-Sectional Study

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**Purpose:** Scoliosis has been frequently reported in patients with osteogenesis imperfecta (OI). We aim to show the differing prevalence of scoliosis among the types of OI, as well as characteristics and clinical implications of scoliosis among our ethnically Chinese cohort.

**Materials and Methods:** In this single centre cross-sectional study, patients with OI and at least one radiograph of the spine were enrolled and classified into Sillence types I, III, IV, and V based upon clinical and radiological features. Cobb angle was measured, with severity and characteristics of curve noted according to the Scoliosis

Research Society glossary.

**Results:** One hundred and twenty-seven patients (75 males, 52 females; mean age, 9.6 years) were included. The overall prevalence of scoliosis among all patients was 53%. The prevalence of scoliosis was highest among type III (76%) compared to types V (60%), and IV (44%), while type I had the lowest (29%). Type III also had the highest prevalence of severe scoliosis (38%). Severity of scoliosis was positively correlated with age in OI types (type III,  $p < 0.001$ ; type IV,  $p < 0.001$ ; type V,  $p = 0.004$ ; respectively), apart from type I ( $p = 0.222$ ). Fifty-eight percent of all scoliotic curves were located in the thoracic region (T2–T11). Sixty-three percent of primary curves were right sided.

**Conclusion:** Type III OI demonstrated the highest prevalence of scoliosis, both overall and severe. Given that scoliosis occurs mostly in the thoracic region (affecting cardiopulmonary function) and is correlated with age, early and aggressive intervention is appropriate. Meanwhile, type I has a relatively lower prevalence and no correlation with age, thus may be treated more conservatively.

## Radiographic Analysis of Correlations between Coronal Tilt of Individual Cervicothoracic Vertebra and Parameters of Shoulder Balance in Adolescent Idiopathic Scoliosis Patients after Correctional Surgery

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**Purpose:** This study was to examine the correlation between the coronal tilt of individual vertebra in cervicothoracic junction and radiographic parameters of shoulder balance before and after receiving posterior spinal fusion, in aims of determining potential radiographic parameters that may serve as intra-operative reference in the corrective surgery of adolescent idiopathic scoliosis (AIS) patients.

**Materials and Methods:** From AIS patients who underwent posterior spinal fusion, preoperative and 1-year postoperative standing anteroposterior radiographs for whole spine were retrospectively reviewed. Curves were classified using the Lenke classification for AIS. Following parameters for shoulder balance were measured, including clavicular angle, coracoid height difference, clavicular tilt

angle difference, clavicle–rib cage intersection difference, and 1st rib tilt. Coronal tilt of individual cervicothoracic vertebra as well as the upper instrumented vertebra (UIV) tilt were also recorded for analysis. The *t*-test were used to compare the baseline characteristics. Pearson and Spearman correlation coefficient were introduced to examine the correlation between coronal tilt of vertebrae (C5–T4, UIV) and shoulder balance parameters before and after the operation.

**Results:** A total of 21 patients of AIS, who received posterior correction and fusion between July 2015 to August 2017, were recruited for analysis. Mean preoperative Cobb angle for main thoracic curve was  $56.6^{\circ} \pm 10.1^{\circ}$  (range,  $46.4^{\circ}$ – $91.5^{\circ}$ ), and the postoperative Cobb angle was  $22.3^{\circ} \pm 7.8^{\circ}$ .

**Conclusion:** While most coronal tilts of cervicothoracic vertebrae were not associated with the shoulder balance parameters in the preoperative analysis, the postoperative C7 tilt was highly correlated to the shoulder balance parameters in postoperative analysis. Our findings suggested that C7 coronal tilt may serve as an intra-operative reference, for its correlation with the postoperative shoulder balance that was modified in the operation.

## Effects of Lowest Instrumented Vertebra for Non-instrumented Lumbar Curve in Thoracic Adolescent Idiopathic Scoliosis

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**Purpose:** Unfixed lumbar segments and coronal off-balance are sometimes prominent after the correction of thoracic adolescent idiopathic scoliosis (AIS). How the correction of thoracic curve affects for them is not known well. The lower instrumented vertebra (LIV) may play a role to control the unfixed lumbar segments and coronal off-balance. The aim of this study is to examine how the correction of LIV affects the unfixed lumbar curve and coronal balance in thoracic AIS.

**Materials and Methods:** Eighty consecutive patients with corrective surgery for Lenke 1 and 2 AIS were examined retrospectively. Measurements were LIV angle from the

orthogonal line drawn upper instrumented vertebra to LIV (LIV angle for construct), major Cobb angle, non-instrumented lumbar Cobb angle, L4 tilting angle (L4 tilt), coronal balance (central sacral vertical line [CSVL]–C7 plumb line [C7PL]) using up-right whole spine radiographs at preoperation, postoperation, and 2 years after the correction. LIV rotation was measured by computed tomography. The values of correction coefficient about LIV in the radiological parameters and background data were examined.

**Results:** Postoperative LIV rotation showed the correlation with L4 tilt ( $r = -0.511$ ,  $p < 0.0001$ ). Postoperative LIV angle for construct correlated with postoperative non-instrumented lumbar Cobb angle ( $r = -0.573$ ,  $p < 0.0001$ ). Postoperative LIV rotation together with postoperative major Cobb angle affected CSVL–C7PL ( $r = 0.517$ ,  $p < 0.0002$ ).

**Conclusion:** LIV rotation was a unique driver for the change of L4 tilt. Non-instrumented Lumbar Cobb angle could be controlled by LIV angle for construct. CSVL–C7PL was affected by the combination of LIV rotation and major Cobb angle. Discordance of correction of major Cobb angle and LIV rotation would occur coronal off balance.

## Risk Factors for Pseudarthrosis after Pedicle Subtraction Osteotomy in Degenerative Lumbar Kyphosis: Joint Pathologies as a Hidden Risk Factor

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**Purpose:** To evaluate the risk factors for pseudarthrosis in lumbar degenerative kyphosis (LDK).

**Materials and Methods:** Seventy-four patients with LDK who underwent pedicle subtraction osteotomy (PSO) were enrolled. Follow-up was a minimum of 2 years. Patients were divided into groups with or without pseudarthrosis (pseud group vs. non-pseud group). Risk factors included spinopelvic parameters, fused segments, age, bone mineral density, body mass index, and joint pathologies in the hip and knee (postoperative hip fracture and untreated gonarthrosis).

**Results:** Sixty-four patients (86%) maintained optimal

sagittal vertical axis (SVA) <5 cm at the last follow-up, whereas optimal SVA was achieved in 72 patients (97%) postoperatively. Thirty-six patients (49%) were diagnosed with pseudarthrosis by an average period of 21 months. Significant differences with regard to risk factors included amount of lumbar lordosis correction and joint pathologies ( $p=0.021$  and  $p<0.0001$ , respectively).

**Conclusion:** Higher incidence of pseudarthrosis was seen in our study than in previous reports. Preventive options for pseudarthrosis may include applications of multiple-rod constructs or supplementary interbody fusion above and below the PSO site, efforts to decrease events leading to hip fracture, and perioperative treatments such as joint reconstruction in cases with untreated gonarthroses.

### A Positive Postoperative Upper Instrumented Vertebra Tilt Angle Increases the Risk of Medial Shoulder Imbalance in Lenke 1 and 2 Adolescent Idiopathic Scoliosis Patients by 15 Times

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**Purpose:** To investigate the relationship between a positive postoperative upper instrumented vertebra (UIV) tilt angle and the risk of medial shoulder/ neck imbalance in adolescent idiopathic scoliosis (AIS) patients following posterior spinal fusion (PSF).

**Materials and Methods:** One hundred and thirty-six Lenke 1 or 2 AIS patients operated between 2013 and 2016 (with minimum 2-year follow-up) were recruited. Positive postoperative UIV tilt angle was defined as  $\geq 0^\circ$ . Postoperative T1 tilt/cervical axis were categorized into positive medial shoulder/ neck imbalance ( $\geq +4^\circ$ ), balanced medial shoulder/neck, and negative medial shoulder/ neck imbalance ( $\leq -4^\circ$ ). Clavicle angle was grouped into positive lateral shoulder imbalance ( $\geq +3^\circ$ ), balanced and negative lateral shoulder imbalance ( $\leq -3^\circ$ ). Multivariate linear regression ( $p<0.05$ ) identified independent factors predictive of medial and lateral shoulder/neck imbalance. Multinomial logistic regression was performed to calculate the odds ratio of shoulder and neck imbalance when postoperative UIV tilt angle was positive.

**Results:** Seventy-four point three percent ( $n=101$ ) of pa-

tients had Lenke 1 whereas 25.7% ( $n=35$ ) had Lenke 2 curves. The mean age was  $15.5\pm 4.4$  years old. Fifty-one point six percent ( $n=16$ ) of patients with positive medial shoulder imbalance had a positive UIV tilt angle, in comparison with 3.4% ( $n=3$ ) of patients with balanced medial shoulder who had positive UIV tilt angle. The UIV tilt angle were  $-0.5^\circ\pm 3.0^\circ$ ,  $-6.8^\circ\pm 2.7^\circ$ , and  $-9.6^\circ\pm 3.0^\circ$  for patients with positive medial shoulder imbalance, balanced medial shoulder, and negative medial shoulder imbalance respectively ( $p<0.001$ ). Significant factors that were predictive of positive medial shoulder imbalance were postoperative UIV tilt angle ( $p=0.002$ ) and preoperative T1 tilt angle ( $p=0.006$ ). Patients with positive postoperative UIV tilt angle had 14.92 times odds of developing positive medial shoulder imbalance.

**Conclusion:** Patients with positive postoperative UIV tilt angle had increased odds of developing positive medial shoulder imbalance by 15 times. Patients with positive postoperative UIV tilt angle also had increased odds of developing positive neck imbalance by 3 times.

### Does Thoracic Pedicle Morphological Classification Affect the Outcome of Pedicle Screws Insertion in Adolescent Idiopathic Scoliosis?

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**Purpose:** To evaluate the influence of the thoracic pedicle morphometry, i.e., A, B, C, and D types on the outcome of pedicle screws insertion.

**Materials and Methods:** This was a prospective study carried out in a single center with intra-operative computed tomography evaluation of 191 screws. We classified the thoracic pedicle morphology according to Sarwahi classification. The duration, radiation exposure and blood loss/ screw were documented. Blood loss during screw insertion was evaluated using Boezarrt grading system.

**Results:** Sixty-six screws were inserted in type B, 53 in type C, 37 in type A, and 35 in type D pedicles. The overall perforation rate was 42.9% (82 screws). With the exclusion of lateral perforation (due to extrapedicular screw insertion), the overall perforation rate was 11.0%

(21 screws). Type D pedicles had the highest perforation rate of 18.8% (16.2% were lateral perforations due to extrapedicular screw) and type A had the lowest perforation rate of 2.1%. The mean duration for pedicle screw insertion for type A pedicles were  $129.3 \pm 84.8$  seconds, type B  $153.7 \pm 73.5$  seconds, type C  $212.5 \pm 111.1$  seconds, and type D pedicles were  $330.6 \pm 150$  seconds. Pairwise comparison showed significant difference between type A vs. C, type A vs. D, type B vs. C, type B vs. D, and type C vs. D ( $p < 0.05$ ). Forty-three point five percent (83 screws) had grade 2 bleeding, 34.6% (66 screws) had grade 3 bleeding, 12.6% (24 screws) had grade 1 bleeding, and 9.4% (18 screws) had grade 4 bleeding. Pearson chi-square test comparing blood loss and pedicle type showed significant difference ( $p = 0.012$ ). Insertion of screw in type D pedicles required higher radiation exposure and screening time of  $185.8 \pm 127.6$  mGy/cm<sup>2</sup> and  $5.6 \pm 3.8$  seconds ( $p > 0.05$ ). From our study, one screw needed revision due to grade 2 anterior perforations abutting the right pleura at right T4 level.

**Conclusion:** Pedicle screw placement in dysplastic pedicles, i.e., type C and D, was more technically demanding thus requiring a significant longer duration, higher blood loss, radiation exposure, and perforation rate.

## Prevention of Distal Junction Kyphosis by Inclusion of Sagittal Stable Vertebra in Posterior Spinal Fusion for Idiopathic Scoliosis

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**Purpose:** Distal junctional kyphosis (DJK) is a radiographic finding of an abrupt transition between fused and mobile segments in patients who underwent posterior spinal fusion (PSF). Sagittal stable vertebra (SSV) has been defined as the vertebral level at which 50% of the vertebral body was in front of the posterior sacral vertical line on a standing lateral radiograph. A concept has been proposed that inclusion of the SSV in the PSF for thoracic hyperkyphosis may prevent DJK. The purpose of this study was to investigate the relationship between inclusion/exclusion of SSV in PSF and the occurrence of DJK for patients with idiopathic scoliosis.

**Materials and Methods:** A retrospective review was performed of patients from two hospitals with idiopathic scoliosis who underwent PSF with the lowest instrumented vertebra (LIV) at L2 or above from January 2009 to July 2015. Patients with less than 1-year follow-up were excluded. The primary outcome measure was DJK, defined as  $\geq 5^\circ$  of kyphotic change in the sagittal disc angle below the LIV on a standing lateral radiograph during follow-up. The patients were divided into two groups according to inclusion (group 1) or exclusion (group 2) of the SSV in the PSF. Major Cobb angle, thoracic kyphosis (T5–T12), and lumbar lordosis (T12–S1) were also evaluated.

**Results:** A total of 93 patients met the inclusion criteria. Mean age was 14.9 years (range, 10 to 25 years). Mean Cobb angle of the main thoracic curve was  $52.3^\circ$  (range,  $40^\circ$  to  $74^\circ$ ). The overall rate of DJK was 5.4% (5/93). The occurrence rate of DJK was 16.7% (5/30) in group 2 (SSV not included in PSF) vs. 0% (0/63) in group 1 (SSV included in PSF). There was no significant difference between the two groups with respect to preoperative major Cobb angle, thoracic kyphosis, lumbar lordosis, age at operation, gender, and Lenke classification.

**Conclusion:** For patients with idiopathic scoliosis, inclusion of the SSV in the PSF could effectively prevent the occurrence of DJK. Patients with SSV not included in PSF should be closely monitored the occurrence of DJK during follow-up.

## Motion Preserving Navigated Primary Internal Fixation of Unstable C1 Fractures

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**Purpose:** Concerns have been raised over loss of motion following occipitocervical fusion and atlantoaxial fusion surgeries in unstable atlas fractures. The aim of this study is to assess the safety, efficacy and benefits of computed tomography (CT)-guided isolated C1 fracture fixation allowing for a fusionless surgery.

**Materials and Methods:** Patients with unstable isolated C1 fractures were positioned prone and cranial traction was applied with Mayfield tongs to restore C0–C2 height and obtain reduction of displaced fracture fragments. Intraoperative CT-based navigation system was used for optimal placement of C1 screws. A transverse rod was placed con-

necting the two screws and controlled compression was applied across the fixation. Prospectively they were evaluated for clinical, functional, and radiological outcomes.

**Results:** A total of 10 screws were placed in five patients. Mean duration of surgery was  $77 \pm 13.96$  minutes and the average blood loss was  $84.4 \pm 8.04$  mL. The average screw lengths used were  $26.8 \pm 1.78$  mm. The mean combined lateral mass dislocation at presentation was  $14.6 \pm 1.34$  mm and following surgery it was  $5.2 \pm 1.64$  mm. Follow-up CT showed excellent placement of screws and good healing with no instances of transverse foramen breach. There were no complications and instances of atlantoaxial instability. Good clinical range of movement and functional outcome was achieved.

**Conclusion:** Successful C1 reduction and fixation allows for a motion preserving option in unstable atlas fractures. CT navigation not only enables intraoperative assessment of fracture reduction but also permits accurate and adequate fixation. Excellent clinical and good radiological outcomes were achieved allowing all patients to return to preoperative functional status.

## Vascular Geometry of Lumbar Foramen for Endoscopic Spine Surgery

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**Purpose:** To report vascular geometry around the lumbar foramen to help endoscopic spinal surgery which is frequently disturbed by heavy bleeding.

**Materials and Methods:** We reviewed operating record movie clips of trans-foraminal approach (TFA) using biportal endoscopic spine surgery (BESS). Several bleeding foci were found and vascular geometry was modeled to be matched to that on the endoscopic view.

**Results:** There were four main arterial branches coming out from the lumbar segmental artery. Inferior articular artery, superior articular artery, inter-articular artery, and radicular artery could be faced in order during TFA. While making a basecamp on the transverse process (TP), inferior articular artery arising proximal border of the TP could be easily injured and make a heavy bleeds. Superior articular artery, hidden under the muscles, is overriding along the lateral margin of the facet. During performing

capsulotomy, inter-articular artery made heavy bleeding just proximal to the superior articular process. Radicular artery ran on the midline of the root.

**Conclusion:** The information of the geometric location of the four arterial branches could help escaping heavy bleeding on TFA using endoscopic spine surgery and controlling the bleeding foci to prevent postoperative hematoma.

## Learning Curve Associated with Minimally Invasive Transforaminal Lumbar Interbody Fusion: A Single Surgeon's Experience of 4 Years

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**Purpose:** To evaluate the operative time (OR time) and blood loss associated with minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) of one surgeon's experience over a period of 4 years.

**Materials and Methods:** A retrospective review was performed of initial 48 single level MIS TLIF cases by one surgeon from 2014 to 2018, and these 48 patients were studied in quartiles of 12 patients each. Data was retrieved from electronic database, and OR time and blood loss data were the chief parameters. Comparison between the groups was done using unpaired *t*-test. Statistical significance was considered for a *p*-value of 0.05 or less.

**Results:** Of total 48 patients, 30 were female and 18 male, and average age was 49.66 years old. Operative level was L4/5 in 37 patients, L5/S1 in eight patients, and L3/4 in three patients. Statistically significant difference was noted between the 1st 3rd quartile and 1st 4th quartile (*p*-value  $< 0.05$ ). Average time for 1st group was 209.166 minutes (range, 190–240 minutes), 2nd group 199.166 minutes (range, 140–280 minutes), 3rd group 189.166 minutes (range, 150–210 minutes), and 4th group was 161.125 minutes (range, 150–190 minutes). No significant difference found in blood loss between 1st group and rest of the groups, average blood loss for each group was 157.5, 145, 154.17, and 139.17 mL, respectively.

**Conclusion:** There is a significant learning curve associated with MIS TLIF. Significant differences were noted in OR time after 1st 24 patients. There was statistical signifi-

cant difference of OR time between early versus late cases of MIS TLIF. No significant difference was seen for blood loss.

## Is Conservative Treatment Effective for Unilateral Sagittally Split Fractures of C1 Lateral Mass?

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**Purpose:** Unilateral sagittally split fracture (USSF) of C1 lateral mass (LM) is a rare variant type of C1 atlas fracture. The integrity of transverse atlantal ligament (TAL) is a key factor to determine the stability in the case of C1 atlas fracture. To date, definite treatment guideline of USSF of C1 LM has not been established. Moreover, the effect of TAL injury on surgical outcomes is still controversial in USSF of C1 LM. Therefore, we performed the current study to investigate clinical and radiologic outcomes of USSF of C1 LM that have been treated conservatively and suggest appropriate treatment guideline.

**Materials and methods:** Twenty-six consecutive cases of USSF of C1 LM were included in this study. Sixteen were transverse atlantal ligament (TAL) injury group (nine type I ligamentous injury and seven type II bony avulsion injury by Dickman's classification) and 10 were TAL intact group. All cases were treated by conservative measures. The mean follow-up was 16 months (range, 12–47 months).

**Results:** At last follow-up, for TAL intact group, total LM displacement (LMD), unilateral LMD at fracture side, atlanto-dental interval, clivus canal angle, atlanto-occipital joint axis angle, and basion-dens interval were maintained compared to initial presentation. However, for TAL injury group, all radiological parameters were worsened compared to initial presentation. The worsening of all radiological parameters was more severe in type I TAL injury than type II TAL injury. Neck Visual Analog Scale significantly decreased in TAL intact group compared to

TAL injury group. According to Odom's criteria, satisfactory outcomes were higher in TAL intact group compared to TAL injury group.

**Conclusion:** Conservative treatment for USSF of C1 LM with TAL injury caused coronal and sagittal malalignment of occipitocervical junction, resulting in unsatisfactory clinical outcomes. Our results suggest that early surgical stabilization should be considered as choice of treatment for USSF of C1 LM with TAL injury, especially type I TAL injury.

## Safety Evaluation of Biportal Endoscopic Lumbar Discectomy: Changes of Cervical Epidural Pressure

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**Purpose:** In the percutaneous endoscopic lumbar discectomy, it is known that the irrigation fluid is inevitable shot right into spinal canal and this accumulated fluid can squeeze the thecal sac and act as a potential risk for neurologic complication by disturbing cerebrospinal fluid circulation and increasing intracranial pressure. This study was to evaluate the changes of cervical epidural pressure (C-EP) during the biportal endoscopic lumbar discectomy (BELD).

**Materials and Methods:** Thirty consecutive patients with American Society of Anesthesiologists physical status 1 or 2 were enrolled in this study. The BELD was performed under automated pump system, setting an infusion pressure of 30 mm Hg and allowing continuous lavage through two independent surgical ports. The procedure was subdivided into five phases (1st phase, make surgical port; 2nd phase, create a work space; 3rd phase, perform neural decompression and discectomy; 4th phase, factitious increase of inflow pressure by clogged outflow; 5th phase, dismissal from fluid irrigation system) and the C-EP were measured on C7–T1 for each phase. Neurological complication and independent risk factors were evaluated.

**Results:** In the final 27 patients, change in C-EP during surgery were in similar way. The baseline C-EPs was measured  $14.8 \pm 2.8$  mm Hg and the mean C-EPs in the 3rd phase was not significantly different at  $18.8 \pm 5.1$  mm Hg.

In the 4th phase, however, the C-EPs rose with linear correlation as the inflow pressure increased. In the 5th phase, the elevated C-EPs recovered to baseline in  $2.5 \pm 5.6$  minutes. There are no patients with neurologic complications. In the independent factor analysis, total irrigation time was correlated to change of C-EPs, but not statistically significant ( $p > 0.05$ ).

**Conclusion:** In the BELD, which perform to allow continuous lavage with infusion pressure set to 30 mm Hg, C-EP has not increased beyond the physiologic range.

### Lateral Retroperitoneal Trans-psoas Approach: A Practical Minimal Invasive Surgery Option for Treating Pyogenic Spondylitis of the Lumbar Vertebra

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**Purpose:** The purpose of this study was to evaluate the effectiveness and clinical outcome of using lateral retroperitoneal trans-psoas approach in the surgical management of pyogenic spondylitis of the lumbar spine.

**Materials and Methods:** Twenty patients with pyogenic spondylitis who underwent lateral retroperitoneal trans-psoas approach debridement, strut grafting and posterior instrumentation was analyzed retrospectively. The outcome measures for this study included volume of blood loss, surgical operating time, complications, clinical outcomes (Visual Analog Scale and Oswestry Disability Index [ODI] score), and fusion rates. Data analysis was done using SPSS.

**Results:** The mean operating time was  $90 \pm 25$  minutes and the mean blood loss was reported at  $45 \pm 35$  mL. At final follow-up 18 months after the surgery, back pain was resolved in all cases while nine cases that presented with lower limb weakness had improvement of neurological deficits. ODI score was also improved significantly at the end of follow-up. One patient had dislodged strut graft while performing posterior instrumentation and needed graft revision intraoperatively. Infective markers normalized for all patients subsequently. All subjects also showed radiological evidence of fusion at 8 months postoperatively.

**Conclusion:** Lateral retroperitoneal trans-psoas is an optimal approach in treating pyogenic spondylitis as it allows adequate debridement and reconstruction, fast surgical time, minimal blood loss, high rate of interbody fusion, and good clinical outcome.

### Percutaneous Endoscopic Lumbar Discectomy for L5/S1 Disc Herniation: Does Interlaminar Approach Gives Better Result than Transforaminal Approach?

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**Purpose:** The management of symptomatic lumbar disc herniation has been developed through generation with microdiscectomy as the 'gold standard' for surgical decompression. Transforaminal percutaneous endoscopic lumbar discectomy (T-PELD) under local anesthesia offers many advantages, but the approach to the L5/S1 is very challenging due to high lying iliac crest and narrow intervertebral foramen. The interlaminar PELD (I-PELD) is another alternatives, but the need of general anesthesia and mobilization of the nerve structure is one of the disadvantages of the procedure. The aim of this study is to share the outcome, complication, surgical technique, and obstacle of both approach.

**Materials and Methods:** This is a cohort prospective studies. The inclusion criteria were patients with true lumbar disc herniation. Visual Analog Scale (VAS) for sciatica modified MacNab's criteria was compared pre- and post-operation. All patients in transforaminal group underwent T-PELD in local sedation anesthesia and on interlaminar group underwent I-PELD under general anesthesia.

**Results:** All patients had L5/S1 disc herniation, 27 patients underwent T-PELD under local anesthesia, and 33 patients underwent I-PELD under general anesthesia. The mean sciatica VAS decreased from 5.7 to 2.5 directly after surgery on T-PELD group and from 5.8 to 1.8 on I-PELD group. The straight leg raise test was still below 35 on eight patients in the T-PELD group and negative in all I-PELD group. Five patients on the T-PELD group needs to be reoperated due to persistent symptoms. Two patients had cauda equina syndrome in I-PELD group. On follow-up

the T-PELD group had more back pain and dysesthesia on the L5 root at 1 year. The overall satisfactory result in T-PELD group were 81% and 93% on the I-PELD group.

**Conclusion:** Both of the technique are quite reliable in treating L5S1 disc herniation. It offers many advantages of minimal invasive surgery. Patients selection is very important before deciding which technique to be chose. From the author point of view, I-PELD for L5S1 gives more predictable outcome compare with T-PELD.

## Cervical Arthroscopic Foraminotomy for Cervical Radiculopathy with Lateral Disc Herniation: A Preliminary Clinical Results

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**Purpose:** In the surgical treatment of cervical radiculopathy with lateral disc herniation, posterior cervical foraminotomy is once again emerging as an alternative that replaces anterior cervical decompressive fusion. The purpose of this study is to introduce the cervical arthroscopic foraminotomy (CAF) using two independent ports and analysis of clinical outcomes.

**Materials and Methods:** We enrolled 15 patients who had cervical radiculopathy with lateral disc pathology. All patients were taken the CAF which was based on two independent surgical ports and allowed continuous irrigation flow through these two ports. The deep cervical muscle was stripping and flooding from the cervical lamina, and foraminotomy was performed using diamond bur about 4–5 mm outward from the V-point, where the upper and lower lamina are met with the facet joint. Clinical outcomes were analyzed using a Visual Analog Scale (VAS) and Neck Disability Index (NDI), and discussed about complication and its related risk factors.

**Results:** All patients included in the final analysis. Mean intake and output of irrigation fluid was positive 30 mL (range, negative 10 to positive 70 mL). Mean follow-up was 5.8±2.98 months (range, 3–12 months). At the last follow-up, VAS and NDI of all patients showed significant improvement over baseline score ( $p<0.001$ ). There was no statistically significant difference in the improvement of VAS and NDI score for lateral disc herniation ( $n=10$ ) and cervical foraminal stenosis ( $n=5$ ) ( $p>0.05$ ). No patient re-

quired revision surgery for sustained or aggravated symptoms during whole follow-up period.

**Conclusion:** CAF is an endoscopic surgery in which saline is used as medium and is expected to be relatively free from mechanical compression on the spinal cord as it continually flowing saline. CAF is one of motion preserving alternative can provide good clinical outcomes similar microendoscopic or percutaneous uniportal cervical foraminotomy

## Biportal Endoscopic Spine Surgery for Treatment of Moderate to Severe Lumbar Spinal Stenosis

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**Purpose:** Various endoscopic spine surgical techniques are developed but there are limitations in treating spinal stenosis. Biportal endoscopic surgery for spinal stenosis are tried and the results were evaluated especially for the moderate to severe lumbar spinal stenosis.

**Materials and Methods:** The authors reviewed 108 cases of moderate to severe central, lateral, and foraminal lumbar stenosis patients.

**Results:** Effective circumferential and focal decompression were achieved in most cases. We have excellent (63.8%) to good (22.2%) results without significant complications.

**Conclusion:** Biportal endoscopic spinal surgery for treatment of lumbar spinal stenosis is safe and innovative approach under clear and wide endoscopic vision preserving nerves and spinal structures.

## Clinical Outcomes of Unilateral Approach Biportal Endoscopic Surgery in Lumbar Degenerative Central Stenosis Patients

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**Purpose:** To know clinical outcomes of unilateral approach biportal endoscopic (UBE) surgery in lumbar degenerative central stenosis patients.

**Materials and Methods:** Total of 23 patients with degenerative lumbar central canal stenosis were treated us-

ing UBE between March 2017 and February 2018. The patients were single level, lumbar central canal stenosis without instability and no previous surgery at the current site, refractory to conservative management for at least 12 weeks. The following clinical parameters were assessed: Visual Analog Scale (VAS) score for leg pain, Oswestry Disability Index (ODI), and modified Macnab criteria, operative time, and complications related to the operation. Preoperative and postoperative ODI and VAS at final follow-up were compared.

**Results:** The mean operation time was 94 minutes (range, 62–113 minutes) and the mean hospital days after surgery was 5.1 days (range, 3–8 days). The mean VAS scores for leg pain preoperatively and at 1-month and 6-month follow-ups were  $7.6 \pm 1.9$ ,  $1.7 \pm 1.3$ , and  $1.5 \pm 1.1$ , respectively. The mean ODI result at preoperatively, 1-month, and 6-month follow-ups were  $67.2 \pm 11.3$ ,  $24.3 \pm 4.5$ , and  $18.1 \pm 3.2$ , respectively. The outcome of the procedure was excellent for 11 patients, good in 10 patients, and fair in 2 patients according the modified Macnab's criteria, 1 cases of cerebrospinal fluid leakage and and there were one case of neuropraxia at post surgery.

**Conclusion:** UBE is newly tried technique in minimally invasive spine surgery for lumbar spine stenosis and certain complications could be expected in an early learning with favorable outcomes

## Contralateral Ligament Flavum Sparing Lateral Recess Decompression and Foraminotomy by Unilateral Biportal Endoscopic Spine Surgery

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**Purpose:** The use of endoscopy has especially enabled central or lateral recess or foraminal stenosis decompression without fusion surgery. However, it is difficult to resolve the lesion on the medial side of the foramen.

**Materials and Methods:** With our technique, the contralateral ligament flavum sparing foraminotomy, makes it possible to decompress the lesion on the medial side of the foramen or the lesion in the hidden zone. We will discuss the surgical anatomy, surgical procedures, pros and cons, and possible complications.

**Results:** Complete decompression in medial foraminal stenosis and hidden areas are clearly confirmed by contra-

lateral ligament flavum sparing foraminotomy.

**Conclusion:** Using contralateral ligament flavum sparring foraminotomy, lateral recess stenosis and foraminal stenosis of the medial section can be resolved.

## One-Time Minimally Invasive Surgery Combination of Cervical Laminoplasty and Anterior Fusion for Cervical Kyphosis

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**Purpose:** The invasion of surgical treatment for cervical stenosis with cervical kyphosis or intervertebral instability tends to be higher invasion such as long posterior fusion or second surgery. If such risky cases treated by simple laminoplasty (LP), kyphosis and instability would deteriorate to poor results. Long fusion is a one of the safety way to avoid postoperative poor result, but which seizes cervical mobility. We have challenged to minimally invasive LP (MIS-LP with 2.54 cm incision) from 2014 and MIS-LP combined with anterior fixation (MIS-ASF, 2.54 cm) for cases that have severe kyphosis or instability (K-line plus). We hypothesized this combination procedure would be the good way to avoid long fusion. This study aims to analyze the results of this procedure.

**Materials and Methods:** An observational retrospective study was performed, and 29 cases with combination procedure (AP group: 20 males/9 females; average age, 63 years old; follow-up, 13.2 months) were investigated. For comparative cases, 61 cases were undergone posterior surgery (LP group: 40 males/20 females; average age, 61 years old; follow-up, 15.8 months). Japanese Orthopaedic Association score (JOA score) and Hirabayashi's recovery rate were evaluated. Operative time, amount of bleeding, and postoperative pain measured by Numerical Rating Scale were evaluated. We also checked postoperative change from preoperative cervical lordosis. For comparison between two groups, the Wilcoxon test was used for statistical analysis.

**Results:** There were no worsened neurological deficit nor no C5 palsy. JOA recovery rate among two procedures was also same. Surgical time of AP group (average, 153 minutes) was significantly longer to LP group (average, 75 minutes). The mean amount of bleeding during com-

bination procedure (average, 43.6 g) was significantly more than LP group (average, 33 g). However, there were no significant difference in nape pain, alignment change. There is no case which need reoperation.

**Conclusion:** Our device is one of the best options for kyphosis or instability to avoid long fusion or salvage.

## Comparison of Clinical and Radiological Outcomes between the Unilateral Biportal Endoscopic Lumbar Decompression and Microscopic Unilateral Laminectomy Bilateral Decompression

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**Purpose:** Unilateral laminectomy for bilateral decompression is a developed minimally invasive surgical technique for decompression of the spinal canal. A new endoscopic technique that uses a unilateral biportal endoscopic (UBE) approach has been applied to conventional arthroscopic systems for spinal disease. In this study, we hypothesized that the endoscopic approach showed similar clinical results when compared with microscopic surgery and that the risk of complications and adverse events were less.

**Materials and Methods:** In this study, we conducted a retrospective study of 185 patients, who underwent bilateral decompression from March 2015 and March 2018. The patients were divided into two groups according to the surgical methods. We compared the outcomes between the two groups in terms of operative time, amount of bleeding, duration of hospitalization, use of analgesics, reduction of postoperative pain, postoperative neurological improvement, serum creatine kinase, postoperative radiologic results, and complications.

**Results:** The prevalence of postoperative bleeding, length of hospital stay, postoperative analgesic use, reduction of postoperative pain level, serum creatine kinase, radiographic changes in disc height, and segmental angle in flexion/extension were significantly lower in the endoscopic group than in the microscopic group. The postoperative improvement in neurological symptoms was significantly improved after surgery in both groups, and there was no significant difference between the two

groups.

**Conclusion:** Same clinical outcomes was resulted both group, but UBE for single-level decompression has several advantages including pain improvement, functional disability, patient satisfaction, minimal estimated blood loss, length of hospital stay, and postoperative back pain, while preserving the spinal tissues.

## Percutaneous Endoscopic Bilateral Stenosis Decompression: A Future Gold Standard in Managing Lumbar Canal Stenosis

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**Purpose:** Until recently open decompression is still being considered as the gold standard for management of spinal stenosis but the evolution of minimally invasive spine device has brought new dimension in the management of spinal stenosis management. Full endoscopic surgery has a lot of advantages in term of minimal soft tissue damage, less bleeding, less hospital stay, and earlier return to work. We tried to compare the result of open decompression and full endoscopic decompression for management of spinal stenosis case.

**Materials and Methods:** This is a prospective cohort study of a single spinal stenosis case without instability consisting of 42 cases of open decompression and 40 cases of full endoscopic decompression. We evaluate the pre- and postoperative Visual Analog Scale (VAS) of leg pain, walking distance, Oswestry Disability Index (ODI) and 36-item Short-Form Health Survey (SF-36) score, intraoperative bleeding, and length of hospital stay. We observe patient until 1 year post operation.

**Results:** The clinical parameter of VAS, ODI, and SF-36 were better in the postoperation compare to preoperation. The ODI, VAS of leg pain, and walking distance was significantly better in both group compared to preoperation with p-value of 0.033, 0.04, and 0.035. The main difference between open and full endoscopic decompression was the level of back pain and amount of bleeding. In the full endoscopic group the mean VAS for back pain was 0.7 and amount of bleeding was very minimal but in the open decompression the mean VAS back pain was 3.5 and amount of bleeding was around 75 mL. Length of hospital stay was shorter in the full endoscopic group which

is 1.2 days compared to 3.6 days in open decompression ( $p=0.021$ ).

**Conclusion:** Full endoscopic decompression showed better early result compared to open decompression group, even though long-term study is still needed for further evaluation in clinical result. The use of full endoscopic technique is very promising in the management of spinal stenosis, further advancement in the technique should be available in the next future.

## The Rate and Risk Factors for Reoperation and Joint Replacement Surgery after Short-Segment Lumbar Spinal Surgery for Degenerative Disk Disease: A Population-Based Study

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**Purpose:** Short-segment lumbar spinal surgery is the most commonly performed procedure for treatment of radiculopathy caused by degenerative disk disease. However, population-based data regarding reoperation and joint replacement surgery after short-segment lumbar spinal surgery is limited. So we decided to look into the reoperation and joint replacement surgery rate after short-segment spinal surgery.

**Materials and methods:** The study was a retrospective cohort design and we used Taiwan national health insurance research database for data collection. Patients diagnosed with lumbar disc disease and first received lumbar discectomy between 2002 and 2013 were included. The patients with previous joint or spine surgery, malignancy, and pathologic fracture were excluded. The Kaplan-Meier method was used to estimate the incidence of rate of 1-year reoperation and joint replacement surgery and Cox proportional hazard regression was used to examine the

risk factors associated with reoperation.

**Results:** Total 90,105 patients were identified as patients who received lumbar discectomy surgery (29,719 patients in fusion with fixation group, 2,897 patients in fusion without fixation, and 57,489 patients in non-fusion group). The overall rate for 1-year reoperation and joint replacement surgery for hip and knee was 0.27%, 0.04%, and 0.04%, respectively. Fusion with fixation group had lower risk of reoperation compared to fusion without fixation and non-fusion group. The risk factors for reoperation were fusion without fixation, non-fusion surgery, age older than 45 years old, male gender, diabetes, Charlson Comorbidity Index=0, lowest social economic status, and steroid use history. There was no difference in the rate for hip and knee joint surgeries in each group.

**Conclusion:** The rate of reoperation and joint replacement surgery in short-segment lumbar spinal surgery for degenerative disk disease were 0.27% and 0.04%. Non-fusion surgery and spinal fusion without fixation had higher risk for reoperation compared to spinal fusion with fixation.

## Percutaneous Transforaminal Endoscopic Surgery and Oblique Lumbar Interbody Fusion Combined with Anterior Screw Fixation for Surgical Treatment of Lumbar Spine Spondylolisthesis

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**Purpose:** We designed percutaneous transforaminal endoscopic surgery (PTES) technique under local anesthesia and oblique lumbar interbody fusion (OLIF) combined with anterior screw fixation for the treatment of single level lumbar spine spondylolisthesis in order to obtain the direct neurological decompression, rigid fixation and high fusion rate, and protect the paraspinal muscles and bone structures as much as possible.

**Materials and Methods:** Fifteen cases of L4/5 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 for L4/5 in a right lateral position under general anesthesia. During OLIF, the fixation of pedicle screws and rod was used in the same approach after insertion of cage into L4/5. The average follow-up duration was 18 months

(range, 13–24 months). 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.

**Results:** There was a mean blood loss of 30 mL (range, 20–45 mL). The mean stay at the hospital was 4 days (range, 3–5 days). For the clinical evaluation, the VAS pain index and the ODI showed excellent outcomes. For the radiological evaluation, 15 cases showed complete bone union at the 1-year follow-up. No patients had any form of permanent iatrogenic nerve damage and a major complication.

**Conclusion:** PTES and OLIF combined with anterior screw fixation is a good choice of minimally invasive surgery for lumbar spine spondylolisthesis, which can get direct neurological decompression, rigid fixation, and solid fusion, and hardly destroy the paraspinal muscles and bone structures.

## Outcome and Safety of Transforaminal Lumbar Interbody Fusion: A Single Center Experience

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**Purpose:** To evaluate the outcome of transforaminal lumbar interbody fusion (TLIF) in terms of symptoms improvement, fusion, and complications.

**Materials and Methods:** This descriptive cross-sectional study was performed from January 2012 to January 2017. All patients who underwent TLIF for degenerative disc disease, spondylolisthesis, or recurrent intervertebral disc herniation were included. Clinical results in terms of Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) score were measured. Modified Lee criteria was used for radiological evaluation of fusion.

**Results:** A total of 140 patients were included in this study out of which 31 (22.1%) were male while 109 (77.9%) were female. Mean±standard deviation (SD) age of the patients was 44.8±10.9 years. Out of 140 patients operated, 48 (34.3%) were with degenerative disc disease, 18 (12.9%) with recurrent intervertebral disc herniation, and 74 (52.9%) were with spondylolisthesis. The most

common level operated was L4/L5 with 64 cases (45.7%) followed by L5/S1 61 cases (43.6%). In majority of the patients single level surgery was performed 133 (95%). Mean preoperative VAS was 6±1.2 with minimum of 4 and maximum 9. Mean VAS at last follow-up was 2.1±0.6 with minimum of 1 and maximum 4. Mean preoperative ODI was 33.4±11.1 with minimum of 16 and maximum 66, while mean ODI at last follow-up was 13.3±5.8. Mean body mass index was 31.85±3.6 kg/m<sup>2</sup> with minimum of 20.5 kg/m<sup>2</sup> and maximum of 39.25 kg/m<sup>2</sup>. Majority of our patients were nonsmokers 129 (92.1%). Mean follow-up was 32.9±14.8 months. Fusion assessment was done using Lee criteria. According to this criteria, 57 (40.7%) had definitive fusion, 72 (51.4%) had probable fusion, and eight (5.7%) had possible pseudoarthrosis while three (2.1%) had definitive pseudoarthrosis. In 16 patients (11.4%) we had complication. In six patients (4.3%) we had dural tear, in four (2.9%) we had early postoperative infection while in 6 (4.3%) implant-related problems occurred.

**Conclusion:** TLIF is an excellent procedure producing promising clinical and radiological results.

## Is Routine Use of a Drain Really Necessary for Extensive Spinal Fusion Surgery?: 50 Consecutive Cases without Drain

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**Purpose:** Contrary to the long-standing belief in the need for a drain in spinal surgery, its usefulness has still been controversial. The purpose of this study was to observe the surgical outcomes of extensive multilevel spinal fusion (EMSF ≥3 levels) without a drain and to evaluate the usefulness of a drain.

**Materials and Methods:** We included 100 consecutive patients with degenerative spinal disease who underwent EMSF surgery (average, 5.5 segments). The participants were divided into two groups by the use of a drain or not: drain group (n=50) and no-drain group (n=50). We observed various surgical outcomes of EMSF without a drain and compared demographics, comorbidities (hypertension, brain infarct, cardiac disease), anticoagulant use, perioperative surgical and clinical factors, surgical site

infection (SSI), revision surgery, and laboratory findings between the two groups. Pedicle subtraction osteotomy was performed in 12.2% of a no-drain group and in 13.7% of a drain group, respectively ( $p=0.826$ ).

**Results:** In the no-drain EMSF surgeries, there was neither newly developed neurological deficit nor reoperation due to hematoma. In the no-drain group, there was one patient (2.0%) who suffered from SSI requiring revision surgery. Time to walk after surgery (4.3 days) and hospital stay (13.0 days) of the no-drain group were faster than those of the drain group ( $p<0.001$ ). The rate of perioperative blood transfusion of the no-drain group (49%) was significantly lower than the drain group ( $p=0.004$ ). No significant differences existed between the two groups in demographics, comorbidities, additional surgery for hematoma evacuation, SSI, and perioperative hemoglobin levels.

**Conclusion:** In 50 extensive multilevel spinal fusion surgeries without the use of a drain, no hematoma-related neurological deficits, or reoperations were observed. The no-drain group did not show significantly more frequent postoperative complications than did the drain use group; hence routine insertion of a drain following extensive multilevel spinal fusion should be reconsidered carefully.

## To Assess the Efficacy of Different Types of Conservative Management in Low Back Pain due to Intervertebral Disc Prolapse: Randomized Controlled Trial

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**Purpose:** The present study assesses the efficacy of different types of conservative management in low back pain due to intervertebral disc prolapse.

**Materials and Methods:** Adult patients of either sex with low back pain due to disc prolapse with or without neurological deficits visiting or admitted in our hospital during October 2014 to June 2016 were taken into the study. A total of 160 patients were included in the study. Forty patients were treated with bed rest, 40 patients were allowed to continue routine daily activities, 40 patients were treated with back school exercises, and 40 patients were treated with McKenzie exercises. The patients were followed for a period of 3 months with serial neurological

examination and functional outcomes.

**Results:** Back school group and McKenzie group had more favourable scores with respect to Visual Analog Scale (VAS), Oswestry Disability Index (ODI), and Japanese Orthopaedic Association (JOA) score which is statistically significant ( $p<0.001$ ). Among back school group and McKenzie group, latter had better results with respect to VAS, ODI, and JOA score which is statistically not significant. JOA post-intervention improvement is maximally seen in McKenzie group. Majority of patients from McKenzie group returned to work at the end of 12 weeks.

**Conclusion:** Back school exercises and McKenzie exercises have better results for low back pain due to disc prolapse compared to other types of conservative management.

## Clinical Outcome of Inter-Laminar Spacer Implantation in Patient with Lumbar Spinal Stenosis: 18-Month Follow-up

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**Purpose:** This study was undertaken to determine clinical outcome after inter-laminar spacer, with 18-month follow-up.

**Materials and methods:** Fourteen patients who underwent inter-laminar spacer treatment for lower back pain with intermittent claudication due to lumbar stenosis between January 2016 until December 2018 were included in the study. Six of them underwent two vertebra level intra-laminar spacer surgery. Clinical outcome was evaluated with Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) score preoperative and at 6th, 12th, and 18th months. Averaged follow-up was 18 months.

**Results:** Significant reduction was observed of VAS, from 7 (range, 6–8) preoperative to range 2–3 ( $p<0.01$ ) at 18-month follow-up. Minimal disability was achieved in the ODI score among patient with single level interlaminar spacer while 83% patient with two vertebra level interlaminar spacer scored moderate to severe disability.

**Conclusion:** Implantation of inter-laminar spacer device is effective and safe produce. Improvement in symptom severity and physical functioning was significant especially

among one level lumbar stenosis. Inter-laminar spacer offers an alternative to both conservative and more invasive surgical therapies in selected symptomatic lumbar stenosis.

## Ligamentum Flavum Hematoma in the Lumbar Spine Connecting to the Facet Joint: A Case Report

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**Purpose:** We describe a case of ligamentum flavum hematoma (LFH) in the lumbar spine connecting to the facet joint.

**Materials and Methods:** A 68-year-old woman presented low back and left leg pain without any cause. Magnetic resonance image (MRI) demonstrated severe spinal stenosis due to posterolateral extradural mass in the ligamentum flavum connecting to the facet joint at the left side of L2–3. After performing laminectomy, we observed the ligamentum flavum, which contained a brownish mass, compressed the dural sac. The mass was connected to the joint space of the left side of L2–3 facet, and the facet itself was also filled with the hematoma. Histological examination revealed hemorrhage surrounded by fibrous connective tissue without synovium lining in the degenerated ligamentum flavum.

**Results:** Her symptoms resolved immediately after surgery. LFH is a rare condition which usually occurs in the lumbar spine. Previous reports represented that ruptured irregular vessels of the degenerated and hypertrophic ligamentum flavum were assumed one of the pathogenesis of LFH. Ligamentum flavum is composed of elastic and collagen fibers. It exists between upper and lower lamina and attaches the facet joint. The mass formation in the lumbar spine around the dural sac, we suspect the synovial cyst for the first time, and associate with the facet joints, but ligamentum flavum hematoma should be included in the differential diagnosis.

**Conclusion:** This is the rare case of LFH which could be recognized the connection to the facet from both MRI and intraoperative finding. We believe that the cause of the bleeding in the ligamentum flavum was from the

facet. Rapid improvement of the patient's symptoms were noticed after surgery.

## Macrophage Infiltration Is a Causative Factor for Ligamentum Flavum Hypertrophy through the Activation of Collagen Production in Fibroblasts

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**Purpose:** To establish a ligamentum flavum (LF) hypertrophy mouse model, and to clarify the interplay between fibroblasts and macrophages on LF hypertrophy.

**Materials and Methods:** To deplete macrophages, clodronate-containing liposomes (clodronate-lip) injected intraperitoneally after microinjury into mice LF. For identification of fibroblasts in the LF, we used collagen type I  $\alpha 2$  linked to green fluorescent protein (GFP) transgenic mice. GFP-positive fibroblasts were selectively isolated from the intact and injured areas of the LF in the microinjury group using laser microdissection (LMD). Their profiles were compared by reverse transcription-quantitative polymerase chain reaction (RT-qPCR).

**Results:** Induction of macrophages into the mouse LF by applying a microinjury resulted in LF hypertrophy along with abnormal collagen accumulation at the injured site, which were very similar to the characteristics observed in the severely hypertrophied LF of human. However, macrophage depletion by injecting clodronate-lip counteracted LF hypertrophy even with microinjury. A RT-qPCR of selectively isolated GFP-positive fibroblasts with LMD revealed that the gene expression of collagen markedly increased in the fibroblasts at the injured site with infiltrating macrophages compared with the uninjured location.

**Conclusion:** These results suggested that macrophage infiltration was crucial for LF hypertrophy by stimulating collagen production in fibroblasts, providing better understanding of the pathophysiology of LF hypertrophy.

## Shockwaves Induced Reactive Oxygen Species from Xanthine Oxidase Promote the Extracellular Matrix Synthesis of Nucleus Pulposus Cell

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**Purpose:** Intervertebral disc (IVD) degeneration is one of the major causes of low back pain. Biological repair has emerged as a feasible way of treating pathologic disc segments aimed at restoring IVD homeostasis. Shock-wave (SW) is a noninvasive and effective tool which can precisely deliver the mechanical signal to the deep-seated tissue in the body. The purpose of this study is to investigate the biologic effect and to elucidate the mechanism of action triggered by the SW on nucleus pulposus (NP) cells of IVD.

**Material and Methods:** NP cells obtained from IVD of 8-week-old male black pig and were subsequently cultured in the pellet. The cell pellets were cultured for 5 days and then exposed to focused model SW applications. The cell viability was assessed by Alamar Blue assay and the reactive oxygen species (ROS) was assayed using 2',7'-dichlorofluorescein diacetate, according to the manufacturer's instructions. Matrix production was determined by glycosaminoglycan (GAG) using the DMMB assay and further normalized by the DNA amounts.

**Results:** SW can significantly enhance the GAG production ( $p < 0.01$ ) without affecting the viability and proliferation of NP cells when the energy and impulse of were of  $\leq 0.3 \text{ mJ/mm}^2$  and  $\leq 500$  impulses. The SW increased the intracellular ROS production in a dose- and time-dependent fashion. Pretreatment with allopurinol (xanthine oxidase inhibitor) inhibited the SW induced ROS production. The quantitative polymerase chain reaction and Western blot showed the expressions of collagen II (Col2) and aggrecan (Acan) were significantly increased after SW treatment ( $p < 0.01$ ). Elimination of SW induced ROS production with N-acetyl-L-cysteine (ROS scavengers) and allopurinol inhibited the expression of Col2 and Acan expression, as well as GAG production.

**Conclusion:** We found that SW induced ROS production of NP cells were mainly from xanthine oxidase and were crucial for induction gene and protein expression of Col2 and Acan as well as GAG production. Our result demon-

strated that the SW had a promising potential for enhancing IVD regeneration.

## A Computational Comparison of Lumbar Interbody Fusion Utilizing Different Interbody Cages with Unilateral or Bilateral Fixation

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**Purpose:** Extreme lateral lumbar interbody fusion (XLIF) is a surgical approach to manage severe low back pain associated with lumbar degenerative diseases. In comparison with transforaminal interbody fusion (TLIF), XLIF reduced the range of motion thus achieving improved stability postoperatively. Observational studies also suggested that unilateral pedicle screw fixation (PSF) is similar to bilateral screw fixation in terms of fusion rate, but with significant reduction in operative time and blood loss. However, its fixation stability is unknown. The aim of study is to perform a computational simulation of the stability of LIF with unilateral or bilateral PSF.

**Materials and Methods:** Computed tomography scans of a human L4 and L5 were acquired with an isotropic spatial resolution of 1 mm. Two interbody cages (22 mm and 16 mm) were developed to represent XLIF and TLIF, respectively. A cylinder (length, 45 mm; diameter, 5.5 mm) was built as an idealized shape of the pedicle screw (PS) implant and connected by a third cylinder (radius, 5.5 mm) representing the rod. Axial compression was performed across these models.

**Results:** The maximum stress at rods with XLIF was reduced (23.92 MPa) compared with TLIF (17.49 MPa) with bilateral PSF. The maximum strain at the facet joint was reduced using XLIF (0.096) rather than TLIF (0.14). The maximum bone deformation was similar. Maximum rod stress and facet joint strain were comparable with bilateral and unilateral PSF on the left side but stability reduced on right side (no fixation with unilateral PSF) suggesting possible effects of facet tropism.

**Conclusion:** This biomechanical simulation suggests that XLIF, with bilateral or unilateral PSF, provided improved stability over TLIF constructs. Bilateral and unilateral PSF

can achieve similar postoperative stability, but it may be subjected to variable facet orientation. Unilateral PS with XLIF is less invasive and more economical with equal stability achieved. All while keeping the contralateral side available in case of future revision surgery.

## Biomechanical Study of Posterior Pelvic Fixations in Vertically Unstable Sacral Fractures: An Alternative to Triangular Osteosynthesis

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**Purpose:** To investigate the relative stiffness of a new posterior pelvic fixation for unstable vertical fractures of the sacrum.

**Materials and Methods:** To simulate a vertically unstable fractured sacrum, 12 synthetic pelvic models were prepared. In each model, a 5-mm gap was created through the left transforaminal zone (Denis zone II). The pubic symphysis was completely separated and then stabilized using a 3.5-mm reconstruction plate. Four each of the unstable pelvic models were then fixed with two iliosacral screws, a tension band plate, or a transiliac fixation plus one iliosacral screw. The left hemipelvis of these specimens was docked to a rigid base plate and loaded on an S1 endplate by using the Zwick Roell z010 material testing machine. Then, the vertical displacement and coronal tilt of the right hemipelvis and the applied force were measured.

**Results:** The transiliac fixation plus one iliosacral screw constructions could withstand a force at 5 mm of vertical displacement greater than the two iliosacral screw constructions ( $p=0.012$ ) and the tension band plate constructions ( $p=0.003$ ). The tension band plate constructions could withstand a force at 5° of coronal tilt less than the two iliosacral screw constructions ( $p=0.027$ ) and the transiliac fixation plus one iliosacral screw constructions ( $p=0.049$ ).

**Conclusion:** This study proposes the use of transiliac fixation in addition to an iliosacral screw to stabilize vertically unstable sacral fractures. Our biomechanical data demonstrated the superiority of adding transiliac fixation to withstand vertical displacement forces.

## Comparison of Pullout Strength according to Thread Design of Pedicle Screw under Various Bone Quality Circumstance

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**Purpose:** The purpose of the study was to investigate the biomechanical performance of two types of dual-threaded pedicle screws by comparing pullout strength with single-threaded screw in various bone quality circumstance.

**Materials and Methods:** We designed four types of pedicle screws with different thread patterns: type I: single thread screw (conventional single-threaded screw); type II: double threads screw; type III: dual-threaded screw with double threads in proximal one-fourth; and type IV: dual-threaded screw with double threads in proximal and distal one-fourths (newly designed double dual-threaded screw). Four types of polyurethane foam blocks simulating various bone quality were as follows: type A: cancellous bone; type B: cancellous bone with cortical bone in upper margin; type C: osteoporotic cancellous bone; and type D: osteoporotic cancellous bone with cortical bone in upper and lower margin. To perform comparison in normal quality and osteoporotic bone, type A, B, and C specimens were used to compare pullout strength among type I, II, and III screws. To perform comparison in osteoporotic bone with and without cortical bone, type C and D were used for comparisons among type I, II, and IV screws.

**Results:** Compared to type I screw, type III screw showed higher pullout strength in type A and B specimens, and inferior pullout strength in type C specimen; while, type IV screw exhibited lower and higher pullout strength in type C and type D specimens, respectively.

**Conclusion:** Compared to conventional single-threaded pedicle screw, dual-threaded pedicle screws exhibited higher and significantly lower pullout strength in normal quality and compromised osteoporotic bone, respectively. With the trend of statistical significance, the double dual-threaded pedicle screw exhibited better biomechanical performance in osteoporotic bone with cortical bone. Pedicle screws with optimal thread design would be selected according to patients' bone quality in real surgical procedure.

## The Proteomic Signature of Nucleus Pulposus in Human Fetal Intervertebral Discs

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**Purpose:** Low back pain (LBP) is the commonest musculoskeletal disorder causing a significant decrease in quality of life, and, disc degenerative disorders contributes the most to this huge socio economic burden. Despite extensive research, the exact pathomechanisms behind disc degenerative disorders are poorly described. Clarifying the molecular nature of human fetal disc which has not been exposed to mechanical, traumatic, inflammatory, or infective insults would pave way for a better understanding of normal structure and homeostatic mechanisms of intervertebral disc.

**Materials and Methods:** Three fetal disc samples obtained from medical abortions and six discs from magnetic resonance imaging normal, healthy brain dead voluntary organ donors were subjected to proteomic analysis. Discs obtained from fetus was taken as group A, donors <40 years were considered as young group (group B), and those >40 years as aged (group C). The entire proteome map and alteration in protein expressions were further analyzed using Gene Functional Classification tool in DAVID and STRING database.

**Results:** A total of 745 proteins were identified in the fetal group (group A) 409 in group B, and 512 in group C. Amongst the 584 unique proteins in fetus, periostin, collagen 9 A1 & A2, matrilin 1 & 3, and collagen 11A1, 12A1, and 14A1 were some of the noted extracellular matrix proteins. 2A, 2B, 4A, and 4B which are part of cytoskeletal organization were also unique to fetus. Majority of the other unique proteins belonged to glycolytic and gluconeogenesis mechanisms. Interestingly, there were a large number of antioxidant and anti-apoptotic proteins.

**Conclusion:** This study provides fundamental information on the proteomic constitution of healthy human fetal disc. Comprehensive catalogue of the various structural, biochemical, and metabolic regulatory proteins has been performed and this is first important step in identifying and distinguishing the cellular process and pathways

involved during normal biological ageing and disease. It also throws light on possibility of potential regenerative therapies.

## Unraveling the Molecular Mechanisms behind Normal and Herniated Human Lumbar Intervertebral Discs

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**Purpose:** Low back pain (LBP) is the most common musculoskeletal disorder and is the leading cause of disability worldwide and intervertebral disc pathology is the commonest cause of LBP which remains poorly understood. The experimental study was designed to understand the proteome of normal and herniated discs.

**Materials and Methods:** Eighteen disc samples in (disc herniation group) and four in control group were subjected to protein extraction, solvent precipitation to remove the interfering glycans followed by pre-fractionation sodium dodecyl sulfate polyacrylamide gel electrophoresis and were analyzed using Orbitrap Velos Pro LC-MS/MS Mass Spectrometer. The entire proteome map and alteration in protein expressions were further analyzed using Gene Functional Classification tool in DAVID database and STRING database.

**Results:** Total protein identified were 2,086 in DH group and 651 in control group. Six clusters were detected in the 181 common proteins. One hundred and five proteins were unique to DH group compared to 470 in control group. This difference in protein expression was statistically significant ( $p=0.0019$ ). Two significant clusters comprising immunoglobulin and complement family were present in the DH group.

**Conclusion:** The current study provides a clear evidence of proinflammatory state in DH. The presence of immunoglobulin and complement cluster of proteins along with microbial enrichment pathways in the herniated samples provides evidence of subclinical infection as a cause of disc degeneration leading to herniation.

## Quantitative Analysis of Local Bone Graft Harvested from the Posterior Elements during Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis Patients with Evaluation of Spinal Fusion at the End of 2-Year Follow-up

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**Purpose:** To study the quantity of local bone graft obtained from different anatomical parts of the posterior elements during corrective surgery for adolescent idiopathic scoliosis (AIS) patients and to evaluate spinal fusion that was achieved at the end of 2-year follow-up.

**Materials and Methods:** This was a prospective study that involved 40 AIS patients who underwent posterior spinal fusion (PSF). All PSF surgeries were conducted by the same surgical and anesthetic team with a single observer collecting and measuring the quantity of bone grafts harvested. The bone grafts harvested from each components of the posterior element (spinous processes, laminae, facets, and transverse processes) was measured to the closest 0.01 g using a digital weighing device. Plain radiographs of this cohort of patients were available for review of spinal fusion at the end of 2-year follow-up.

**Results:** Among the 40 patients, 36 (90%) of them were females and four males (10%). There were 13 (32%) Lenke 1, 11 (28%) Lenke 2, 3 (8%) Lenke 3, 9 (22%) Lenke 5, and 4 (10%) Lenke 6 curves. The total number of thoracic fusion level was 333, whereas there were 81 lumbar fusion level. The mean total weight of bone graft obtained per case was  $36.5 \pm 13.7$  g. The total weight of lumbar bone graft to the number of lumbar fusion levels ( $4.5 \pm 1.2$  g/fusion level) was significantly higher than the total weight of thoracic bone graft to the number of thoracic fusion levels ( $3.2 \pm 1.2$  g/fusion level). The amount of bone graft obtained was highest from lumbar spinous process (42%), followed by thoracic spinous process (32%), lumbar lamina (29%), lumbar facet (28%), thoracic lamina (25%), thoracic facet (22%), and thoracic transverse process (21%). At 2-year follow-up plain radiographs demonstrated fusion in all cases with no evidence of implants loosening.

**Conclusion:** Lumbar vertebra provided more bone graft than thoracic vertebra. Spinous processes contributed the

highest amount of local bone graft in the thoracic and lumbar spine. Usage of local bone graft was adequate to promote good spinal fusion for AIS patients at the end of 2-year follow-up.

## Risk Factors of Distal Adding-on Following Posterior Corrective Surgery for the Lenke 1 or 2 Adolescent Idiopathic Scoliosis Patients with A–R Lumbar Modifier

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**Purpose:** There was a report that Lenke 1A curves could be divided into two groups based on the direction of L4 vertebral tilt (lumbar modifier A–R and A–L). The purpose of this study was to find out the risk factors associated with distal adding-on (DA) in the Lenke 1 or 2 A–R.

**Materials and Methods:** Thirty-six Lenke 1 or 2 A–R adolescent idiopathic scoliosis (AIS) patients with a minimum 2-year follow-up (FU) were recruited for this study (Lenke type 1, 13 patients; type 2, 23 patients; mean age at surgery, 15.2 years; and average FU period, 44.1 months). We evaluated the radiographic parameters preoperative (PreO), postoperative (PO), and final FU (FFU). Adding-on was defined as (1) an increase in Cobb angle of at least 5° and distalization of the end vertebra or (2) a change in disc angulation of 5° or greater below the lowest instrumented vertebra (LIV) from PO to FFU. LIV levels were evaluated LIV–last substantially last touched vertebrae (LSTV).

**Results:** DA occurred in the 10 patients (27.8%), and additional surgery was necessary for the one patient. The mean age at surgery were 14.0 years old in the DA (+) group and 15.7 years old in the DA (–) group, respectively ( $p=0.14$ ). The radiographic parameters (PreO/PO/FU) in the DA (+) group were proximal thoracic (PT, 39.2°/18.8°/19.5°), main thoracic (MT, 66.4°/13.3°/19.1°), thoracolumbar/lumbar (TL/L, 31.1°/3.9°/9.2°), radiographic shoulder height (RSH, -10.5/10/8.9 mm), thoracic apical vertebral translation (TAVT, 55.5/10.0/17.1 mm), LIV-tilt (25.3°/0.1°/8.6°), coronal vertical axis (CVA, 11.9°/-8.8°/-2.9 mm), and LIV–LSTV (-1.0). The parameters in the DA (–) group were PT (33.6°/14.1°/14.6°), MT (60.0°/12.3°/13.4°),

TL/L (29.8°/4.7°/5.2°), RSH (-14.0/10.1/8.4 mm), TAVT (48.1/9.6/8.3 mm), LIV-tilt (20.5°/0.2°/1.4°), CVA (10.2/-2.3/-1.0 mm), and LIV-LSTV (0.3). The statistical analysis indicated that LSTV-LIV was significant risk factors for DA ( $p=0.03$ ).

**Conclusion:** The incidence of DA was 27.8% in this series. A LIV at or distal to the LSTV may prevent postoperative adding-on in Lenke type 1 or 2 A-R curve.

## Reciprocal Change in Thoracic Kyphosis after Correction of Lumbar Lordosis in Adult Spinal Deformity

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**Purpose:** The lumbar hypo-lordosis in adult spinal deformity patients is compensated by loss of thoracic kyphosis, pelvis retroversion, and knee flexion. We noticed spontaneous restoration of postoperative thoracic kyphosis at non-fusion levels after lumbar spine osteotomy. The purpose of this study is to address the phenomenon of reciprocal change in thoracic kyphosis.

**Materials and Methods:** We retrospectively reviewed patients with adult spinal deformity treated with lumbar spine osteotomy in our institute from 2013 to 2018. Patients with pre- and postoperative whole spine X-rays were included. Upper fusion level above T9 or lower fusion level above L5 were excluded. Pre- and postoperative thoracic kyphosis and lumbar lordosis were measured.

**Results:** There are 22 patients (male, 8; female, 14) with a mean age of 61 years (range, 27–84). The diagnoses included 14 degenerative deformity, two post-traumatic kyphosis, five adjacent degeneration, and one post-laminectomy kyphosis. The surgical methods included four multiple level posterior column osteotomies, 17 pedicle subtraction osteotomies, and one vertebral column resection. The pre- and postoperative lumbar lordosis increased significantly from  $-11.6 \pm 13.4$  (range, -33.1 to 11.6) to  $-28.7 \pm 10.6$  (range, -51.4 to -9.5) ( $p < 0.001$ ) with a change of  $-17.1 \pm 9.6$  (range, -5.0 to -44.1). The pre- and postoperative thoracic kyphosis increased significantly from  $10.7 \pm 13.9$  (range, -11.4 to 43.9) to  $27.4 \pm 12.1$  (range, 7.5 to 52.8) ( $p < 0.001$ ) with a change of  $16.7 \pm 7.3$  (range,

8.2 to 39.2). The Pearson correlation coefficient between lumbar lordosis change and thoracic kyphosis change was  $R = -0.4985$  ( $p = 0.018$ ).

**Conclusion:** The postoperative lumbar lordosis and thoracic kyphosis both increased significantly. Spontaneous reciprocal change of thoracic kyphosis at non-fusion levels accounts for the restoration of sagittal alignment after surgical correction of lumbar lordosis. This characteristic significantly affect postoperative spinal sagittal alignment, which should be taken into consideration in postoperative planning for spine osteotomy.

## L5 Closing–Opening Wedge Osteotomy as a Salvage Procedure for Post-fusion Failed Back Surgery Syndrome

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**Purpose:** Surgical treatment modalities for post-fusion failed back surgery syndrome (PF-FBSS) as postoperative lumbosacral loss of lordosis with symptomatic back pain remain as a great challenge. L5 closing–opening wedge osteotomy (COWO) can provide most degrees of kyphotic correction at the lumbosacral junction. Compared with L5 pedicle subtraction osteotomy, L5 COWO may provide more central correction center of the vertebral body and it may cause less kinking of the dura sac at the time of correction. This study was aim to present the radiographic and clinical outcomes of L5 COWO in a case series with PF-FBSS.

**Materials and Methods:** Five patients who have received lumbosacral posterior instrumented fusion had persistent postoperative low back pain with kyphotic posture. Loss of lumbar lordosis with mainly L4–S1 kyphotic change or pseudarthrosis were noted from lateral standing and dynamic palin film and PF-FBSS were confirmly diagnosed. The L5 COWO procedure through a single posterior approach was then performed. The Cobb angle was assessed preoperatively, postoperatively, and at the final follow-up. Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) were used to evaluate back function preoperatively and at final follow-up.

**Results:** Mean lumbar lordosis was reduced from 5.7° kyphosis preoperatively to 28° lordosis postoperatively. The VAS improved from 7.3 to 4.2 and ODI improved from

38.2 to 22.3 at postoperative 6 months, respectively. Bony fusion was achieved according to postoperative-12-month computed tomography scan.

**Conclusion:** L5 COWO with solid long level instrumented fusion, as a salvage procedure, can provide satisfactory outcomes for the patient with PF-FBSS.

## The Importance of Combined Anterior Column Realignment Compared to Pedicle Subtraction Osteotomy only for Severe Rigid Sagittal Plane Deformity

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**Purpose:** Pedicle subtraction osteotomy (PSO) may be limited for the correction of severe rigid sagittal deformity cases. This study aims to evaluate the efficacy and consequence of combined anterior column realignment with PSO, compared to PSO only for severe rigid sagittal plane deformity.

**Materials and Methods:** We retrospectively reviewed the medical records and the radiographs of patients who underwent surgical correction between January 2012 and December 2016. Thirty-eight consecutive patients were included and were divided into two groups according to surgical strategy (combined anterior column realignment with PSO [group I] and PSO only [group II]). Severe rigid sagittal plane deformity was defined by the unmeasurable sagittal vertical axis (SVA) in the standard X-ray. Time-dependent radiographic come analysis with spinopelvic sagittal parameters were performed statistically.

**Results:** Group I had the smaller immediate postoperative SVA (-20 mm vs. 70 mm,  $p=0.041$ ) and the larger immediate postoperative change of lumbar lordosis (LL, 72° vs. 51°;  $p=0.011$ ), pelvic tilt (PT, -13° vs. -8.1°;  $p=0.041$ ), and proximal junctional angle (PJA, -1.2° vs. 6°;  $p=0.031$ ), compared to group II. In the group I, SVA (-20 mm vs. 43 mm,  $p>0.05$ ), LL (56° vs. 53°,  $p>0.05$ ), PT (22° vs. 20°,  $p>0.05$ ), and PJA (4.8° vs. 8.3°,  $p>0.05$ ) achieved at immediate postoperative were maintained until ultimate follow-up. On the other hand, group II demonstrated that SVA (70

mm vs 139 mm,  $p<0.05$ ), LL (45° vs. 33°,  $p<0.05$ ), PT (24° vs. 29°,  $p=0.063$ ), and PJA (9.8° vs. 18°,  $p<0.05$ ) achieved at immediate postoperative were not maintained at ultimate follow-up.

**Conclusions:** Combined anterior column realignment with PSO can provide a larger magnitude of correction at the immediate postoperative, compared to PSO only for severe rigid sagittal plane deformity and maintaining of acquired correction at the minimum 2-year follow-up.

## Homogenous Halo Gravity Traction and Its Pan Spinal Effect in Severe Rigid Neglected Deformities

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**Purpose:** Acute correction of severe rigid curves with poor flexibility requires multiple osteotomies, which are known to cause numerous complications. To evaluate the benefits of halo gravity traction (HGT) in severe rigid spinal deformities with primary curve of Cobb angle  $>120^\circ$  or sum of Cobb angles  $>150^\circ$ .

**Materials and Methods:** Patients with primary curve Cobb angle  $>120^\circ$  or sum of Cobb angle  $>150^\circ$  underwent pre-operative HGT. Radiographic parameters analyzed were Cobb angles of curves—major scoliosis (MSCA), compensatory (CSCA1 and 2) kyphosis (MKCA), flexibility index, costo-iliac impingement (CILD), shoulder height difference (SHD), and sagittal profile. Pulmonary function was assessed by respiratory rate (RR), breath holding count (BC), and pulmonary function testing.

**Results:** Fourteen males and 12 females were included. The mean weight and height gained were 3.6 kg and 4.4 cm, respectively. The correction efficacy of HGT in MSCA, CSCA1 and CSCA2 were 15.6%, 13.3%, and 18.7%, respectively. Significant improvements were noted in MKCA, CILD, coronal imbalance (CI), and truncal shift (TS). Mean SHD improved from 2 to 1.1 cm. Mean forced vital capacity improved from 43.3% to 48.5% and forced expiratory volume in one second from 37.1% to 41.9%. Similar improvements were noted in RR & BC. There were no instances of neurological worsening or failure of instrumentation.

**Conclusion:** HGT safely and effectively increases the flexibility of major curves as well as compensatory curves in severe rigid deformities. It improves the overall balance of the patient by reducing the TS, CI, and SHD. It also provides adequate time to optimize the patient for major surgical undertaking and minimizes complications.

## Management of Rigid Scoliosis and Early Scoliosis Detection in Banjarmasin, Indonesia

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**Purpose:** In Banjarmasin, there are approximately 48 patients per year with 50% in rigid scoliosis due to neglected scoliosis. For preventing the progress, this study aims to determine the number of potential scoliosis in fifth- and sixth-grade primary school students in Banjarmasin using three different examinations.

**Materials and Methods:** The method of this study is using observational descriptive. The population of this research is all the fifth- and sixth-grade students in eight primary schools in Muhammadiyah and 10 primary schools in Banjarmasin. The sample is determined by purposive sampling method with inclusion criteria. This study took place in August 2017. Data were obtained using Scoliometer, Visual Inspection Physical Examination, and C7 plumb line test on 127 students.

**Results:** The results showed that the number of students who have potential scoliosis was 33 students (25.98%) with scoliometer, 12 students (9.44%) with direct visual inspection physical examination, and nothing with C7 plumb line test. Students aged >10 years have a higher percentage of potential scoliosis (27.5%) than students aged ≤10 years (25.3%) in scoliometer measurement, but vice versa in visual inspection. Female students have a higher percentage of potential scoliosis (36.73% with scoliometer and 16.33% with visual inspection) than in male students (19.23% and 5.13%).

**Conclusion:** At conclusion, early detection is important and in rigid scoliosis, even though surgical intervention is done well by orthopedic, but the patient didn't feel satisfied.

## Halo Vest in Cervical Spine Disorders: A Simple Yet Highly Effective Device

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**Purpose:** To evaluate the efficacy of Halo Vest in a wide range of cervical disorders.

**Materials and Methods:** This is a single center retrospective study of 30 cases having various cervical spine pathologies treated by Halo Vest in 2010–2017. Data was retrieved using electronic medical record system and clinical and radiological images were retrieved using PACS software. Patients were followed up at regular intervals of 1, 3, 6, and 12 months. Halo was kept for a period of 8–12 weeks. At subsequent follow-up, all the patients were assessed clinically and radiologically.

**Results:** Thirty cases with age ranging from 2–65 years with at least 1-year follow-up were included. Fourteen patients had a traumatic aetiology, two were congenital in origin, five infective, one had primary bone tumor, and eight patients underwent postoperative Halo Vest immobilization for added stabilization. There was significant improvement both functionally (Visual Analog Scale, Neck Disability Index, Frankel grade, and Japanese Orthopaedic Association) and radiologically (healing/fusion), in all patients except one where therapeutic Halo immobilization had failed. Five patients had superficial pin tract infection which was managed by oral antibiotics and by pin removal/readjustment. None of the cases had pin migration or brain abscess.

**Conclusion:** Halo Vest is an important tool in a surgeons armamentarium due to its wide spectrum of application with minimum complications and therefore stands out as one of the promising devices in managing cervical disorders.

## Influence of Spinal Interventions on Adrenal Function before a Surgical Treatment

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**Purpose:** A representative and instrumental option of non-surgical remedies is epidural steroid injection. Though there have been many concerns of complication of repeated steroid injection, there have been few studies about the adrenal function of the spine patients who ended up with surgical treatments.

**Materials and Methods:** This was a retrospective study with prospective data collection. Those who received elective spinal surgeries and having history of multiple spinal interventions from January 2017 to June 2017 in authors' hospital were reviewed as a study group. Those who received knee arthroplasty surgeries and not having history of spinal interventions and any kind of steroid injection in other area during the same period were reviewed as a control group. Demographic data were compared to see the homogeneity of both groups. The primary endpoint was the difference of serum cortisol level at the day of operation between the two groups. The secondary endpoint was adrenal response to a surgery. The preoperative and postoperative serum cortisol levels were compared in each group. The serum cortisol levels were divided into two categories: normal (range, 7–28 µg/dL) and abnormal. The secondary endpoint was what are the risk factors of abnormal cortisol level in multivariate logistic regression test. Blood sampling was done at 6:00 am.

**Results:** There were 53 patients in the study group and 130 patients in the control group. The preoperative serum cortisol level was  $10.4 \pm 4.8$  µg/dL in the study group and  $12.0 \pm 4.2$  µg/dL in the control group. The difference was significant ( $p=0.026$ ). The preoperative one day serum cortisol level was  $11.6 \pm 5.0$  µg/dL in study group with no rise from preoperative level ( $p=0.117$ ) and  $14.4 \pm 4.4$  in control group with significant rise ( $p=0.000$ ). Among all patients, 18 patients were subnormal and 165 patients were the independent risk factors irrespective of age and sex ( $p=0.015$ ; odds ratio, 3.472).

**Conclusion:** There was great concern of suppressed adrenal function in the patients who ended up with a surgical treatment after multiple interven.

## The Consequence of Antiplatelet Drug Medication on a Spine Surgery

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**Purpose:** The incidence of cardiovascular and neurovascular diseases of elderly population has been increased. As the average age of spinal surgery patients is increasing, it has become more popular to take antiplatelet drugs (APD). There has been a great concern on the adverse effects of APD on a spine surgery. To our knowledge, though there have been many studies on the above subject, their results were conflicting. We wanted to verify the consequences of APD on a spine surgery in terms of intraoperative bleeding and postoperative spinal epidural hematoma complication.

**Materials and Methods:** Those who underwent posterior thoracolumbar decompression and instrumentation for 2 years were reviewed. There were 34 APD takers (APT). Seventy-nine APD non-taker (APNT) were selected as a control group in consideration of demographic and surgical factors. There were two primary end points. First, the amount of bleeding per 10 minutes was compared. Second, the caudaequina compression by epidural hematoma was compared by measuring the cross-section area of thecal sac in maximal compression site by epidural hematoma at day 7.

**Results:** Both groups had homogeneity on age, sex as demographic factors and on number of fusion segments, operation time, whether virgin or revision operation as surgical factors and on number of platelets, prothrombin time, activated partial thromboplastin time, as coagulation related factors. However, as a matter of course platelet function analysis (EPI) was delayed in APT group (203.6: 170.0 seconds,  $p=0.050$ ). Intraoperative bleeding per 10 minutes was  $40.1 \pm 12.8$  mL in APT group and  $43.8 \pm 9.8$  mL in APNT group. There was no significant difference between the two groups ( $p=0.154$ ). The cross-section area of thecal sac at maximal compression site by epidural hematoma was  $120.2 \pm 48.2$  mm<sup>2</sup>, and  $123 \pm 50.4$  mm<sup>2</sup>, respectively and there was no significant difference between the two groups ( $p=0.766$ ).

**Conclusion:** APD medication did not increase intraoperative bleeding and postoperative spinal epidural hematoma.

## How to Avoid Postoperative Remaining Ossification Mass in Anterior Controllable Antedisplacement and Fusion Surgery

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**Purpose:** To retrospectively review the cases with ossification of the posterior longitudinal ligament (OPLL) treated by anterior controllable antedisplacement and fusion (ACAF). And patients with postoperative remaining ossification mass (PROM) are analyzed to figure out the causes and preventions of this problem.

**Materials and Methods:** A total of 75 patients were included. PROM were identified as remaining OPLL existed in the spinal canal other than included in the vertebral-OPLL complex on postoperative computed tomography. The Japanese Orthopaedic Association (JOA) scoring system was used to evaluate the neurological status. Surgery-related complications such as cerebrospinal fluid (CSF) leakage and spinal cord or nerve injury were all recorded. The patients with PROM group and patients without PROM group were compared.

**Results:** There were six patients with wide base OPLL (8%) and three patients (4%) with PROM among the 75 OPLL patients. The three patients with PROM were all with wide base OPLL. The average improvement rate of JOA score in patients without PROM was significantly larger than that in patients with PROM ( $69.5 \pm 22.6\%$  vs.  $23.8\%$ ,  $-28.6\%$  to  $75\%$ ;  $p < 0.01$ ). Incidence rate of postoperative CSF leakage and neural deterioration were significantly higher in patients with PROM than that in patients without PROM (CSF leakage:  $66.7\%$  vs.  $5.6\%$ ,  $p < 0.01$ ; neural deterioration:  $66.7\%$  vs.  $2.7\%$ ,  $p < 0.01$ ). No other complications were observed.

**Conclusion:** PROM is a rare complication but might cause complications and poor neural function recovery in ACAF treated OPLL patients. Surgical techniques should be noted to avoid PROM in ACAF surgery.

## Transpedicular Percutaneous Biopsy of Vertebral Body Lesions Using Kyphoplasty Cannula: A Technical Note

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**Purpose:** To describe technical details and utility of transpedicular percutaneous biopsy using kyphoplasty cannula in vertebral body lesions.

**Materials and Methods:** Over a period of 8 years, we carried out transpedicular biopsy procedures in 55 patients of various vertebral lesions in thoracic and lumbosacral spine for adequate diagnosis. To improve accuracy the maximum area of bone destruction was localized by pre-operative computed tomography scan in all patients. All procedures were performed under fluoroscopic guidance under general anesthesia via a coaxial transpedicular approach used for Vertebroplasty/kyphoplasty using 11 no bone biopsy needle and kyphoplasty working cannula. Sample was retrieved by aspiration followed by use of small pituitary ronger through the cannula for retrieval of solid tissues from at least three different directions from the lesion. Samples were sent for Gene Xpert, Gram and Ziehl Neelsen stain, acid-fast bacilli culture, and histopathology. We evaluated the clinical validity of this less invasive diagnostic method in terms of the accuracy of the pathological diagnosis.

**Results:** Discussion From 2011 to 2018, we evaluated 55 patients (27 males, 28 females) from age of 10 to 81 years who underwent transpedicular biopsy for T1-S1 lesions of the vertebral bodies. According to site, there were one cervical, 16 dorsal, 18 dorso-lumbar (D10 to L2), 18 lumbar, and three sacral lesions. The needle passed through the pedicle into the site of disease in all patients, as confirmed by C-arm fluoroscopy. Diagnosis was established in 44 out of 55 specimens (80%). There were 21 tumors (six primary bone tumor, eight metastasis, and seven plasma cell neoplasm); 16 cases of tuberculosis, pyogenic infection in six, and Paget's disease in one. There were no complications.

**Conclusion:** Percutaneous transpedicular biopsy of deep vertebral body lesions using a bone biopsy needle and Kyphoplasty cannula under fluoroscopy guidance can be performed safely and efficaciously.

## Simple Predictor of Postoperative Neurologic Status in Patients with Metastatic Spinal Cord Compression: Cord Compression Ratio on Magnetic Resonance Imaging

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**Purpose:** To identify magnetic resonance imaging (MRI) parameters to predict postoperative ambulatory status

**Materials and Methods:** Sixty-three patients underwent surgeries for metastatic spinal cord compression (MSCC) between 2011 and 2017. On preoperative MRI, the change in signal intensity (SI) of spinal cord on sagittal T2WI was recorded, and anteroposterior (AP) diameter and width of spinal cord at maximal compression lesion and two adjacent levels were measured on axial T2WI. The mean value of two products of AP diameter and width at two adjacent levels was compared with that at the lesion. Compression ratio (CR) was calculated by division of the value of the lesion by the mean values of two adjacent levels. The parameters were analyzed statistically regarding the postoperative ambulatory status at the postoperative 1 month.

**Results:** Preoperatively, 33.3% of the patients (n=21) were non-ambulatory, whereas 77.8% of the patients (n=49) were ambulatory at postoperative 1 month. The difference between the value of the lesion and the mean value of adjacent levels showed a prognostic relationship for postoperative ambulatory status ( $p=0.011$ ). CR showed significant correlation with postoperative ambulatory status ( $p=0.001$ ). Receiver operating characteristic curve analysis demonstrated that the optimal cutoff value of CR for postoperative ambulatory status at 1 month was 0.84. When high SI of the cord determined by both examiners was positive, it was also a significant predictive factor ( $p=0.017$ ). However, the Cohen's kappa regarding the change of SI of spinal cord was 0.416.

**Conclusion:** CR may help spine surgeons to predict the postoperative ambulatory function. The change of SI of the spinal cord on sagittal T2WI showed poor interobserver agreement. Although some imaging features have proposed for prediction of postoperative functional prognosis, the compression ratio is considered simple and reliable.

## Additive Manufactured Ti-6Al-4V/Polyetheretherketone Composite Porous Cage for Interbody Fusion: Bone Growth and Biocompatibility Evaluation in a Porcine Model

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**Purpose:** Several materials have been used to manufacture the cages, the most common being polyetheretherketone (PEEK), and titanium (Ti) alloy (Ti-6Al-4V). Each material has its advantages and disadvantages. We attempted to utilize the advantages of each material in combination with additive manufacturing technology to develop a new porous Ti alloy/PEEK composite interbody cage.

**Materials and Methods:** Porous Ti alloy/PEEK composite cages were produced with controlled different porosities. *In vitro* cell culture analysis for alkaline phosphatase (ALP) activity, ALP and osteocalcin mRNA expression were assayed. This study was the animal study using 20 female pigs through an anterior intervertebral lumbar fusion and posterior pedicle screws augmentation. Each level was randomly implanted with one of five testing cages. The first was a commercialized pure PEEK cage (group 1). The second was a Ti alloy/PEEK composite cage with nonporous Ti alloy endplates (group 2). The third, fourth, and fifth groups were composite cages with porosity of 40%, 60%, and 80% (groups 3, 4, and 5), respectively. Micro-computed tomography (CT), back-scattered-electrons (BSE) scanning electron microscope (SEM), and histological analyses were performed.

**Results:** The shear strength reached 33.4 MPa at the Ti alloy/PEEK interface. ALP activity and ALP mRNA expression were positively correlated with the porosity rate and peaked at 60% porosity. Micro-CT and BSE SEM dem-

onstrated that structures with high porosities, especially 60% and 80%, facilitated more bone formation inside the implant but not outside the implants. Histological analysis also showed that bone formation was better in Ti alloy groups than in the PEEK group.

**Conclusion:** Our *in vitro* and *in vivo* results express that the innovative designed additive manufactured Ti-6Al-4V/PEEK composite porous cage is biocompatible and works well in lumbar fusion surgery.

### Prognostic Factors of Surgical Treatment for Spinal Intramedullary Ependymoma (World Health Organization Grade II)

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**Purpose:** Among intramedullary spinal tumors, ependymoma (World Health Organization grade II) is the most frequent and the basis of treatment is total resection by surgery. However, postoperative exacerbation of motor function occurred occasionally. The purpose of this study is to explore postoperative prognostic factors of spinal intramedullary ependymoma.

**Materials and Methods:** Eighty patients (54 males and 26 females; mean age,  $50.0 \pm 15.0$  years old) who underwent surgery at our institute for 2003 and 2015 with more than 2-year follow-up were enrolled. We defined 'good' group as the cases with final follow-up McCormick scale remaining the same grade as preoperative or stayed in IV or V, and 'bad' as the cases with motor paralysis as one or more McCormick scale exacerbations. The surveyed items are as follow: pre- and postoperative McCormick scale, sex, age, preoperative Visual Analog Scale (VAS), tumor localization, degree of tumor resection (gross total resection [GTR] or near/subtotal resection), hemosiderin caps, cavity length, and tumor length on magnetic resonance imaging. We performed univariate and multivariate logistic regression analysis between the two groups.

**Results:** Motor function exacerbations were observed in 15 cases. As a result of univariate analysis, the factors related with postoperative motor paralysis were as follows: older age, preoperative McCormick scale severity, preoperative higher VAS, thoracic localized, hemosiderin

capped, and GTR. We conducted multiple logistic regression analysis using these factors and found that older age, preoperative McCormick high, and GTR were significant poor prognostic factors.

**Conclusion:** Although GTR for spinal ependymoma is the basis of treatment, our data showed that the risk of exacerbation of paralysis is high by carrying out the total removal in cases of older patients with strong preoperative paralysis. Preoperative careful informed consent is essential in cases with these risks, and it may be necessary to consider planning a two-staged surgery depending on the intraoperative motor-evoked potential monitoring.

### Preoperative 'Cervical Axis' Deviation Is an Important Factor That Increases the Risk of Distal Adding-on Following Posterior Spinal Fusion in Lenke 1 and 2 Adolescent Idiopathic Scoliosis Patients with Non-AR Curves

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**Purpose:** To evaluate the relationship between shoulder and neck imbalance with postoperative distal adding-on phenomenon and to identify other predictive factors for this phenomenon in Lenke 1 and 2 (non-AR curves) adolescent idiopathic scoliosis patients.

**Materials and Methods:** One hundred Lenke 1 and 2 patients (non-AR curves) who underwent posterior spinal fusion with lowest instrumented vertebra (LIV) cephalad to or at L1 were recruited. Medial shoulder or neck balance was represented by T1 tilt and cervical axis (CA). Lateral shoulder balance was represented by clavicle angle (Cla-A) and radiographic shoulder height (RSH). Positive preoperative or immediate postoperative T1 tilt and CA values were defined for measurements  $>0^\circ$ . Distal adding-on phenomenon was diagnosed when there was disc wedging below LIV of  $>5^\circ$  or distalization of the end vertebra at final follow-up. Predictive factors and odds ratio were derived using univariate and multivariate binary logistic regression analysis.

**Results:** Mean age of this cohort was  $15.9 \pm 4.4$  years. Mean follow-up duration was  $30.9 \pm 9.6$  months. Distal adding-on phenomenon occurred in 19 patients (19.0%). Only Risser grade, preoperative CA, and final follow-up lumbar

Cobb angle were the independent predictive factors. A positive preoperative CA deviation increased the odds of distal adding-on by 5.4 times (95% confidence interval [CI], 1.34–21.51;  $p=0.018$ ). Immediate postoperative medial and lateral shoulder or neck parameters were not significantly related to distal adding-on phenomenon. The mean T1 tilt, CA, RSH, and Cla-A (immediate postoperative measurement) were comparable between the group with distal adding-on and the group without.

**Conclusion:** Distal adding-on phenomenon occurred in 19.0% of patients. Preoperative ‘cervical axis’ is an important factor and increases the risk of distal adding-on by 5.4 times. Other significant predictive factors were Risser grade and lumbar Cobb angle at final follow-up. Immediate postoperative shoulder or neck imbalance was not a significant factor for postoperative distal adding-on phenomenon.

## Radiological Risk Factors for Adjacent Segment Disease Requiring Surgery Following Posterior Lumbar-Interbody Fusion: A Minimum 10-Year Follow-up Results

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**Purpose:** One of the major issues after lumbar fusion is the development of adjacent segment disease (ASD). Because ASD significantly increases over time, long-term follow-up (FU) data were essential to address risk factors. The purpose of this study was to evaluate radiological risk factors for ASD requiring surgery following posterior lumbar-interbody fusion (PLIF).

**Materials and methods:** This retrospective comparative study based on the participants with degenerative spinal diseases underwent PLIF (less than 3 level). ASD patients requiring surgery within 10-year FU were included in the ASD group ( $n=66$ ) and patients who followed up greater than 10 years without revision surgery were included in the control group ( $n=103$ ). We evaluated the demographics and preoperative radiological conditions of the adjacent segment: Pfirrmann grade and Modic change on magnetic resonance imaging (MRI), intervertebral disc vacuum phenomenon and facet joint degeneration on

computed tomography (CT), UCLA grade, and types of osteophyte on the plain radiograph.

**Results:** ASD group showed significantly greater proportion of high grade in Pfirrmann grade (53% vs. 30%,  $p=0.002$ ), Modic change (12% vs. 3%,  $p=0.017$ ), facet joint degeneration (75% vs. 47%,  $p=0.002$ ), and UCLA Gr. (55% vs. 37%,  $p=0.022$ ) compared to the control group. The proportion of vacuum phenomenon (20% vs. 9%,  $p=0.052$ ) and traction spur (50% vs. 31%,  $p=0.033$ ) of ASD group were higher than those of the control group. Multivariable logistic regression analysis identified two independent risk factors: Pfirrmann grade (adjusted odds ratio [OR], 9.33–9.83;  $p=0.038$ ,  $p=0.035$ ) and facet joint degeneration (OR, 4.55–13.83;  $p=0.003$ ,  $p=0.037$ ).

**Conclusion:** In the comparison between the ASD and control group based on 10-year FU data, radiological risk factors for ASD were facet joint degeneration on CT and Pfirrmann grade on MRI. Comprehensive preoperative radiological evaluation using our results could help to predict ASD or long-term FU without revision surgery after PLIF.

## Diffuse Idiopathic Skeletal Hyperostosis Extended to the Lumbar Segment Is a Risk Factor of Reoperation after Surgeries for Lumbar Spinal Stenosis

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**Purpose:** Few studies have evaluated diffuse idiopathic skeletal hyperostosis (DISH) as a potential risk factor of poor surgical results for lumbar spinal stenosis (LSS). The purpose of this study was to investigate the association between DISH and reoperation after surgeries for LSS in long-term results by a retrospective longitudinal cohort study.

**Materials and Methods:** This study included 1,063 responders to a postoperative postal survey out of 2,363 consecutive patients who underwent surgery for LSS between 2002 and 2010. The survey included questions about reoperations at another hospital and the patient-reported outcomes. DISH was evaluated by preoperative standing whole-spine radiographs. We investigated DISH

as a predictor of reoperation and characteristics of poor outcomes in patients with DISH.

**Results:** Reoperations were performed in 115 patients (10.8%) during an average of 8.6 years after the initial surgeries. Patients who only had DISH were not associated with reoperation; however, incidence of reoperation were significantly higher in patients with DISH extended to the lumbar segment (L-DISH) than in patients without (22% and 7.3%, respectively;  $p < 0.001$ ). Cox analysis showed that L-DISH was an independent predictor for reoperation (hazard ratio, 2.05;  $p = 0.009$ ). Surgery-free survival was significantly shorter in patients with L-DISH than in patients without ( $p = 0.005$ ). The cause of reoperation did not differ between the patients with and without L-DISH.

**Conclusion:** L-DISH was independently associated with reoperation for LSS. Decreased number of lumbar mobile segments due to L-DISH might lead to unfavorable outcomes. Special attention is needed for patients with L-DISH after surgery for LSS.

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## The Epidural Injections on Lumbar Spondylosis Patients May Be Associated with the Risk of Osteoporosis: A Nationwide Population-Based Cohort Study

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**Purpose:** Epidural injections (EI) involve the administration of local anesthetic, steroids, or both into the spinal epidural space. The procedure was regarded as a reasonable approach for lumbosacral radiculopathy. The refractory period may prolong over 6 weeks, which makes an option of nonsurgical management. However, recent studies have revealed the negative effect on bone mineral density. The main purpose of this study is to illustrate the association between EI and the following risk of osteoporosis based on the nationwide population database.

**Materials and Methods:** Patients ( $N = 5,253$ ) with lumbar spondylosis have received EI between 2000 and 2013 were identified from the National Health Insurance Research Database. Each was randomly selected and frequency-matched with an individual without EI by age, sex, and the index year. Furthermore, the risk factors of osteoporosis were stratified by gender, age, urbanization level,

income level, and comorbidity.

**Results:** The incidence rates of osteoporosis in the EIs group and the non-EI group were 8.42 and 7.30 per 1,000 person-years, respectively. The EIs group had a higher risk of osteoporosis (adjusted hazard ratio, 1.21; 95% confidence interval [CI], 1.03–1.42). Correlated risk factors included male (adjusted subhazard ratio [aSHR], 1.33; 95% CI, 1.00–1.77), lowest urbanization level (aSHR, 1.42; 95% CI, 1.07–1.89), low income populations (aSHR, 1.86; 95% CI, 1.14–3.06), and without comorbidity (aSHR, 1.58; 95% CI, 1.08–2.32).

**Conclusion:** According to previous literature, anti-osteoporotic prescription following EIs may achieve better prognosis. The lowest urbanization level and lower income level may decrease the accessibility to further follow-up and anti-osteoporotic agent. While patient without comorbidity may lack in motivation to further follow-up after the symptom relief by the procedure successfully. EIs on lumbar spondylosis are related to higher risks of osteoporosis. The therapy should be recommended with caution, especially in patients with correlated risk factor.

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## Clinical Outcomes of One-Stage Anterior Debridement, Interbody Fusion with Allograft, and Anterior Fixation for Lumbar Segment Tuberculosis

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**Purpose:** To evaluate the clinical, radiological, and functional outcomes in patients who underwent one-stage anterior debridement, interbody fusion with allograft, and anterior fixation for lumbar segment tuberculosis.

**Materials and Methods:** In a prospective clinical study, 86 patients diagnosed with lumbar segment tuberculosis were operated by anterior debridement, autologous iliac bone grafting, and anterior fixation between January 2014 to December 2016. Surgery was performed when the toxic symptoms of tuberculosis were controlled, and local kyphotic angle, percentage of anterior vertebra height, back pain by Visual analog Scale (VAS), erythrocyte sedimentation rate (ESR), and neurological status were assessed preoperatively and at 6 months postoperatively. Finally functional status was assessed by modified MACNAB criteria.

**Results:** Mean local kyphotic angle was significantly de-

creased from the mean preoperative angle ( $14.6^{\circ} \pm 3.9^{\circ}$ ) to ( $1.8^{\circ} \pm 2.5^{\circ}$ ) at final follow-up ( $p < 0.001$ ). The mean VAS scores and ESR were significantly decreased from preoperative levels ( $7.6 \pm 0.8$ ,  $68.2 \pm 14.8$  mm/hr, respectively) to ( $0.4 \pm 0.5$ ,  $20.5 \pm 6.1$  mm/hr, respectively) at final follow-up (all  $p < 0.001$ ). The mean percentage of anterior vertebra height was significantly increased from the mean preoperative height ( $40.1 \pm 8.3$ ) to ( $81.1 \pm 4.9$ ) at final follow-up ( $p < 0.001$ ). Forty-eight patients who had non-functional neurological performance (Frankel B and C) before surgery had normal neurological performance after 6 months, and only nine patients still had sensory impairment (Frankel D). Eight patients were excellent, five patients were good, and three patients were fair at functional status. It was assessed by modified MACNAB criteria.

**Conclusion:** Two important benefits of this surgical approach include adequate removal of the infected material and early postoperative ambulation (because of the firm internal fixation and correction of the spinal deformity).

## Minimally Invasive Resection of Extradural Dumbbell Tumors of Thoracic Spine

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**Purpose:** Successful treatment for the dumbbell-shaped thoracic tumors depends on gross total resection (GTR) via an open laminectomy and facetectomy or transthoracic transpleural approach. In this study, we use minimally invasive method for the removal of extradural dumbbell thoracic tumor and evaluate the feasibility, efficacy, and safety of this technique.

**Materials and Methods:** We retrospectively reviewed 15 patients with dumbbell-shaped thoracic tumors who underwent minimally invasive resection and unilateral transforaminal thoracic intervertebral fusion (TTIF) through unilateral paraspinal muscle approach with an expandable tubular retractor from December 2013 to May 2014. The mean age was 41.3 years (range, 18–53 years). Clinical data and tumor characteristics were analyzed. The pain intensity in the previously symptomatic region was graded with Visual Analog Scale. The severity of the neurologic deficit was assessed by using the American Spinal Injury Association impairment scale before and after surgery. The radiological outcomes were evaluated ac-

cording to the change of bone bridging, the radiolucency, the instability, and the disc height.

**Results:** All patients underwent successful minimally invasive treatment of their spinal neoplasms. There were no procedure-related complications. The efficacy in terms of neurological recovery, pain improvement, and operative variables (length of incision, operative duration, blood loss, and hospital stay) was better when compared with prior published studies. Postoperative computed tomography image demonstrated complete resection of dumbbell tumor in the patients. The solid fusion was obtained after 3-month follow-up and there was no failure of internal fixation.

**Conclusion:** If the medial border of intracanal component of extradural dumbbell tumor is near the midline of canal and the pedicles of adjacent vertebrae to tumor are intact, minimally invasive resection of tumor through unilateral paraspinal muscle approach combined with unilateral TTIF is good choice.

## Spontaneous Acute Spinal Epidural Hematoma: A Clinical Case, a Retrospective Review, and Data Analysis of 52 Cases

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**Purpose:** To improve knowledge about such an unpopular and dangerous condition by data analyzing of 52 published cases.

**Materials and Methods:** We reported a case study and reviewed 34 published reports on PubMed from 1994 to 2017, collected 54 patients characteristics used American Spinal Injury Association (ASIA) score to analyze more easily by SPSS ver. 16.0 software (SPSS Inc., Chicago, IL, USA).

**Results:** The average age was 57 years old; sudden onset of severe spinal pain or paraspinal pain was in 80.4%; the interval time to the neural deficit was 34 hours; and the time interval to magnetic resonance imaging (MRI) was 54 hours. ASIA at admission was as follows: A (15.4%), B (28.8%), C (19.2%), D (28.8%), and E (7.7%); hematoma width was 5 levels (range, 1–13 levels); most affected level: C4 (67.3%); surgical treatment was in 86%; last follow-up outcomes were death (1.9%), A (1.9%), B (3.8%), C (7.7%), D (30.8%), and E (53.8%); and recovery rate was highest

in patient who had preoperative ASIA C score.

**Conclusion:** Early MRI may help to early gain accuracy diagnosis of spontaneous acute spinal epidural hematoma and surgical treatment is necessarily indicated when the patients had neuro deficits at ASIA A, B, or C.

## Comparison of Pedicle Screw and Paravertebral Foramen Screw about Insertion Torque for Salvage of Failed Lateral Mass Screw

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**Purpose:** Paravertebral foramen screw (PVFS) was reported as a new technique for posterior cervical fusion surgery. The purpose of this study is to compare insertion torque of pedicle screw (PS) and PVFS in the case of salvage for lateral mass fracture in insertion of lateral mass screw (LMS).

**Materials and Methods:** Three fresh frozen cadavers were included. First, we inserted LMS on both sides from C3 to C6. Second, a drill was put into the screw hole and the superior cortex of the lateral mass was made a fracture by the drill through the screw hole. After that, we inserted PVFS and PS in order. All screws were inserted under fluoroscopy and insertion torque was measured using a dedicated instrument. The insertion torque was compared for each type of screw and each level. For the statistical study, the Kruskal-Wallis test and the Steel-Dwass post-hoc test were used.

**Results:** We measured 24 screws in each of three types. The median value of insertion torque was 40.0 N·m (range, 30.0–56.8 N·m) for LMS, 77.5 N·m (range, 68.5–99.8 N·m) for PS, and 57.0 N·m (range, 40.5–77.5 N·m) for PVFS. For comparison of each screw, PS and PVFS were significantly higher insertion torque than LMS. Insertion torque of PS tended to larger insertion torque than PVFS, but it was not significant. There was no statistically significant difference in comparison of level.

**Conclusion:** Both of PVFS and PS were larger insertion torque than LMS even after the lateral mass fracture. This result indicated that these screws has sufficient fixing force in the salvage surgery. Since PVFS has low complication risk such as vascular injury and nerve injury, PVFS is effective for salvage surgery.

## Impact of Tobacco Smoking on Outcomes after Posterior Decompression Surgery in Patients with Cervical Spondylotic Myelopathy

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**Purpose:** Smoking has been associated with poor outcomes in the field of spinal surgery. However, the impact of tobacco smoking on outcomes following posterior decompression surgery has not been fully evaluated in patients with cervical spondylotic myelopathy (CSM).

**Materials and methods:** This is a retrospective multicenter study. Five hundred and eighty-seven patients diagnosed as CSM were enrolled at 17 high-volume institutions in Japan. Patients underwent cervical laminoplasty or laminectomy, and were followed up for at least 1 year after surgery. Outcome measures were preoperative smoking status, perioperative complications, the Japanese Orthopaedic Association scale (JOA), and the Visual Analog Scale (VAS) for neck. Smoking and nonsmoking groups were compared using unpaired *t*-test for continuous variables or a chi-square test for categorical variables.

**Results:** There were 182 (31%) current smokers and 405 (69%) nonsmokers including previous smokers. Smokers were younger than nonsmokers (average 65.1 vs. 68.4,  $p < 0.01$ ). There were no significant differences in body mass index, number of operated laminae, operative time,

and number of comorbidities; but the estimated blood loss during surgery was significantly higher in the smokers (57.6 mL vs. 37.0 mL,  $p < 0.01$ ). Regarding postoperative complications, there was no significant difference in the rate of surgical site infection, cerebrospinal fluid leakage, hematoma, and neurological deficit. However, smokers showed a significantly higher risk for delirium (3.3% vs. 0.2%,  $p < 0.01$ ). Both smokers and nonsmokers had comparable functional recovery in JOA scores (difference 3.1 vs. 2.9,  $p = 0.33$ ) and neck pain reduction using VAS (difference -1.8 vs. -1.4,  $p = 0.24$ ) at the final follow-up.

**Conclusion:** This is the largest studies analyzing the efficacy and safety of posterior surgical decompression in smokers with CSM. Although the estimated blood loss was larger in smokers, they gained functional restoration and neck pain reduction at the final follow-up. Attention is required, however, on postoperative complications such as delirium.

## High Cervical Spinal Cord and Foramen Magnum Lesions Our Experiences: A Review of 15 Cases

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**Purpose:** Clinical features of upper cervical spinal cord tumors are not clear because there have been too few published reports. The purpose of this study was to review the clinical features of these tumours.

**Materials and Methods:** We reviewed 15 patients who underwent surgery for an upper cervical spinal cord tumour. Data regarding age, sex, duration and type of symptoms, levels, topographical locations, surgical results, and histological features were investigated retrospectively.

**Results:** Among 15 patients analysed eight patients were male and seven were female, the mean age of presentation was 38.5 years, the mean duration of the first symptom before clinical diagnosis was 16.5 months. The most common clinical presentation was motor weakness but most of the patient experienced occipital cephalgia during their disease course. Among 15 cases majority were nerve sheath tumor ( $n=9$ , 60%), meningioma was the second most common tumour, and other tumour encountered were haemangioblastoma, astrocytoma, chordoma, and ganglioglioma. We

used the Frankel Grading system for assessment of pre- and postoperative patient's condition. Surgical outcome was good and nine out of 15 patients had good (Frankel grade E) outcome.

**Conclusion:** A majority of the foramen magnum tumors are amenable to excision via the standard posterior approach. Small anterior dural based meningiomas/recurrent tumours may require a lateral approach like the far lateral approach.

## Long-Term Results after Anterior Cervical Discectomy and Fusion with Polyetheretherketone Cage: Plate Constructs in Degenerative Cervical Spinal Diseases

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**Purpose:** To evaluate the long-term clinical and radiologic outcomes of anterior cervical discectomy and fusion with polyetheretherketone (PEEK) cage-plate constructs for the degenerative cervical spinal disorders.

**Materials and Methods:** We enrolled 215 patients who underwent multilevel anterior cervical discectomy and fusion (ACDF) due to degenerative cervical spinal disorders, and they had minimum 3-year follow-up period after the operation. We analyzed the survival rate for the revision operation due to adjacent segmental disease (ASD), implant related complications, and non-union by Kaplan-Meier survival analysis. We also evaluated the influences of age at the operation, sex, level of fusion, C2-7 lordosis, fusion segment lordosis, bone mineral density (BMD) and occupation on the revision surgery, and implant-related complication.

**Results:** The mean duration of follow-up was 84.8 months (range, 36-182 months). The median age of the patients were 52.4 years (range, 24-83 years), and 40% of patients were female. Twenty-seven out of 215 patients showed adjacent segmental disease (12.5%) and 11 out of 215 patients (5.1%) needed a revision surgery. As ASD, the 3-year survival rate was 94.4%, 5-year was 89.9%, and 7- and 10-year survival rate were 86%. As revision surgery, the 3-year survival rate was 96.0%, 5-year was 95.4%, and 7- and 10-year survival rate were 93.9%. As implant related complications, the 3-, 5-, 7-, and 10-year survival

rate were 94.4%. The reasons for the revision surgery were ASD in seven cases, infected nonunion in two cases, pseudoarthrosis in one case, and neurologic deterioration in one case. Using univariate and multivariate analyses, age at the operation, sex, level of fusion, pre- and postoperative change of cervical lordosis, and occupational factor had no relation with revision surgery, adjacent segmental degeneration, and complications related with implants. Only BMD was related with implant-related complications ( $BMD < -2.0$ ,  $p=0.02$ ).

**Conclusion:** The construct with PEEK cage and anterior plate fixation for ACDF in the degenerative cervical spine disorders is a recommendable treatment option.

## Anterior Cervical Discectomy Fusion with Self-Locked Cages for 4-Level Cervical Disc Herniation

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**Purpose:** Anterior cervical plate has protruding profile, which usually leads to the sensation of swallowing foreign body, and self-locked cage has no profile. The purpose of study is to evaluate the feasibility, efficacy, and safety of anterior cervical discectomy and fusion (ACDF) with self-locked cages for the treatment of 4-level cervical disc herniation.

**Materials and Methods:** Sixteen cases of C3/4, 4/5, 5/6, and 6/7 disc herniation with myelopathy or radiculopathy were included in this study. ACDF with self-locked cages (LDR Medical, Troyes, France) and allograft was performed for C3-7 under general anesthesia. Arm pain was preoperatively and postoperatively evaluated using Visual Analog Scale (VAS) and the severity of the neurologic deficit was assessed using the American Spinal Injury Association impairment scale. The clinical outcomes were evaluated with Oswestry Disability Index (ODI) and cervical range of motion (CROM) in six directions was measured at the 2-year follow-up. The radiological outcomes were evaluated according to the change of bone bridging, the radiolucency, the instability, and the disc height.

**Results:** Sixteen patients (seven women and nine men; mean age,  $61.2 \pm 10.6$  years) were included in the present study. The mean length of the incision was  $2.2 \pm 0.4$  cm. There was a mean blood loss of 35 mL (range, 15–180

mL). The average follow-up duration was 26 months (range, 24–36 months). There were no perioperative complications such as swallowing foreign body sensation. The VAS score and ODI showed excellent outcomes. CROM in six directions was close to normal, which had not affected daily life. For the radiological evaluation, 15 of 16 patients (93.8%) showed complete bone union at the 2-year follow-up.

**Conclusion:** ACDF with self-locked cages is a good choice of minimally invasive surgery for 4-level cervical disc herniation, which can get good clinical outcomes, rigid fixation, solid fusion, and no swallowing foreign body sensation.

## Anterior Cervical Decompression and Fusion in Cervical Myelopathy

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**Purpose:** To identify the aetiology of cervical myelopathy, to measure the neurological outcome by American Spinal Injury Association (ASIA) score and functional outcomes by modified Japanese Orthopaedic Association (mJOA) score in patients who underwent anterior cervical discectomy and fusion (ACDF) in limited facility condition.

**Materials and Methods:** This study was a retrospective study of 2-year duration, 2016 to 2017 in 22 patients. This study was approved by ethical committee of university review board. Both post-traumatic and degenerative cases were involved. Age ranged from 18–80 years.

**Results:** Male patients were more prone than female patients. C3–4 level 2 (9.09%), C4–5 level 7 (31.82%), C5–6 level 7 (31.82%), and C6–7 level 6 (27.27%) cases were involved in the study. All cases show neurological improvement according to ASIA score. For mJOA score traumatic cases have less recovery than degenerative cases. Complications rate is very low.

**Conclusion:** ACDF is safe and effective for cervical myelopathy patients whether caused by trauma or degeneration.

## Pathological Fracture of C4 Vertebra Secondary to Lung Adenocarcinoma Metastasis with Concomitant Fungal Spine Infection: A Case Report

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The spine is the most common site of skeletal metastases; the thoracic spine is the most common region involved in spinal metastasis (70%), followed by the lumbar spine (20%), while the cervical region is affected in 10% of the cases. Lung, prostate, breast, renal cell, thyroid and gastrointestinal carcinomas are the most common tumors that metastasize to the spinal column. The majority of vertebral metastases originate via hematogenous dissemination from primary carcinoma of the breast, lung, or prostate. The most common symptom in cervical metastases is neck pain which occurs in 90% of patients; 50% of cases complain of severe deficit, such as acute weakness that may progress to quadriplegia. The mean survival after diagnosis of vertebral metastasis was 7.1 months. Fungal infections of the spine are relatively uncommon and occur primarily as opportunistic infections in immunocompromised patient. They mostly arise as a result of hematogenous spread from another focus, most commonly the lung. We reported a case of 69-year-old gentleman who had pathological fracture of C4 secondary to lung adenocarcinoma metastasis with concomitant fungal spondylitis. Surgical intervention was done with long course of antifungal treatment; however, due to late presentation of the metastases and concomitant fungal infection, the prognosis is poor.

## The Incidence and Management Trends of Metastatic Spinal Tumors in South Korea: A Nationwide Population-Based Study

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**Purpose:** The contemporary spinal surgeons are becoming increasingly aware of metastatic spinal tumors. However,

variations still exist in the occurrence and management of patients for spinal metastases. This study aimed to examine the incidence of metastatic spinal tumors and trends in its management in South Korea.

**Materials and Methods:** In a population-based study, there were a total of 38,007 metastatic spinal tumor cases, from 2008 to 2017. The 2008 to 2017 national database acquired from the Korean Health Insurance Review & Assessment Service was analyzed. The international disease category in the revised International Classification of Disease, 10th revision codes, medical behavior codes, and examination codes were used to identify metastatic spinal tumor patients.

**Results:** Metastatic spinal tumor was the most common in patients in their 60s (25.7%). The age-adjusted incidence of metastatic spinal tumor per 100,000 persons was 8.16 patients in 2008 and 6.18 patients in 2017 ( $p=0.03$ ). In 2008, the sex-adjusted incidence of males and females was 8.60 and 8.20 patients per 100,000 persons, respectively. However, In 2017, it was 8.70 and 4.15 patients, respectively ( $p<0.001$ ,  $p=0.04$ ). For the decade, the most common primary tumor site was lung (26.9%). In the treatment, radiation therapy decreased from 3,502 to 3,435 patients ( $p=0.62$ ). On the other hand, surgical therapy increased from 1,158 to 1,382 cases ( $p<0.001$ ). In particular, the debulking procedure and instrumentation have increased in surgical procedures ( $p<0.001$ ). Total medical healthcare costs were US\$ 19,925,296 in 2008 and US\$ 30,268,217 in 2017 ( $p<0.001$ ), revealing a continuous rise.

**Conclusion:** The 10-year incidence of spinal metastases per 100,000 persons was 6.68 patients in South Korea. The surgical procedure such as debulking procedures and instrumentation increased in terms of treatment. The total medical healthcare cost of metastatic spinal tumors is increasing rapidly.

## What Is the Role of Surgery for Spinal Metastasis of Lung Cancer?: Propensity Score Matched Analysis between Surgery with Radiotherapy and Radiotherapy Alone

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**Purpose:** Although metastatic spine disease is increasing,

the debate on therapeutic modality still remains due to heterogeneous primary sites and different patient's condition. In addition, molecular targeted therapy has been introduced and reported to be effective. The purpose of this study is to evaluate the efficacies of surgery as well as molecular targeted therapy for spinal metastasis of lung adenocarcinoma.

**Materials and Methods:** Twenty-two patients treated with surgery and radiotherapy (surgery group) for lung adenocarcinoma were matched in a 1-to-1 format with 94 patients undergoing radiotherapy alone (only RT group) by age, sex, Tokuhashi score, and spinal instability neoplastic score using propensity score. Eastern Cooperative Oncology Group (ECOG)-performance status (PS), Frankel grade, and the possibility of ambulation were compared. In subgroup analysis, clinical outcomes and survival were evaluated along with molecular targeted therapy for mutations of epidermal growth factor receptor (EGFR) or anaplastic lymphoma kinase (ALK).

**Results:** The patients with better ECOG-PS (0, 1, 2) and Frankel grade (D, E) before treatment were significantly greater in the only RT group (95.5% vs. 72.7%, respectively;  $p=0.039$ ). However, the number of the patients unable to ambulate was significantly greater in the surgery group (27.3% vs. 4.5%,  $p=0.039$ ). Although significant improvements of Frankel grade (22.7% vs. 0%,  $p=0.018$ ) and ambulation (18.2% vs. 0%,  $p=0.036$ ) were observed in the surgery group, survival was not significantly different between the two groups ( $p=0.790$ ). Longer survival and significant improvement of ECOG-PS were observed in patients with mutations of EGFR or ALK ( $21.0\pm 2.8$  vs.  $5.0\pm 1.5$  months,  $p=0.042$  for survival; 35.3% vs. 7.4%,  $p=0.02$  for ECOG-PS).

**Conclusion:** Surgery with radiotherapy significantly improved ambulation and Frankel grade compared with radiotherapy alone, while molecular targeted therapy for mutations of EGFR or ALK significantly improved the performance status and survival rate.

## Neurological Outcome in Patients with Metastatic Spinal Cord Compression

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**Purpose:** Metastatic spinal cord compression (MSCC) by a metastatic tumor can cause back pain, paralysis, and urinary/bowel dysfunction and requires prompt treatment. The aim of this study is to estimate surgical results and its prognostic factors on motor deficit in patients with MSCC.

**Materials and Methods:** All patients with MSCC treated with surgery in our department from March 2014 to May 2018 were included in this study. The patients were divided into two groups—those who underwent surgery within 48 hours (group 1,  $n=20$ ) and after 48 hours (group 2,  $n=65$ ). The outcome measures studied were neurological outcome (ambulatory function), incidence of infection, and complications.

**Results:** A total of 85 operations were performed in 78 MSCC patients. The mean age of the patients was 59.1 years and the most common origin of metastasis was non-small cell lung cancer (23%) followed by hepatocellular carcinoma (22%) and renal cell carcinoma (13%). All patients could not walk preoperatively, and 63 patients (74%) regained ambulatory function after surgery. There was no difference in length of ambulatory function, incidence of infection, and postoperative complications between the groups. Preoperative lower extremity motor grade was the most important factor in ambulatory function. 94% of patients with motor grade 3 or more regained ambulatory function after surgery.

**Conclusion:** Neurologic recovery and regain ambulatory function can be expected even surgery was done after 48 hours after paralysis in MSCC patient when preoperative lower extremity motor power is grade 3 or higher.

## Aggressive Vertebral Hemangioma Presenting as Vertebral Planar in Pregnancy: A Case Report and Literature Review

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**Purpose:** We report a rare case of aggressive vertebral hemangioma in pregnancy with radiological finding of vertebra planar with literature review of available reports.

**Materials and Methods:** A multigravida lady at her second trimester of fourth pregnancy presented with worsening bilateral lower limbs neurological deficit and urinary incontinence secondary to aggressive vertebral hemangioma. She underwent a successful laminectomy and spinal fusion with subsequent improvement in neurological function. To the best of our knowledge, this is the first reported case of vertebral hemangioma in pregnancy with radiological finding of vertebral planar. We discuss the dilemma in diagnosis, and literature review of aggressive vertebral hemangioma in this case is written up.

**Results:** Our transpedicular biopsy yielded inconclusive result and as tuberculosis (TB) spine was endemic in our region, anti-TB medication was started empirically. Final diagnosis was only confirmed by intraoperative bony specimens and anti-TB was stopped. Only six cases of aggressive vertebral hemangioma operated during antepartum in the past 30 years have been reported in the literature. Almost all of the cases had complete return of neurological functions. This is consistent with the outcome in our case.

**Conclusion:** Aggressive vertebral hemangioma in pregnancy is rare, and prompt management involving multi-discipline is vital to ensure both maternal and fetal safety.

## Rod Fracture and Related Factors after Total En Bloc Spondylectomy

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**Purpose:** Several studies have reported favorable on-cosurgical outcomes after total en bloc spondylectomy (TES) for treatment of primary malignant tumors or oligometastatic tumors. Considering that TES is indicated for patients with longer life expectancy, long-term instrumentation-related issues such as rod fracture needs to be addressed. We aimed to investigate delayed rod fracture and related factors after TES. This study is a multicenter and retrospective study. Thirty-two patients who survived for more than 2 years after TES consisted of 18 men and 14 women (mean age, 49.0 years). Twenty patients had primary tumors and 12 patients had metastatic tumors.

**Methods:** The relationships between rod fracture and related factors were investigated using Kaplan-Meier survivorship analysis with log-rank test. The analyzed factors were sex, age (<60 years or ≥60 years), tumor histology (primary or metastatic), location of resected tumor (thoracic [above T11], thoracolumbar [cases including T12–L1], or lumbar [below L2]), number of resected vertebrae (1, 2, or 3), anterior support method (expandable cage, mesh cage, or strut bone graft), rod diameter (5.5 mm or 6.0 mm), and history of radiotherapy including preoperative or postoperative radiotherapy.

**Results:** The mean follow-up duration was 49.8 months (range, 24–166 months). Twelve of 32 patients (37.5%) experienced rod fractures at an average of 29.2 months (range, 8–93 months) after TES. Of these 12 patients, eight underwent revision surgery due to back pain aggravation (n=7) or nonunion on computed tomography scan (n=4). Location of resected tumor and history of radiotherapy were significantly associated with rod fracture ( $p=0.004$ ,  $p=0.019$ , respectively).

**Conclusion:** Rod fracture was not a rare complication after TES surgery. History of radiotherapy and TES at lumbar level were significant risk factors related to rod fracture. A robust strategy to obtain solid osseous fusion should be considered when planning TES.

## Primary Malignant Melanoma of Thoracic Spine- A Rare Case Report

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**Purpose:** To notify the extremely rare case of primary malignant melanoma of the thoracic spine.

**Materials and Methods:** A 31-year-old Malay lady who has no known any medical illness before was presented to our casualty with a complaint of upper back pain with progressive weakness of bilateral lower limbs for the past 4 days prior to admission. It was associated with numbness up to the chest level. She, however, denied urinary and bowel symptoms. On examination, she had incomplete spinal cord neurological deficit with motor and dermatome level of T5. Magnetic resonance imaging of the whole spine revealed enhanced large mass originating from the posterior element of T5 which extending anteriorly to the T5 vertebral body. The mass also extends into the spinal canal causing compression onto the spinal cord posteriorly. Emergency decompression and posterior instrumentation have been carried out. Intraoperatively, the blackish, poorly differentiated diffuse and extensive mass was removed and sent for histopathological examination (HPE). HPE confirmed that the mass was malignant melanoma. Postoperatively, the patient was well and underwent radiotherapy. She had neurological improvement and currently, after 1 and a half year, she is able to walk with complete neurological recovery.

**Results:** Malignant melanoma of thoracic spine that proofed by HPE and patient was recovered from the illness.

**Conclusion:** Primary malignant melanoma of the thoracic spine is an extremely rare tumor of the spine that can be presented with spinal cord compression. It was successfully treated with early decompression, stabilization, and radiotherapy.

## Non-transfusion Surgery of Adolescent Idiopathic Scoliosis Surgery with Minimal Invasive Surgical Technique and Transamine Medication

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**Purpose:** Minimally invasive spine surgery (MISS) technique and transamine medication on adolescent idiopathic scoliosis (AIS) might decrease the intra-operative blood loss, and it could lead to satisfactory radiologic and clinical results without transfusion.

**Materials and Methods:** A total of 16 patients were enrolled (one male and 15 females). In all patients, correction was performed using the rod-rotation maneuver after pedicle screwing on the whole functional vertebral segment through 2–3 small 3.0-cm-sized skin incisions. Thoracoplasty was performed through the same incisions. Preoperative transferrin injection and transamine were given before and during operation. For the radiological evaluation, Cobb's angle, coronal balance (CB), and spinal vertical axis (SVA) were measured. For the clinical evaluation, Scoliosis Research Society-22 (SRS-22) questionnaire was surveyed, and surgical complications were also checked. Pre- and postoperative hemoglobin levels were evaluated sequentially.

**Results:** The mean age of enrolled patients was 16 years (range, 13–18 years), and the scoliosis curve type was comprised of 14 and two cases of Lenke type 1 and 3, respectively. The mean 11 vertebral segments were fixed through an average of two incisions. The mean five ribs were resected. Cobb's angle was corrected from 62° to 23°, with a 73% of correction rate ( $p < 0.001$ ). The CB and SVA were significantly corrected ( $p < 0.05$ ). The average amount of blood loss was 497 mL (range, 170–1,000 mL) during the approximately 5-hour operation. Hemoglobin levels had changed as follows: 13 g/dL (preoperation), 11 g/dL (immediate postoperation), and 10 g/dL (7 days postoperation). All patients were discharged after 7–12 days without any complications or blood transfusions. On the SRS-22 survey, the total score significantly increased from 3.8 to 4.6 ( $p < 0.001$ ), and the satisfaction score was measured as 4.5 out of 5.0.

**Conclusion:** In AIS correction, the MISS technique combined with tranexamic acid administration can minimize blood loss, which might allow for non-transfusion surgery.

## The Efficacy of Halo Traction for Scoliosis in Osteogenesis Imperfecta: The Optimal Duration of Traction

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**Purpose:** This study aimed to investigate the optimal duration of halo traction for scoliosis in osteogenesis imperfecta (OI) patients.

**Materials and Methods:** A review was performed on six consecutive patients who have undergone halo traction before posterior release and spinal fusion. Cobb angles of the major coronal curves were measured. The amount of correction achieved by the 1st month, 2nd month, and beyond 2 months of traction were analyzed. Patient outcomes were also reviewed.

**Results:** In this cohort of six patients with a pre-traction Cobb angle 114.5°, the average amount of correction achieved by halo traction was 23.6%. The percent of correction achieved at the first month was 63.2% ( $p=0.026$ ). Further improvement achieved in the 2nd month was of an average of 10.5%. None of the patients develop neurological complications during the traction.

**Conclusion:** Preoperative halo traction for scoliotic OI patients is effective and safe. Significant radiographic curve correction occurred by the 1st month of traction. Traction beyond 1 month should only be considered if the perceived benefit outweighs the risk of prolonged traction.

## The Outcome of Kyphosis Tuberculosis Treated with One Stage Reconstruction Surgery

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**Purpose:** Commonly, two stages combined anterior - posterior approaches were performed to treat significant kyphotic deformity, but potentially increase morbidity level. Recently, single-stage posterior approach for anterior column reconstruction have shown sagittal alignment improvement. The objective of this study is to describe radiology and clinical outcomes of kyphotic tuberculosis deformity patients who were treated using one stage

reconstruction surgery for posterior and anterior instrumentation.

**Materials and Methods:** Data collected from all kyphotic deformity patients in Fatmawati Hospital who treated with one stage reconstruction surgery between 2016 until 2017. In addition, this technique could address kyphotic correction.

**Results:** Ten patients were reported, the mean age was 37.1 years (five males and five females). Procedures were performed with lateral extracavitary approach. The mean estimated blood loss and length of surgery were 1,190 mL and 194 minutes, respectively. The mean preoperative local kyphotic angle was 54.1 degrees, and regional kyphotic angle was 37.5°. The mean postoperative local kyphotic angle was 23.9°, and regional kyphotic angle was 16.8°. All of the patients have good clinical outcomes, with mean 11 year postoperatively Visual Analog Scale of 0.3 and Oswestry Disability Index of 6.7. Two patients had post operative neurological deficit hypoesthesia.

**Conclusion:** Lateral extracavitary approach for anterior column reconstruction and posterior instrumentation is a viable alternative method to treat kyphotic deformities. This surgical procedure will produce a good alignment, strong fixation, better fusion, and reduced morbidity with one stage surgery.

## Percutaneous Posterior Tension Band Reconstruction for Fracture Kyphotic Deformity in Thoracolumbar Spine: Preliminary Surgical Report

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**Purpose:** Restoring structural alignment and preserving the stability are the keys to treat spine fracture. We used minimal invasive percutaneous pedicle screws insertion to reconstruct posterior tension band and sagittal alignment. Rapid bone union may result from the mesenchymal cells around vertebral ligaments which induce local osteogenesis by repetitive mechanical stimulation.

**Materials and Methods:** From March to October in 2018, seven patients was diagnosed as thoracolumbar spine fracture with kyphotic deformity. We used long segment

percutaneous pedicle screws instrumentation under O-arm navigation to restore the sagittal alignment. Anterior vertebral body height and kyphotic angle change were measured before and after surgery. The Oswestry Disability Index questionnaire and Visual Analog Scale (VAS) for pain were also used. The blood loss, hospitalization stay, and complication were also record.

**Results:** The mean intra-operative blood loss was 64.4 mL (range, 50–150 mL) and hospital stay is 5 days. The mean follow-up was 6 months (range, 1–8 months). At final follow-up, the mean VAS for pain was 1.5, and the mean anterior vertebral body height improved from 7.2 to 20.2 mm. The mean kyphosis angle change is 19° (range, 11°–30.6°). All patients returned to their original daily activity. There were no intra-operative complications or implant failures.

**Conclusion:** Percutaneous posterior instrumentation is a safe and effective surgery for reconstruction of sagittal alignment and pain relief. All patients recovered soon and returned to daily activity. However, long-term clinical outcome shall be followed up.

## Spino-Pelvic Thresholds for Prevention of Proximal Junctional Kyphosis Following Combined Anterior Column Realignment and Short Posterior Spinal Fusion in Adult Spinal Deformity

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**Purpose:** To analyze ideal indication for combined anterior column realignment (ACR) with short posterior spinal fusion (PSF) and posterior column osteotomy (PCO) for preventing proximal junctional kyphosis (PJK) in adult spinal deformity (ASD) patients with lower lumbar kyphosis and compensatory thoracolumbar (TL) lordosis.

**Materials and Methods:** This study included 27 ASD patients with lower lumbar kyphosis and compensatory TL lordosis, underwent short PSF with PCO following ACR. The minimum follow-up period was 5 years. The patients were divided into two groups based on the sagittal vertical axis (SVA) of the last follow-up radiographs.

**Results:** The prevalence of PJK was significantly higher in the suboptimal SVA group ( $p=0.008$ ). The mean lumbar

lordosis (LL) values in the optimal SVA and suboptimal SVA groups were 4.4° and 4.2° preoperatively ( $p=0.639$ ), –48.1° and –35° postoperatively ( $p=0.007$ ), and –45.2° and –20.7° at the last follow-up ( $p<0.000$ ). Overcorrection was seen in seven patients in the optimal SVA group, whereas all of the patients of the suboptimal SVA group were in the category of undercorrection ( $p=0.021$ ). Pelvic incidence (PI) of optimal SVA group ( $<50$  mm,  $n=16$ ) and suboptimal SVA group ( $\geq 50$  mm,  $n=11$ ) was 44.1° and 53.8° ( $p=0.009$ ).

**Conclusion:** Combined ACR with short PSF and PCO could effectively prevent sagittal decompensation of PJK and help achieve sagittal balance in the treatment of ASD patients with lower lumbar kyphosis, compensatory TL lordosis, and especially low PI ( $<50^\circ$ ).

## The Cranial Sagittal Vertical Axis Is a Better Radiographic Measure to Predict Clinical Outcomes in Adult Spinal Deformity Surgery than C7 Sagittal Vertical Axis

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**Purpose:** Our study aimed to confirm the correlation between the cranial sagittal vertical axis (CrSVA) and patient-reported outcomes and to compare clinical correlation between CrSVA and C7 sagittal vertical axis (C7SVA) in adult spinal deformity (ASD) patients.

**Materials and Methods:** One hundred and eight consecutive ASD patients were evaluated using the EOS two- and three-dimensional radio-imaging device. A vertical plumb line from the cranial center was utilized to measure the distance to the posterior corner of S1 (CrSVA-S), and to the centers of the hip (CrSVA-H), the knee (CrSVA-K), and ankle (CrSVA-A), as well as measuring the standard C7SVA. We analyzed the correlation between each CrSVA parameter with the Oswestry Disability Index (ODI) and revised Scoliosis Research Society-22 (SRS-22r) form.

**Results:** All four CrSVA measures demonstrated strong correlation with the ODI and SRS-22r total score and the

pain, self-image, and function subscores. Of note, CrSVA-A (global SVA) also strongly correlated with the SRS satisfaction subscore. Univariate linear regression showed similar results. The strongest predictor of outcomes was CrSVA, not C7SVA; (CrSVA-H for ODI, SRS total score, and the pain, self-image, and function subscores; and global SVA for satisfaction and mental health subscores).

**Conclusion:** The clinical correlation effect of outcome scores to the CrSVA measures is validated. Global SVA has an especially strong correlation with ODI and all the SRS subscores. Our study confirms that CrSVA is a stronger predictor of preoperative clinical outcomes than the C7SVA in adult deformity patients.

## Why and How I Perform the Staged Smith-Peterson Osteotomy for Thoracolumbar Kyphosis in Ankylosing Spondylitis

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**Purpose:** Smith-Peterson osteotomy (SPO) has been one of the most important techniques to correct deformities of thoracolumbar spine caused by ankylosing spondylitis. This technique comprises three components: a posterior column osteotomy, a reduction force, and the resultant osteoclasts through the disc space. The reduction force plays the central role in the correction mechanism of SPO, which determine the capacity and relative easiness or difficulty for the correction. Different reduction forces have been used including forces from manual manipulation, adjusting operation table, and spinal instrumentation systems. We would like to describe a staged SPO technique, which involves the use of a group of novel reduction forces: the gravitational force, muscle forces, and viscoelasticity property.

**Materials and Methods:** In the first stage operation, after placing the pedicle screws, only the posterior column osteotomy is performed. There is no further instrumentation. The patient then returns to the ward with a 'loosened' spine, and is kept in recumbency for 4 to 7 days on bed. During this period, the gravitation force and muscle force may act on the already compromised spine, resulting in controlled osteoclasts and spontaneous correction. Satisfactory correction is usually achieved at this moment

and the second operation is arranged to complete the instrumentation and fix the spine in corrected position.

**Results:** From 1998 to 2018, there are 93 patients receiving staged SPO. All the patients have satisfactory results. Their deformities are well corrected despite of the preoperative severity. There is no major complication except for three infections requiring repetitive surgeries and one pseudarthrosis requiring anterior grafting.

**Conclusion:** The staged SPO is an easy, effective, and safe technique to correct most of the thoracolumbar kyphotic deformities in ankylosing spondylitis.

## Experiences of Early Air Travel after Anterior Scoliosis Surgery by Retropleural Approach

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**Purpose:** Healthcare service in Sarawak is geographically challenging with air travel the preferred choice for most. Retropleural approach in anterior scoliosis surgery always carried risk of pneumothorax and its consequences. The Aerospace Medical Association (AsMA) and The British Thoracic Society (BTS) have recommended delay of post-operative air travel. However, these had been widely challenged.

**Materials and Methods:** We report three cases, whom had pleural injury during surgery and developed pneumothorax. All three cases were asymptomatic. Each were allowed discharge after confirming stable or resolved pneumothorax. They insisted on early air travel back home despite being informed of the possible consequences. None reported pulmonary symptoms during and after approximately 60 minutes of air travel.

**Results:** Current recommendations are based on AsMA and BTS. Both suggest 2–3 weeks delay of air travel after uncomplicated thoracic surgery or a week after full radiographic pneumothorax resolution. Pneumothorax is considered an absolute contraindication to air travel. However, literature reviews show no experimental supporting evidence. According to Boyle's law, the volume of gas within the thoracic cavity in a pressurized cabin will expand by about 25%–30%. In a patient with a 20% pneumothorax, assuming each hemithorax contains 2L of gas volume, there will be 400 mL of gas as pneumotho-

rax which may expand to 500 mL in a pressurized cabin above sea level. It is doubtful that additional 100 mL of gas volume will significantly cause compromise especially in patients without underlying lung pathology or injury. This hypothesis may explain our patient's asymptomatic condition. Sacco and his colleagues concluded safe air travel 24 hours post chest tube removal, if chest radiograph showed stable or resolved pneumothorax.

**Conclusion:** Current recommendations of postoperative air travel may not be suitable for all. Patients who have stable or resolved pneumothorax without lung parenchymal disease or trauma may tolerate pressurized cabin flight.

## Spinal Osteoid Osteoma: An Unusual Cause of Secondary Scoliosis and Review of Literature

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**Purpose:** Osteoid osteoma can lead to secondary scoliosis which can be the presenting complaint and hence be misdiagnosed. Thorough clinical and radiological examination including computed tomography (CT) and magnetic resonance imaging (MRI) is essential to diagnose it. A meticulous surgical excision can relieve the patient of his pain and also will correct the secondary deformity. Here we share with our experience with the case and also review what the literature has to say.

**Materials and Methods:** A 33-year-old man with thoracic deformity that was diagnosed with scoliosis was being treated for the same at various hospitals. He was given an orthosis and analgesics for pain relief at all the centres and was also advised correction of the deformity if pain doesn't settle. We did CT, which was suggestive of D9 thoracic osteoid osteoma. Surgical removal of the lesion resection was done and an intra-operative frozen pathology indicated features of osteoid osteoma. Immediately after the surgery, patient was free of his discomforting pain, and his deformity also got corrected on 3-month follow-up X-ray.

**Results:** Six months after the surgery, patient showed marked improvement of scoliosis deformity and complete relief of thoracic pain.

**Conclusion:** Although spine osteoid osteoma is clinically rare, it shall not be overlooked when patients present with scoliosis first. Radiological examinations including CT and MRI shall be undertaken carefully as reference when making diagnosis. Surgical resection of the lesion could well improve scoliosis and relieve the pain.

## A Staged Approach for Lateral Lumbar Interbody Fusion and Open Posterior Corrective Fusion in Patients with Degenerative Kyphoscoliosis

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**Purpose:** Corrective fusion surgery in patients with degenerative kyphoscoliosis has been associated with high invasiveness and frequent complications. We performed staged lateral lumbar interbody fusion (LIF) surgery and open posterior corrective fusion (PCF) to reduce invasiveness and complications. We aimed to clarify the clinical outcomes of lateral LIF staged surgery.

**Materials and Methods:** This study was a retrospective case series comprising 48 patients (mean age, 69.8 years) with degenerative kyphoscoliosis with a Cobb angle of over 20° who underwent thoraco-pelvic corrective fusion surgery with a minimum 2-year follow-up. Spino-pelvic parameters and peri-operative and mechanical complications were investigated. Clinical results were evaluated using the Oswestry Disability Index (ODI) preoperatively and after 2 years. A minimum clinically important difference (MCID) of ODI was defined as 15% in this study.

**Results:** Average operation time and blood loss totaled 449 minutes and 1,039 g (406 minutes and 996 g in PCF), respectively. The mean preoperative radiographic parameters were lumbar lordosis 13.2° and sagittal vertical axis 107 mm, which showed improvement at the 2-year follow-up (46.1° and 37 mm, respectively). Peri-operative complications included transient muscle weakness after LIF (n=4), muscle weakness (n=3), pulmonary embolism (n=1), surgical site infection (n=1), and abdominal wall muscle weakness (n=1) after PCF. Rod fractures were observed in 15 patients. Revision surgeries were performed in eight patients. ODI improved from 42.6% to 25.2% in over 2 years (MCID achieved rate=68.4%)

**Conclusion:** Through staged surgery with LIF and PCF, sagittal alignment was restored with less bleeding, fewer complications, and improved clinical outcomes. Nonetheless, the present study indicated that there was a high incidence of mechanical complications when using our approach. Countermeasures should immediately be devised for the prevention of rod fractures.

## Postoperative Spinal Epidural Hematoma: The Danger Caused by Misused Thrombin Containing Local Hemostatics

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**Purpose:** To examine the hypothesis that the misuse of thrombin-containing local hemostatics (TCLH) increases the risk of postoperative spinal epidural hematoma (POSEH).

**Materials and Methods:** Posterior instrumented lumbar spine surgery cases over 2 consecutive years were divided into two groups: a study group (98 patients in whom TCLH was used) and a control group (176 patients in whom TCLH was not used). The excess TCLH matrix that was not associated with blood clot was not removed from the patients in the study group. The senior author decided whether to use TCLH or not. Suction drains were used in all patients. The demographics, coagulation-related factors, and intraoperative factors of the patients in the two groups were analyzed. The development of POSEH was compared between the two groups.

**Results:** The two groups were homogenous in demographics (age and sex), coagulation-related factors (platelet count, prothrombin time, activated partial thromboplastin time, and platelet function analysis), and surgical factors (total blood loss, operation time, blood loss/10 minutes, number of fusion segments, posterolateral fusion/posterior lumbar interbody fusion, and virgin or revision surgery). POSEH developed more frequently in the patients in the study group than in those in the control group (14/98 patients, 14.3% vs. 3/176 patients, 1.7%, respectively;  $p=0.000$ ; odds ratio, 17.1)

**Conclusion:** TCLH causes blood clot not only at the edge of damaged vessels but also at the site of extravascular blood. Excess TCLH matrix not associated with blood clot

at the epidural space can enhance POSEH development because early clotted hematomas do not drain through suction drains.

## Relationship between the Degree of Retraction of Posterior Cervical Extensor and Axial Pain after Cervical Laminoplasty

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**Purpose:** Axial pain is well known as one of the complications after cervical laminoplasty. The degree of the retraction of cervical posterior extensor after cervical laminoplasty was evaluated by simple X-ray image and it was examined whether the degree of the retraction of cervical posterior extensor is related to axial pain.

**Materials and Methods:** In January 2017 to March 2018, we performed double-door laminoplasty for 14 patients who had cervical spondylosis myelopathy, ossification of posterior longitudinal ligament, and disc herniation. Those with cervical surgical history and with fixed surgery were excluded. Patients were checked the highest spinous process of the double-door lamina with the lateral cervical spine simple X-ray image at 6 months after laminoplasty and examined how much distance the spinous process retracted. The movement distance was expressed by the number of vertebral bodies. As evaluation items, C2–7 angle, C2–7 sagittal vertical axis, Japanese Orthopaedic Association (JOA), and JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ) Visual Analog Scale (VAS) were evaluated before surgery and at 6 months after surgery, and was compared.

**Results:** The average number of the retracted spina was 1.42 vertebral bodies, and was divided into two groups of 1 vertebral body and 1.5 vertebral bodies or more. The highest rank of the lamina of laminoplasty was that C2 was one case, and 13 cases were C3. In preoperatively, it was no significant difference between the two groups in all the items. At 6 months postoperatively, JOACMEQ VAS was 0.67 for 1 vertebral body and 5.00 for 1.5 vertebral bodies or more, and only item of JOACMEQ VAS was showed a significant difference between the two groups ( $p=0.003$ ).

**Conclusion:** JOACMEQ VAS was high when the retraction amount of the cervical posterior extensors was large

at 6 months after cervical laminoplasty. I believe that the retraction of the posterior extensor after cervical laminoplasty could be one of cause of axial pain.

### Prognostic Nutritional Index Less than 50 and Age over 70 Are Risk Factors of Delirium after Adult Spinal Deformity Surgery

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**Purpose:** Recently, malnutrition was reported as one of the risk factors of delirium which was common complication after surgery. The prognostic nutritional index (PNI) are a simple method of nutritional evaluation using albumin and lymphocytes count of blood sampling. However, there are no reports that the delirium is related to the PNI in patients after adult spinal deformity (ASD) surgery. The purpose of this study is to identify the risk factors of delirium after ASD surgery, including nutritional state.

**Materials and Methods:** A consecutive 319 patients who underwent ASD surgery were divided into a delirium group (group D) or non-delirium group (group ND) according to the incidence of postoperative delirium. Preoperative risk factors, including PNI, were assessed.

**Results:** Group D and ND were 30 patients and 289 patients, respectively. There was significant difference in age (group D [n=30]:group ND [n=289],  $p=0.000$ ), serum albumin ( $4.2\pm 4.3$ ,  $p=0.028$ ), operative time ( $422\pm 395$  minutes,  $p=0.029$ ), and PNI score ( $49\pm 52$ ,  $p=0.011$ ). The significant risk factors for delirium using multiple logistic regression analysis were age ( $p=0.006$ ; odds ratio [OR], 1.11; 95% confidence interval [CI], 1.03–1.19) and PNI ( $p=0.003$ ; OR, 0.87; 95% CI, 0.79–0.96). A receiver operating characteristic curve showed that the cut-off value of PNI and age for delirium were 49.7 and 68.5 years, respectively.

**Conclusion:** The risk factors of delirium following ASD surgery were PNI <49.7 and age >68.5 years. Patients who undergo ASD surgery beyond these cut-off values should be treated their nutritional status before surgery and be required to provide adequate informed consent.

### Predictive Factors Affecting Intraoperative Blood Loss for Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis with Dual Attending Surgeons Technique

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**Purpose:** To determine the predictive factors affecting blood loss in dual surgeons technique and to develop a formula to predict intraoperative blood loss during posterior spinal fusion (PSF) in adolescent idiopathic scoliosis (AIS) patients.

**Materials and Methods:** One hundred and seventeen AIS patients (18 males, 99 females) who underwent PSF with dual attending surgeons from January 2015 to December 2016 were included in the study. Patients' demographics, preoperative and intraoperative data were analyzed using simple linear regression analysis. Stepwise multiple regression analysis was performed to identify the most significant independent predictors and to develop a predictive formula.

**Results:** The mean age was  $14.0\pm 2.7$  years old. The mean preoperative Cobb angle was  $68.4^\circ\pm 16.4^\circ$ . The average number of fusion level was  $11.3\pm 2.2$  and the average number of screws inserted was  $13.7\pm 2.3$ . The mean wound length was  $30.4\pm 6$  cm. The average operative time was  $128.8\pm 37.4$  minutes. The average arterial pressure was  $66.6\pm 3.1$  mm Hg. The mean intraoperative blood loss was  $875\pm 458.5$  mL, estimated blood loss (EBL)/estimated blood volume ratio was  $27.7\%\pm 14.2\%$ , and blood loss per level fused was  $75.3\pm 31.2$  mL. For EBL, the operative time, gender, and number of levels fused were found to be the independent predictors ( $R^2=0.531$ ,  $p<0.05$ ). The predictive formula is  $183+(4.5\times \text{Duration in minutes})+(64\times \text{number of levels})-(330\times G)$ ; where  $G=1$  if male, 2 if female. For blood loss per level fused, operative time and gender were found to be the independent predictors ( $R^2=0.313$ ,  $p<0.05$ ). The predictive formula is  $\text{EBL/level}=83+(0.3\times \text{duration in minutes})-(G\times 28)$ ; where  $G=1$  if male, 2 if female.

**Conclusion:** Operative time, gender, and number of levels fused were found to be the most important predictors for affecting blood in PSF for AIS done by dual surgeons'

strategy.

## Assessment of Delirium in Elderly Patients after Spine Surgery

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**Purpose:** Postoperative delirium is a common complication in the elderly after surgery but few papers have reported after spinal surgery. Therefore, the risk factors for postoperative delirium following spinal surgery have not been fully clarified.

**Materials and Methods:** Between March 2016 and July 2017, 138 patients over 65 years of age were reviewed retrospectively. The patients were divided into two groups: group A with delirium and group B without delirium. For preoperative assessment, cognitive function was investigated with the Korean version of the Mini-Mental State Examination (MMSE-K) and Korean version of Delirium Rating Scale-revised-98 (K-DRS-98). Various preoperative assessments included age, gender, admission type, reason for surgery, laboratory findings, Visual Analog Scale score, and Oswestry Disability Index score. Intraoperative assessments included type of surgery, blood loss, and duration of surgery, and postoperative assessments included type of immediate postoperative pain controller. We analyzed the risk factors for delirium with each odds ratio using univariate and multivariate regression analysis.

**Results:** Postoperative delirium developed in 25 patients (group A). The preoperative scores for the MMSE-K in group A was  $28.12 \pm 1.24$  and significantly lower than that of group B ( $29.65 \pm 0.87$ ) ( $p < 0.05$ ). The scores for the K-DRS98 also shows significantly higher result in group A ( $1.92 \pm 1.35$ ) than group B ( $0.35 \pm 1.02$ ) ( $p < 0.05$ ). And odds ratio of MMSE-K was 0.337 ( $p < 0.0001$ ), and K-DRS 98 was 2.315 ( $p < 0.0001$ ). The duration of surgery of group A ( $185.8 \pm 106.8$ ) was longer than group B ( $147.7 \pm 83.29$ ) ( $p = 0.0517$ ), and odds ratio was 1.004 ( $p = 0.0592$ ). On multivariate regression analysis, 75–79-year-old patients had higher risk than 65–69-year-old (odds ratio, 3.207;  $p = 0.0013$ ) but lower risk than  $\geq 80$  year-old patients (odds ratio, 0.002;  $p = 0.0001$ ). The odds ratios of MMSE-K and K-DRS98 were 0.351 ( $p = 0.0094$ ) and 2.941 ( $p = 0.0071$ ).

**Conclusion:** The elder age and low level of preoperative cognitive function (e.g., lower MMSE-K and higher

K-DRS 98) are most important risk factor of postoperative delirium after spine surgery. Also, long duration of surgery can affect the postoperative delirium. Therefore, surgeons have to keep in mind about this factor.

## Dysphagia and Prevertebral Soft Tissue Swelling after Cervical Spine Surgeries

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**Purpose:** This study was to find association between anterior soft-tissue swelling of cervical spine lateral view plain film and postoperative dysphagia in the patients who have received cervical spine surgeries.

**Materials and Methods:** The enrolled patients were divided into three groups: anterior only, anterior and posterior, and posterior only. Baseline patient demographic characteristics and history were recorded. Two dysphagia questionnaires, including Bazaz dysphagia score (BDS) and Dysphagia outcome and severity scale (DOSS), were administered preoperatively and 3 days, 5 days, 2 weeks, 4 weeks, 6 weeks, and 3 months postoperatively. Lateral cervical radiographs were also obtained at the same time points. The anterior cervical soft-tissue shadow width was measured at C2, C3, C4, C5, C6, and C7 level. Correlation analysis was used to assess the relationship between BDS, DOSS, and anterior soft-tissue swelling.

**Results:** Fifty-two patients (32 females; average age, 56.0 years) were enrolled. Fourteen of them have received anterior and posterior surgery and 28 of them received anterior surgery. The anterior soft-tissue shadow width increased significantly from preoperative values at all levels at postoperative 3 days, 5 days, and 2 weeks and it almost returned to normal width as preoperative value at 6 weeks. Both dysphagia scales returned to nearly preoperative value at 5 days postoperatively at posterior only group at 6 weeks postoperatively at the other two groups, which had no significant difference between them. There was significant correlation between the DOSS and anterior soft-tissue swelling at 3 days and 5 days postoperatively.

**Conclusion:** There is a significant increase in anterior cervical soft-tissue swelling after anterior cervical spine surgery. The width of prevertebral soft-tissue may mostly correlate with postoperative dysphagia in postoperative 5 days.

## Neurological Complications of Posterior Spinal Surgery: Incidence and Clinical Features

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**Purpose:** To identify clinical features and risk factors helpful for the prevention and early diagnosis of neurological complications.

**Materials and Methods:** This was an observational study of patients who underwent posterior thoracolumbar spinal surgery in the orthopedic department of a single hospital over the course of 19 years (1995–2013). The incidence, cause, onset time, and risk factors of complications were investigated. Neurological deterioration was graded on a 5-point numeric scale: G1, increased leg pain or sensory loss; G2, unilateral motor weakness; G3, bilateral motor weakness; G4, cauda equina syndrome; and G5, complete paraplegia.

**Results:** Sixty-five cases (0.989%) out of 6,574 developed neurological complications due to the following causes: epidural hematoma, 0.380%; instrumentation with inadequate decompression, 0.213%; mechanical injury, 0.167%; inadequate discectomy, 0.061%; and unknown cause, 0.167% ( $p=0.000$ ). The grade of neurological deterioration was G1 in 0.167% of patients, G2 in 0.517%, G3 in 0.228%, G4 in 0.046%, and G5 in 0.030%. Neurological deterioration was most severe in patients who experienced epidural hematoma, followed by those in whom complications occurred due to instrumentation with inadequate decompression, unknown causes, mechanical injury, and inadequate discectomy, in order ( $p=0.009$ ). Revision surgery was a significant risk factor ( $p=0.000$ ; odds ratio, 2.741). The time that elapsed until symptom development was as follows, in order: unknown cause, 0.6 hours; epidural hematoma, 5.4 hours; mechanical injury, 6.6 hours; inadequate discectomy, 18.0 hours; and instrumentation with insufficient decompression, 36.0 hours ( $p=0.001$ ).

**Conclusion:** The incidence of neurological complications in our cohort was 1%. Revision surgery increased the risk by 3 times. Severe cases (cauda equina syndrome or complete paraplegia) rarely developed, occurring in 0.08% of patients. The major causes of neurological decline were epidural hematoma and instrumentation with inadequate decompression. Close observation in the early period was important.

## Revision Strategies for Failed Vertebroplasty: A Proposed Algorithm Based on Modified Dynamic Radiographs

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**Purpose:** To propose a surgical strategy for treatment of failed percutaneous vertebroplasty (PVP) using parameters from modified dynamic radiographs, magnetic resonance imaging (MRI), and neurological symptoms.

**Materials and Methods:** From January 2011 to December 2016, 32 patients (infections were excluded) underwent revision surgery due to failed PVP. Preoperative examinations included routine radiographs, modified dynamic radiographs, and MRI. Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) were used as clinical parameters. The preoperative, postoperative, and final follow-up local kyphotic angles were used as the radiological parameters.

**Results:** The age of the patients ranged from 57 to 90 years; four patients were men and 28 were women. Twenty patients (62.5%) with intact endplates and discs, and presence of vacuum in the cemented vertebrae were treated with repeat PVP alone. Eight patients (25%) with broken endplates and collapsed discs spaces, and a vacuum in the cemented vertebrae were treated with repeat PVP plus posterior instrumentation. Four patients (12.5%) with longitudinal split of the cemented vertebrae without vacuum underwent anterior surgery combined with posterior instrumentation. There was significant improvement in VAS, ODI, and radiological outcome at final follow-up. There were no surgery related complications. No implant failure was noted within the follow-up time (mean, 15.2 months).

**Conclusion:** Surgical decision for failed PVP depends on four parameters: integrity of discs and endplates of the cemented vertebrae, presence of vacuum in the cemented vertebrae, longitudinal split of bodies of the cemented vertebrae, and symptomatic dura compression. Modified dynamic radiographs are valuable for the evaluation of these parameters and choosing the optimal surgery.

## Management of Osteoporosis in Spine Surgery: Screw Fixation Techniques, Augmentation Methods, and Perioperative Care

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**Purpose:** Osteoporosis is a common disease in elderly population. It is not uncommon to perform spinal instrumented surgeries for osteoporotic patients. However, in patients with osteoporosis, instrumented fusion may result in screw loosening, implant failure, or nonunion because of poor bone quality. Therefore, techniques to enhance the pedicle screw fixation are required for osteoporotic spine.

**Materials and Methods:** We reviewed current surgical strategies for screw fixation and augmentation in osteoporotic spine and discussed their indication and effectiveness. Usefulness of drug administration for osteoporosis to enhance screw stability and spinal fusion was also reviewed.

**Results:** In surgeries for osteoporotic spine, proper screw size and trajectory, the number of pedicle screw placements, and fusion levels should be carefully considered to obtain sufficient spinal stability and rigid fixation. It is also important to evaluate preoperatively not only bone quality but also morphology such as spontaneous fusion/ankylosis in adjacent levels, global alignment as well as patient's daily activity. Various optional instruments, such as spinal hook, sublaminar wiring/band, and S2AI screw, are available for augmentation of the pedicle screw fixation. Other materials, including cement augmentation and hydroxyapatite stick to be inserted in prepared pedicle holes, can be used to enhance the screw fixation. Previous studies revealed that teriparatide to improve bone quality can reduce pedicle screw loosening and increase fusion rate.

**Conclusion:** Various surgical techniques to enhance pedicle screw fixation can be used for patients with osteoporosis. More rigid screw fixation with effective augmentation may reduce risks of screw loosening and implant failure, and provide better postoperative clinical outcomes. Pre- and postoperative drug administration to improve osteoporosis can enhance pedicle screw stability and spinal fusion after surgery. Various factors should be considered pre-, intra-, and postoperatively for optimal surgical treatment of osteoporotic spine.

## Esophageal Injury after Anterior Cervical Spine Surgery

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**Purpose:** To investigate the causes, diagnosis, and management of seven cases of esophageal injury occurring after anterior cervical spine surgery.

**Materials and Methods:** Seven patients were included in this study. According to the diagnosis time of esophageal injury, intraoperative group were two cases, perioperative group were two cases, and delayed finding group were three cases.

**Results:** In the intraoperative group, infectious spondylitis was the causes of all two cases and methicillin-resistant *Staphylococcus epidermidis* was identified in 50% of them. In both cases, anterior plate and screw removal and then posterior instrumentation was done. Injured esophagus was reconstructed by omentum flap in one case and primary repair was performed in one case. In the perioperative group, esophageal injury was occurred in revision surgery due to infection in one case and metal failure in other case. In both cases, the food residue was drained on the third day after surgery. Accompanying infection was identified in one case and both cases were treated conservatively. In delayed finding group, two cases occurred 3 months and one case occurred 32 months after anterior instrumentation due to trauma. In all cases, there was no associated infection. All the anterior instrumentation was removed, and two cases were treated with primary repair and one case with sternocleidomastoid muscle flap was used to repair the esophagus injury. Among seven cases, one case in intraoperative group was expired due to sepsis.

**Conclusion:** Intraoperative esophageal injury was caused by adhesions of the esophagus such as infectious spondylitis, and perioperative and delayed finding esophageal injury was caused by chronic irritation of metal failure. Treatment is performed removal of the anterior plate and screw and esophageal rupture was treated with conventional treatment, primary repair, or flap reconstruction, taking into account the degree of esophageal injury. Depending on the fusion, posterior instrumentation and fusion may be necessary.

## The Risk Factors of Neurological Aggravation in Spinal Tumor Surgeries

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**Purpose:** Deterioration of neurological status sometimes occurs after the spinal tumor surgeries with the backgrounds of spinal invasion or spinal cord compression. The aim of this study was to clarify the risk factors of neurological aggravation after spinal tumor surgeries.

**Materials and Methods:** One hundred and seventy-four consecutive spinal tumor cases from 2003 to 2018 were examined retrospectively. They were 71 males and 88 females with the age 53.8 years (range, 6–87 years). They were 113 patients of intra-canal spinal benign tumor, 37 patients of metastatic spinal tumor, one patient of malignant tumor with spinal origin, and 16 patients of benign spinal tumors with World Health Organization (WHO) grade 2. They showed 12% of bladder and rectal disturbance (BBD) and Frankel grade A (0%), B (1%), C (14%), D (43%), and E (42%). Operation was conducted basically posterior decompression and tumor resection with or without fusion, with eight cases of total en-block spondylectomy (TES), eight cases of corpectomy, and seven cases of stabilization without decompression. Univariate and multivariate analysis for neurological aggravation at 3 weeks after operation were conducted regarding background status and operative procedures.

**Results:** The patients with neurological aggravation were 16 patients (9.1%). Univariate analysis showed gender ( $p=0.795$ ), age ( $p=0.905$ ), metastatic spinal tumor ( $p=1.000$ ), tumor with vertebral origin ( $p=0.646$ ), benign spinal tumors with WHO grade 2 ( $p=0.011$ ), preoperative neurological status with Frankel grade C ( $p=0.125$ ), preoperative BBD ( $p=0.373$ ), TES ( $p=0.028$ ), corpectomy ( $p=1.000$ ), and stabilization ( $p=0.499$ ). Multivariate analysis showed that significant differences were shown in benign spinal tumors with WHO grade 2 ( $p=0.004$ ), TES ( $p=0.009$ ), and preoperative neurological deficit of Frankel grade C ( $p=0.044$ ).

**Conclusion:** Neurological aggravations after spinal tumor surgeries occurred in 9%; risk factors of the neurological aggravation were recurrence of benign spinal tumors with

WHO grade 2, severe aggression by TES, and preoperative neurological deficit of Frankel grade related to fragility of spinal cord.

## The Improvement of Cervical Lordosis and Sagittal Alignment after Vertebral Body Sliding Osteotomy in Patients with Spondylotic Cervical Myelopathy

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**Purpose:** Vertebral body sliding osteotomy (VBSO) is a novel technique that can do the anterior decompression more safely in patients with multilevel cervical myelopathy. The purpose of this study was to evaluate the improvement of cervical lordosis and sagittal alignment after VBSO compared to the anterior cervical corpectomy and fusion (ACCF).

**Materials and Methods:** Thirty-four patients who had operated by VBSO and thirty-one patients who underwent ACCF because of the cervical spondylotic myelopathy were included. The mean age was 52 years (range, 27–77 years) in VBSO group and 52 years (range, 46–80 years) in ACCF group. Preoperative, postoperative, and final follow-up radiographs were used to evaluate the improvement of cervical lordosis. Japanese Orthopaedic Association (JOA) score was used to assess the degree of disability.

**Results:** In ACCF group, all operation was one-level corpectomy but 19 patients in VBSO group underwent a two-level operation. There was no difference in preoperative and postoperative JOA score between groups. There was no difference in the preoperative radiologic parameters between groups. However, C2–C7 and segmental lordosis were larger in VBSO group after the operation. After VBSO, not only C2–C7 and segmental lordosis but also C0–C2 lordosis and C2–C7 sagittal vertical axis (SVA) were improved in the comparison between preoperative and final follow-up values.

**Conclusion:** VBSO is a superior technique in terms of the improvement of the global and segmental cervical lordosis compared to ACCF. C0–C2 lordosis and C2–C7 SVA were improved only after VBSO. Especially, VBSO is only

a reliable technique for the simultaneous correction of kyphosis and multiple decompression more than 2 level.

## Comparison of Reoperation Rates after Fusion Surgeries for Spondylosis between Cervical and Lumbar Regions: National Population-Based Administrative Database Study

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**Purpose:** Reoperation is one of key factors affecting post-operative outcomes. There is a low incidence of reoperation after fusion surgeries. Therefore, it is difficult to power studies to compare the reoperation rates between cervical and lumbar regions. National population-based administrative databases may overcome it. The purpose is to compare reoperation rates after fusion surgeries for degenerative spinal diseases according to cervical and lumbar regions in a national population of patients.

**Materials and Methods:** We used the Korean Health Insurance Review & Assessment Service national database to select our study population. We included patients who underwent first spinal surgeries from January 2012 to December 2012 under the diagnosis of cervical and lumbar spondylosis. Subjects were included if they had any of the primary procedures of fusion combined with the procedure of decompression procedures. We identified 42,060 patients. We assigned the patients into two groups based on anatomical regions: cervical and lumbar spine. We compared the reoperation rate between the two groups. The primary endpoint of reoperation was the repeat of any aforementioned fusion procedures. Age, sex, the presence of diabetes, associated comorbidities, hospital types, and surgical approaches were considered potential confounding factors. The entire follow-up period was 4 years. Statistical analysis for comparison between the two groups was performed using Cox proportional hazards regression

modeling.

**Results:** Total reoperation rate was 2.62% during the entire 4-year follow-up period. The reoperation rate of cervical spine group was 2.33% and lumbar spine group was 2.74%. The reoperation rate was higher in the patients underwent lumbar fusion surgery than in the patients underwent cervical fusion surgery during the entire follow-up period. Comorbidities and hospital type were noted to be risk factors for reoperation.

**Conclusion:** The incidence of reoperation was higher in patients underwent lumbar fusion surgery than in patients underwent cervical surgery.

## What Is the Best Neck Posture to Keep Airway Patency after Anterior Cervical Spine Surgery?

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**Purpose:** Airway compromise and prevertebral soft tissue swelling are serious adverse events associated with anterior cervical spine surgery (ACSS). However, no research to date has reported the influence of neck postures on maintenance of airway patency in patients after ACSS. The purpose of this study was to investigate whether the change of neck posture and mouth opening affected the airway patency and prevertebral soft tissue swelling in patients undergoing ACCS, and furthermore, to suggest the best posture to keep airway patent after ACSS.

**Materials and Methods:** From March 2016 to March 2017, a total of 49 consecutive patients underwent ACSS involving C3 or C4. Among them, 39 patients with complete lateral radiographs with different postures were included in this study. To evaluate any changes of airway patency and prevertebral soft tissue thickness in relation to neck posture and mouth opening, we determined the diameter of airway and prevertebral soft tissue at each cervical level on the neutral, flexion, and extension lateral radiographs with mouth closed and mouth open, using repeated-measures analysis of variance.

**Results:** Majority of the narrowest airway levels (98.3%, 230/234 patients) were found in the upper airway (C2, C3, and C4 levels). Both airway and prevertebral soft tissue diameter showed significant changes in relation to

neck posture and mouth opening after ACSS ( $p<0.001$ ). In those of postures, neck extension with closed mouth posture showed significant wider airway diameter than the others ( $p<0.001$ ). Moreover, this posture showed thinnest prevertebral soft tissue, but showed no significant difference compared to neutral-closed and extension-open postures ( $p=1.00$ ,  $p=0.053$ ).

**Conclusion:** Neck posture and mouth opening have a marked effect on airway patency and prevertebral soft tissue swelling after ACSS. Neck extension with closed mouth posture widens airway diameter, and is the best posture to keep airway patent after ACSS.

## The Difference between Ultrasound-Guided and Fluoroscopy-Guided Cervical Nerve Root Block

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**Purpose:** Cervical nerve root block is widely used for pain relief in cases with cervical radiculopathy, and for the confirmation of the affected nerve root in cases with cervical radiculopathy before surgery. Conventionally, fluoroscopy-guided cervical nerve root block (FCNB) has been widely used, but there are several limitations including—but not limited to—severe pain during procedure, radiation exposure, and the potential risk of neurovascular injury. Thus, ultrasound-guided cervical nerve root block (UCNB) has recently become popular; however, the difference is still controversial. We investigated the difference between FCNB and UCNB.

**Materials and Methods:** The study population included eight patients with UCNB (group U) and 13 with FCNB (group F). We investigated pain during procedure, pain relief after nerve root block, and complications. We also investigated anteroposterior view X-rays taken during the procedure in all patients, and the location of the needle tip was evaluated according to the lateral edge of the lateral mass: medial side was defined as (+) and lateral side was defined as (-).

**Results:** In all cases, pain was decreased after the procedure and there were no complications in either group. In group F, all patients complained of severe or moderate pain during the procedure, but in group U, all patients re-

ported mild or no pain. The location of the needle tip was -3.13 mm (range, -9.2 to 0 mm) in group U and 3.83 mm (range, -2.4 to 7.8 mm) in group F. There was a significant difference between the two groups (paired Student t-test,  $p<0.001$ ). Moreover, contrast medium spread more widely in group U than in group L.

**Conclusion:** According to our results, UCNB is more useful for pain treatment than FCNB because the patient experiences less pain during a procedure. However, caution is necessary regarding the efficacy of UCNB for the level diagnosis in cases with cervical radiculopathy before surgery because the needle tip was located significantly more laterally and contrast medium spread more widely in comparison to FCNB. Further studies are necessary.

## Correlation between Magnetic Resonance Imaging Spinal Cord State Score and Japanese Orthopaedic Association Score in Ossification of Posterior Longitudinal Ligament of Cervical Spine

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**Purpose:** To investigate the magnetic resonance imaging (MRI) features of the ossification of the posterior longitudinal ligament (OPLL) of the cervical spine and its relationship with the Japanese Orthopaedic Association (JOA) score.

**Materials and Methods:** From June 2017 to January 2018, 32 patients with OPLL underwent anterior controllable antedisplacement and fusion surgery were performed MRI images in our hospital. According to the sagittal morphology of the spinal cord, the transverse section of the spinal cord, the spinal cord signal, and the spinal cord compression rate were investigated. The spinal cord status was scored (spinal cord state [SCS] score: minimum, 0 points; maximum, 9 points). The continuous variable SCS score and JOA score were analyzed by Pearson correlation.

**Results:** All patients were followed up for 6 months to 1 year with an average of 9 months. There was a good correlation between preoperative and postoperative SCS scores and JOA scores (preoperative:  $r=0.778$ ,  $p=0.008$ ,  $<0.05$ ; postoperative:  $r=0.854$ ,  $p=0.002$ ,  $<0.05$ ).

**Conclusion:** The correlation between SCS and JOA scores in spinal cord status scores is statistically significant and can be used as an objective indicator for evaluating spinal cord function in patients.

## Percutaneous Full Endoscopic Posterior Cervical Laminoforaminotomy Surgery

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**Purpose:** This study was to evaluate the effect and feasibility for the treatment of cervical soft disc herniation and foraminal stenosis.

**Materials and Methods:** This study was performed from March 2009 to March 2017 prospectively. Consecutive 125 patients were enrolled in this study. Surgical indication was severe mono radicular arm pain which was resistant to conservative treatment for more than 6 week in soft disc and more than 3 month in hard disc. Operation was done in prone position with skeletal skull traction under general anesthesia. Longitudinal skin incision (1 cm) on lateral mass of lesioned disc level was followed by insertion of 7.9-mm dilator and endoscope with 4-mm working channel in turn. Laminoforaminotomy was performed by keyhole technique.

**Results:** Male was 93 cases and female was 32 cases. Mean age was 55.6 years (range, 27 to 78 years). Right side lesion were 54 cases and 71 in left side. Level of lesion was six in C4–5, 48 in C5–6, 61 in C6–7, one in C6–7–T1, and nine in C7–T1. Soft herniation was 44 cases (six paramedian and 38 foraminal). Hard disc was 55 cases. The combined disc was 26 cases. By modified Macnab criteria, results were good to excellent (96.4%) and fair (3.6%) in soft disc herniation. In hard disc herniation, results were good to excellent (86.5%), fair (2.7%), and poor (10.8%). A good to excellent outcome (100%) was noted in combined cases. Two cases were recurred (right C5–6 herniated intervertebral disc 15 months later and another one of right C6–7 foraminal stenosis 2 years later). Complication was postoperative transient C8 nerve root palsy in foraminal stenosis of C7–T1, transient C5 nerve root palsy for 3 months in right C4–5 stenosis, and persistent left arm tingling and numbness along the C7 dermatome and another one was postoperative right cerebellar artery embolic infarction in left C4–5 paramedian big soft disc herniation.

**Conclusion:** Percutaneous endoscopic posterior cervical disc surgery is effective, feasible, and good indication for treatment of paramedian, foraminal disc herniation, and foraminal stenosis with preserving mobile joints and posterior neck muscles.

## The Effectiveness of Vertebral Distraction Pin Insertion Aiming Device in Human Cadavers

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**Purpose:** Purpose is to evaluate the effectiveness of Caspar pin insertion aiming device for vertebral distraction pin insertion during anterior cervical discectomy.

**Materials and Methods:** Smith-Robinson approach and anterior cervical discectomy were performed from C3 to C7 in 10 human cadaveric specimens. Caspar pins were inserted using new designed Caspar pin insertion aiming device at levels C3–4, C4–5, C5–6, and C6–7. The different angles between cervical endplate slope and Caspar pin were measured with lateral cervical imaging.

**Results:** The average superior endplate–Caspar pin different angle (SE-CP) and the average inferior endplate–Caspar pin different angle (IE-CP) were  $5.9^\circ \pm 4.1^\circ$  and  $5.7^\circ \pm 4.3^\circ$ , respectively. In proximal pin group, the SE-CP and the IE-CP were  $4.0^\circ \pm 3.7^\circ$  and  $5.2^\circ \pm 5.0^\circ$ , respectively. In distal pin group, the SE-CP and the IE-CP were  $7.7^\circ \pm 3.7^\circ$  and  $6.2^\circ \pm 3.5^\circ$ , respectively. No cervical endplate violation had been observed.

**Conclusion:** The new designed Caspar pin insertion aiming device can control the pin entry points and pin direction with the average SE-CP ( $5.9^\circ \pm 4.1^\circ$ ) and average IE-CP ( $5.7^\circ \pm 4.3^\circ$ ), respectively. This aiming device may provide safe and effective method for Caspar pin insertion. The study shows that the average different angles between the Caspar pin and cervical endplate are less than  $6^\circ$ .

## Cervical Laminoplasty with Posterior Fixation Using Intraoperative Ultrasonographic Evaluation for Sever Ossification of the Posterior Longitudinal Ligament Cases

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**Purpose:** The posterior surgery for sever cervical ossification of the posterior longitudinal ligament (OPLL) is challenging. We routinely use the intraoperative ultrasonography (US) to evaluate spinal cord decompression. In case of detect inadequate decompression, we decide to add decompression levels cephalad and caudal. The purpose of this study was to clarify the usefulness of our treatment strategy.

**Materials and Methods:** We recruited consecutive nine cases (male, 7; female, 2; mean age, 67.3 years) with severe cervical OPLL. We firstly do laminoplasty and the posterior fixation on most severe OPLL levels. After that, we evaluate the degree of decompression of spinal cord using US to check posterior shift of the spinal cord from the OPLL. In contact type (the spinal cord always touches the OPLL), we add the posterior decompression cephalad or caudal and correction for the purpose of shifting spinal cord to posterior until determine complete decompression of US findings. In non-contact type, we finish operation.

**Results:** Average occupation ratio was 44.1% (range, 25%–63%). Three cases were over 60% occupying ratio. Of all cases, six cases were classified as contact type by intraoperative US. These cases were required additional decompression and/or correct kyphosis with instrumentation. In all cases, we confirmed finally a non-contact type under intraoperative US. Postoperative magnetic resonance imaging showed anterior subarachnoid space at all decompression levels in all cases. Japanese Orthopaedic Association score improved from 8 (range, 3.5–13.5) before surgery to 12.9 (range, 8–17) at final follow-up. The mean recovery rate was 53.5%

**Conclusion:** Generally, previous study showed poor surgical outcome after posterior decompression surgery. Our strategy with US to check adequate decompression or not intraoperatively, is simple and useful. If we find contact type at most severe level after laminoplasty, we should add

decompression levels to lead the spinal cord more posteriorly.

## Analysis of the Incompletely Hoisted Vertebrae in the Anterior Controllable Antedisplacement and Fusion Surgery: Causes and Prevention

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**Purpose:** Anterior controllable antedisplacement and fusion (ACAF) has been reported as a safe and effective technique. However, incompletely hoisted vertebrae (IV) were found in the postoperative imaging. This study aims to analyze the causes and prevention of IV.

**Materials and Methods:** The ACAF treated case series were retrospectively reviewed. Vertebrae were separated into IV group and completely hoisted vertebrae (CV) group according to the gap between vertebra and plate. The radiographic data, cervical lordosis, bone mineral density, number of hoisted vertebrae, operative time, blood loss, and Japanese Orthopaedic Association score were compared between patients with IV group and patients without IV group.

**Results:** A total of 248 vertebrae were hoisted in the enrolled patients. Intervertebral disc height in the IV group was  $3.7 \pm 0.4$  mm, which is significantly lower than that in the CV group. The anterior or posterior overhanging lip, osteoporosis, oblique osteotomy trough, and hinge existed after osteotomy were found to be impingements against hoist. There were no differences in age, sex, cervical lordosis, number of hoisted vertebrae, and neurological improvement rate between the patients with and without IV groups.

**Conclusion:** Lower intervertebral space height and impingements against hoist were found to be possible causes of IV in ACAF. Attentions should be paid to prevent the problem.

## A Feasibility Study of a New Muscle Sparing 'C3 Dome-Hybrid Open-Door Laminoplasty': A Surgical Technique, Clinical Outcome and Learning Curve Description

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**Purpose:** Traditional C3–C7 open-door laminoplasty damages the posterior cervical musculature, leading to postoperative cervical kyphotic deformity and persistent neck pain. This study reports the design and feasibility of a new hybrid laminoplasty technique aimed to reduce the complications of the conventional laminoplasty by preserving the dorsal muscles attached at either C2 or C7, with the incorporation of C3 dome-osteotomy, an open-door C4C5C6 instrumented laminoplasty, and C7 cephalad dome-osteotomy.

**Materials and Methods:** A prospective review of consecutive patients who had underwent the new C3 dome-hybrid laminoplasty technique by a single surgeon with a minimum of 2-year postoperative follow-up was studied. A detailed surgical technique was described. Clinical, radiological, and surgical outcome data were analysed.

**Results:** Twenty-five patients with cervical myelopathy had intended for the C3 dome-hybrid laminoplasty and had completed the new technique with mean follow-up 48.6 months (range, 24–101 months). A significant improvement was observed from the preoperative to postoperative Japanese Orthopaedic Association score (13 to 15,  $p<0.001$ ), Nurick grade (2.3 to 1.2,  $p<0.001$ ), Neck Disability Index (23 to 11,  $p=0.020$ ), 36-item Short-Form Health Survey (SF-36) physical component summary (40 to 46,  $p=0.037$ ), SF36 mental component summary (47 to 51,  $p=0.209$ ), and neck Visual Analog Scale (3.2 to 0.7,  $p<0.001$ ). There was no significant loss in preoperative to postoperative cervical lordosis from  $12^\circ$  to  $8^\circ$  at both 2 years ( $p=0.155$ ) and final follow-up ( $p=0.108$ ). There was significant change lost in cervical range of motion from  $38^\circ$  to  $27^\circ$  ( $p=0.042$ ) at 2 years and to  $28^\circ$  ( $p=0.024$ ) at final follow-up. The range of preoperative motion preserved was 81% at 2 years and 78% at final follow-up. At the final follow-up, none of the postoperative patients had revision of index surgery, spinal infection, C5 palsy, symptomatic cervical kyphosis, or persistent axial neck pain.

**Conclusion:** The new 'C3 dome-hybrid laminoplasty' with

C3 dome-osteotomy, C4C5C6 open-door laminoplasty, and proximal C7 partial laminectomy or C7 cephalad dome-osteotomy is safe, feasible, and reproducible with good clinical outcomes.

## Percutaneous Transforaminal Endoscopic Surgery for Symptomatic Lumbar Disc Herniation

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**Purpose:** We designed an easy posterolateral transforaminal endoscopic decompression technique, termed percutaneous transforaminal endoscopic surgery (PTES), for lumbar disc herniation. The purpose of study is to describe the technique of PTES and evaluate the efficacy and safety for treatment of lumbar disc herniation including primary herniation, reherniation, intracanal herniation, and extracanal herniation.

**Materials and Methods:** We found that the entrance point for PTES was located at the corner of flat back turning to lateral side, which has never been mentioned by other scholars, and we named this entrance point after 'Gu's point.' In PTES, press-down enlargement of foramen could make it easy to advance the working cannula into the spine canal and to remove the fragments underneath the nerve root and the central dura, even the contralateral nerve root. PTES was performed to treat 328 cases of 1-level intracanal or extracanal herniations with or without extruding or sequestered fragment, high iliac crest, scoliosis, or calcification.

**Results:** The mean frequency of intraoperative fluoroscopy was 5 times (range, 3–14 times) per level. The patients were followed for an average of  $27.4\pm 3.2$  months. The Visual Analog Scale score of leg pain significantly dropped from 9 (range, 6–10) before operation to 1 (range, 0–3) immediately after surgery ( $p<0.001$ ) and to 0 (range, 0–3) 2 years after surgery ( $p<0.001$ ). At 2-year follow-up, 97.0% (318/328) of the patients showed excellent or good outcomes, 1.8% (6/328) fair, and 1.2% (4/328) poor. No patients had any form of permanent iatrogenic nerve damage and a major complication, although there were one case of infection and two cases of recurrence.

**Conclusion:** PTES for lumbar disc herniation is an effective and safe method with simple orientation, easy punc-

ture, reduced steps, and little X-ray exposure, which can be applied in almost all kinds of lumbar disc herniation, including L5/S1 level with high iliac crest, recurrent herniation, and adjacent disc herniation after decompression and fusion.

## Outcome of Decompression at Late Corda Equina Syndrome

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**Purpose:** To find the clinical outcome of decompression of cauda equina syndrome (CES) presenting late in the course of disease.

**Materials and Methods:** In a retrospective study, time interval between bladder and bowel dysfunction, saddle anaesthesia, and admission to hospital varied from 2 to 24 days. All patients underwent magnetic resonance imaging scanning prior to surgery. A single center experience study was approved by ethical committee. Study period is 2016–2017 and 14 cases were reviewed. The average follow-up was 21.6 months (range, 10 to 34 months).

**Results:** In 2015, total spine operations were performed in 166 patients and 14/166 patients (8.4%) were operated for CES. Motor recovery: almost all patients showed improvement of motor function at medium of 12 weeks. Return of bladder function was seen at medium of 14 weeks (range, 12 to 34 weeks). Sensory recovery is most delay symptom and still complaints up to 1 year. Sexual function is difficult to express due to cultural issue in the study country. Total recovery is 3 (10.3%), near total recovery is 2 (6.98%), and partial recovery is 24 (82.7%) in follow-up duration.

**Conclusion:** The result of surgery in CES is not as dramatic and fast as seen after routine disc surgery. Some improvement can be expected with decompression even in those patients presenting late results are not universally poor. The recovery in these patients can take an exceptionally long time and hence should involve in constant reassurance and rehabilitation of the patient.

## Impact of Psoas Muscle Position Relative to Lumbar Spine for Spinopelvic Alignment

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**Purpose:** The purpose of this study was to investigate the impact of psoas muscle position relative to lumbar for spinopelvic alignment.

**Materials and Methods:** Patients with adult spinal deformity (ASD) who underwent corrective surgery (ASD group) and degenerative lumbar disease who underwent short lumbar decompression and fusion (Deg group) were examined in this study. The measured radiographic spinopelvic parameters were sagittal vertical axis (SVA), pelvic tilt (PT), and pelvic incidence minus lumbar lordosis (PI-LL) in whole spine standing radiograph before surgery. We measured distance between center of disc and line connecting the center points of left and right of psoas major muscle in each lumbar intervertebral disc level on magnetic resonance imaging before surgery (L-P distance). We analyzed the comparison for each parameter between two groups and relationship between spinopelvic parameters and psoas muscle position relative to lumbar spine.

**Results:** One hundred and fifty-five patients, 68 in ASD groups and 47 in Deg groups, met the inclusion criteria. There was no significant difference between two groups (68.6 vs. 69.6 years). The spinopelvic parameters in ASD group had significant worse than in Deg group (141 mm vs. 51 mm in SVA, 43.7° vs. 12.5° in PI-LL, and 34.3° vs. 22.4° in PT). L-P distance in ASD group and Deg group were -10.8 mm vs. -11.6 mm in L1/2, -6.1 mm vs. -8.4 mm in L2/3, 1.7 mm vs. -5.5 mm in L3/4, 4.7 mm vs. 3.2 mm in L4/5, and 18.7 mm vs. 21.2 mm in L5/S1. L-P distance in L2/3 and L3/4 in ASD group were significant larger than in Deg group. L-P distance in L3/4 had most significant correlation with SVA, PI-LL, and PT ( $r=0.63$ ,  $0.52$ , and  $0.36$ ).

**Conclusion:** In sagittal malalignment cases, psoas major muscle shifted anterior relative to lumbar spine significantly at L2/3 and L3/4 level. This result suggested that psoas major performed as flexor of trunk at L2/3/4 and related to sagittal malalignment.

## Lumbar Spinal Stenosis Decompression with Spine Endoscopic Surgery: Preliminary Experiences of Large Caliber Spine Endoscope and Accessory Portals

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**Purpose:** Decompression surgery for lumbar spinal stenosis can be done with spine endoscopic surgery non-inferiorly than open or tubular surgery in terms of results and complications; however, the speed of endoscopic surgery are only comparable to open or tubular surgery on the hands of few masters. This article is to report the preliminary experiences of near en bloc flavectomy by large caliber spine endoscope and accessory portals intended to increase the speed of the surgery.

**Materials and Methods:** This is a retrospective case series done by a single surgeon between October 2018 and March 2019. Visual Analog Scale (VAS), Oswestry Disability Index (ODI), and EuroQol-5D (EQ-5D) were used as evaluation tools and the follow-up periods were up to 6 months. Large caliber spine endoscope was defined as percutaneous endoscopic lumbar discectomy scope with outer diameter of 1 cm and working channel of 7.1 mm. Accessory portals were created 2-cm caudal to the main portal and was used as outflow portal and passing channel of open instruments such as Kerrison punch and disc clamp when needed. Endoscopic high speed burr was used with 12,000–20,000 rpm. Irrigation pump was set and adjusted according to bleeding condition and connected pipe theory. Flavectomy was done by removing the bony attachment site of yellow ligaments with endoscopic high speed burr in 360-degree-fashion.

**Results:** Six consecutive lumbar stenotic cases were enrolled. Average age was around 60s. Average admission days were around 4 days. Average operation time was less than 3 hours. Average blood lost was minimal. VAS, ODI, and EQ-5D greatly improved. No severe consequences were noted. Surgical results according to modified MacNab criteria was good to excellent.

**Conclusion:** Lumbar spinal stenosis decompression with spine endoscopic surgery could be a relatively faster technique with large caliber spine endoscope. Accessory portal could provide an outflow portal to enhance visual field and as a pathway for larger instruments.

## The Influence of Developmental Spinal Stenosis on Reoperation Risk at the Adjacent Segment after Decompression Surgery for Lumbar Spinal Stenosis

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**Purpose:** Developmental spinal stenosis (DSS) is manifested as pre-existing narrowing of the bony spinal canal and may run risk of multi-level stenosis and need for reoperation after decompression surgery. Reoperation at the adjacent level may be attributed to adjacent level degeneration but the influence of DSS on reoperation rate is unknown. The aim of study is to determine the effects of DSS on reoperation rates at the adjacent level after decompression surgery for lumbar spinal stenosis.

**Materials and Methods:** Consecutive patients with decompression-only surgery for lumbar spinal stenosis and minimum 5-year follow-up were recruited. Adult deformities, previous spinal surgery, and spondylolisthesis were excluded. Presented symptoms and levels operated on initially and at reoperation were studied. Magnetic resonance imaging measurements included the anteroposterior bony spinal canal diameter, degree of disc degeneration (disc intensity, herniations, disc height), and ligamentum flavum thickness. DSS was defined by respective bony spinal canal diameter measurements. Risk factors for reoperation at the adjacent level were determined and included into a multivariate stepwise logistic regression for prediction modeling. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated.

**Results:** A total of 235 subjects were analyzed and 21.7% required reoperation at adjacent segments. The mean duration of follow-up was  $10.1 \pm 4.8$  years since the index surgery. Gender and disc degeneration parameters were not factors contributing to reoperation. Reoperation at the adjacent segment was associated with DSS ( $p=0.026$ ), the number of operated levels ( $p=0.008$ ), and age at surgery ( $p=0.013$ ). Multivariate regression model ( $p<0.001$ ) controlled for other confounders showed that DSS was a significant predictor of reoperation at an adjacent segment, with an adjusted OR of 3.93 (95% CI, 1.10 to 14.01;  $p=0.035$ ).

**Conclusion:** Adjacent nonoperated DSS levels are 3.9 times more likely of undergoing future surgery. This is a

poor prognostic marker that can be identified during the index surgery.

## Sagittal Alignment and the Functional Scores after Long Thoracolumbar Instrumented Fusion

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**Purpose:** Restoring better sagittal alignment is known as a key factor to spine fusion surgeries. This study is aimed to investigate the correlation between the sagittal spinopelvic alignment and the functional outcomes after long instrumented fusion for degenerative thoracolumbar spine disease.

**Materials and Methods:** Between 2009 and 2013, data of 120 patients with multilevel degenerative lumbar and thoracolumbar spinal stenosis who underwent long instrumented fusion were collected retrospectively. Perioperative radiographic and functional parameters were measured and analyzed for their correlations.

**Results:** Oswestry Disability Index  $\geq 20$  or Visual Analog Scale  $\geq 4$  were defined as poor functional outcomes. The optimal cutoff points of the radiographic parameters were found as below: the mismatch between pelvic incidence and lumbar lordosis was  $16.2^\circ$ , sagittal vertical axis was 38.5 mm, and pelvic tilt was  $23.4^\circ$ . Poor functional outcomes were significantly correlated with bad sagittal alignment, older age, and poor preoperative function.

**Conclusion:** Functional outcomes were highly impacted by postoperative sagittal alignment in addition to preoperative functional status.

## Risk Factors for Pseudarthrosis at L5–S1 after Lumbosacral Transforaminal Lumbar Interbody Fusion Surgery

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**Purpose:** Pseudarthrosis occurs most commonly at L5–S1 after spinal fusion surgery. Interbody fusion can be performed to reduce the rate of pseudarthrosis. With

transforaminal lumbar interbody fusion (TLIF), however, pseudarthrosis is still found. The purpose of this study is to investigate the incidence and risk factors of pseudarthrosis at L5–S1 after TLIF.

**Materials and Methods:** Ninety-nine patients (34 males and 65 females), who underwent lumbosacral TLIF fusion with pedicle screws with a minimum 2-year follow-up, were included in this study. Mean age was 59.6 years old. Pseudarthrosis was diagnosed by combination of findings on dynamic radiography, plain radiography, and computed tomography. Clinical parameters such as underlying medical disease, smoking history, drug administration, and radiological parameters such as bone mineral density (BMD), sagittal vertical axis (SVA), pelvic incidence, and lumbar lordosis were evaluated as risk factors.

**Results:** Of 99 patients, pseudarthrosis was found in 20 patients. The average number of fused level was 4.25 segment versus 2.2 segment in the pseudarthrosis group and union group, respectively, which was significantly different ( $p=0.0001$ ). Thirteen of 18 patients with long segment fusion more than four segment had pseudarthrosis. The T-score in BMD test was -1.7 in the pseudarthrosis group and -1.4 in the union group ( $p=0.464$ ). Pseudarthrosis group showed higher SVA (51.2 mm vs. 32.2,  $p=0.175$ ), and lower lumbar lordosis ( $28.1^\circ$  vs.  $33.7^\circ$ ,  $p=0.123$ ), higher pelvic tilt ( $25.6^\circ$  vs.  $17.8^\circ$ ,  $p=0.009$ ), lower sacral slope ( $23.2^\circ$  vs.  $32.7^\circ$ ,  $p<0.001$ ).

**Conclusion:** The overall incidence of pseudarthrosis at L5–S1 after lumbosacral TLIF surgery was 20%. Pseudarthrosis was likely to be developed in the patients with long segment fusion. Although they were not statistically significant, sagittal imbalance and lower lumbar lordosis had the tendency to increase pseudarthrosis.

## Age Stratified Sagittal Radiological Parameters in Asian Lumbar Spinal Deformity Patients

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**Purpose:** Recent studies have shown that normal sagittal parameters in adult spinal deformity (ASD) patients varies with different age groups. While most of these data were identified in Caucasian patients, few have confirmed

such changes in the Asian population. Our study aims to investigate whether changes in this age-dependent sagittal parameters hold true in the Asian ASD patients.

**Materials and Methods:** A retrospective review of patients with ASD at a university hospital was performed. The radiological parameters and clinical outcome scores of the patients were captured. Sagittal radiographic data were analysed in age-stratified patients at group A (55–64 years old), group B (65–74 years), and group C ( $\geq 75$  years) using SPSS software.

**Results:** A total of 147 patients of which 86% were female with an average age of  $68 \pm 8$  years were identified. There was a significant increase in sagittal parameter values found from group A to group C patients. These included: lumbar lordosis (LL; A:  $42 \pm 15$ ; B:  $32 \pm 26$ ; C:  $29 \pm 25$ ;  $p=0.013$ ), thoracic kyphosis (TK; A:  $21 \pm 13$ ; B:  $23 \pm 17$ ; C:  $30 \pm 16$ ;  $p=0.034$ ), sagittal vertical axis (A:  $3 \pm 4$ ; B:  $4 \pm 3$ ; C:  $7 \pm 6$ ;  $p=0.000$ ), T1 pelvic angle (A:  $23 \pm 10$ ; B:  $24 \pm 11$ ; C:  $31 \pm 12$ ;  $p=0.001$ ), global tilt (A:  $28 \pm 12$ ; B:  $30 \pm 12$ ; C:  $38 \pm 13$ ;  $p=0.001$ ), T1 slope (A:  $18 \pm 8$ ; B:  $21 \pm 9$ ; C:  $25 \pm 11$ ;  $p=0.003$ ), and LL–TK (A:  $21 \pm 16$ ; B:  $15 \pm 16$ ; C:  $5 \pm 15$ ;  $p=0.000$ ). Although there was no statistical significance, a trend towards increasing radiological sagittal parameter values in older patients were found in pelvic incidence–LL (A:  $16 \pm 16$ ; B:  $17 \pm 19$ ; C:  $21 \pm 17$ ;  $p=0.361$ ), together with Cobb angle, cervical lordosis, pelvic tilt, and thoracolumbar angle. Sub-group analysis of Oswestry Disability Index, Scoliosis Research Society-22, 36-item Short-Form Health Survey (SF36) physical component summary, and SF36 mental component summary showed no statistical changes across group A to group C.

**Conclusion:** A significant increase in radiological sagittal parameter values were noted as patient ages. However, comparing our data to the published normality value, the Asian patients have different values when compared to the Caucasian patients. Following this newly found Asian normality value instead of the Caucasian data may be important in the treatment for Asian patients with ASD.

## Not All the Patients with Pseudoarthrosis Following Pedicle Subtraction Osteotomy Require Revision Surgery

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**Purpose:** There is little data regarding the non-operative management of possible pseudarthrosis after pedicle subtraction osteotomy (PSO). The purpose of this study was to report radiographic and clinical outcomes at a minimum of 5 years after detection for non-operative management and to analyze the characteristics of possible pseudarthrosis after PSO.

**Materials and Methods:** Nineteen consecutive patients with implant breakage indicating probable pseudarthrosis after PSO surgery (13 women, 6 men; average age at surgery, 58 years) without severe pain and disability treated with non-operative management at one institution were identified (average follow-up, 5.8 years; range, 5–10 years). Non-operative management includes medication, intermittent brace wearing, and avoidance of excessive back strain. Radiographic and clinical outcomes analysis was performed.

**Results:** Sagittal vertical axis (SVA,  $p=0.608$ ), proximal junctional angle ( $p=0.388$ ), and thoracic kyphosis ( $p=0.771$ ) achieved by a PSO were maintained after detection of pseudarthrosis through ultimate follow-up. Lumbar lordosis ( $p=0.042$ ) and PSO angle ( $p=0.046$ ) decreased at final follow-up. There was no significant change in Oswestry Disability Index (ODI) scores (36 vs. 40.3,  $p=0.103$ ) and Scoliosis Research Society (SRS) total score (67.4 vs. 62.9,  $p=0.104$ ), or subscales of pain (2.9 vs. 2.7,  $p=0.061$ ), self-image (3.3 vs. 3.0,  $p=0.190$ ), function (3.0 vs. 2.8,  $p=0.053$ ), satisfaction (3.9 vs. 3.8,  $p=0.604$ ), and mental health (3.7 vs. 3.6,  $p=0.272$ ) between detection of pseudarthrosis and ultimate follow-up. SVA greater than 11 cm showed poorer ODI and SRS total score, as well as the pain, self-image, and function subscales ( $p<0.05$ ).

**Conclusion:** Non-operative management of possible pseudarthrosis after PSO offers acceptable outcomes even

at 5 years after detection of implant breakage, provided SVA is maintained. As SVA increased, outcome scores decreased.

## How Many Screws Are Necessary to Be Considered an Experienced Surgeon for Freehand Placement of Thoracolumbar Pedicle Screws?: Analysis of the Learning Curve Using the Cumulative Summation Test for Learning Curve

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**Purpose:** To determine the amount of screws needed to achieve an adequate skill level for pedicle screw placement (PSP) via the freehand technique in the non-deformed thoracolumbar spine using the cumulative summation for learning curve (LC-CUSUM) analysis.

**Materials and Methods:** This study includes the first 85 patients who underwent pedicle screw installation in thoracic and lumbar spine by a single orthopedic surgeon. The surgeon had 1-year experience of fellowship training in the tertiary teaching hospital. The learning curve of freehand PSP was investigated using LC-CUSUM analysis. Procedure success was defined as an acceptable accuracy of pedicle screw, which is divided into two groups (group 1: the screw breaches the pedicle's cortex by less than 2 mm, group 2: the screw is completely within the pedicle).

**Results:** Total 52 cases and 313 pedicle screws were included and analyzed in this study. The LC-CUSUM signaled competency for freehand PSP at the 115th pedicle screw (17th case) in group 1 and at the 312th pedicle screw (52nd case) in group 2. This means that a trainee with no experience with freehand PSP reached adequate accuracy level of pedicle screw with less than 2-mm pedicle breaches at 115th screw, and with completely within the pedicle at 312th screw. There were no major complications, such as neurovascular injury, and life-threatening

complications.

**Conclusion:** In this study, the learning curve analysis demonstrated that a substantial learning period may be necessary before an adequate level of performance is achieved for freehand PSP in the non-deformed thoracolumbar spine.

## Diagnostic Accuracy and Safety of Fluoroscopic versus Computerized Tomography-Guided Percutaneous Transpedicular Core Needle Biopsy for Spinal Infections and Tumours: A Prospective Randomized Trial

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**Purpose:** Early accurate diagnosis of spinal infections and metastasis reduces morbidity and mortality and is more cost effective. It requires collection of biopsy specimens for histopathological examinations (HPE) and culture of infective organisms. This study evaluated diagnostic accuracy and safety of fluoroscopic and computed tomography (CT)-guided transpedicular biopsy techniques.

**Materials and Methods:** A prospective randomized trial was performed in 60 patients divided into fluoroscopic and CT-guided spinal biopsy groups. Transpedicular approach was done with 8G core biopsy needle. Diagnosis were made based on biopsy results, clinical criteria, and disease progression during 6-month follow-up. Clinical criteria include risk factor, inflammatory markers, and magnetic resonance imaging findings. Biopsy samples collected were sent for staining, cultures, tuberculosis polymerase chain reaction, and HPE. Radiation exposure to patients and doctors were measured with optically stimulated luminescence dosimeters. Complications developed were documented. Pre- and post-biopsy pain were assessed with Visual Analog Scale.

**Results:** There was no significant difference between the diagnostic accuracy of both fluoroscopic and CT-guided spinal biopsy ( $p=0.67$ ) and between diagnostic accuracy of spinal infection and spinal tumor in both groups ( $p=0.402$  for fluoroscopy group and  $p=0.223$  for CT group). Radiation dose exposed to patients and doctors was approximately 26 times and 2 times higher in CT group, respectively, without lead protection. Lead shield significantly

reduced the radiation exposure of doctors approximately 2 to 8 times. No complications were observed for both groups and the differences in post biopsy pain scores were insignificant.

**Conclusion:** The accuracy rate, operative time, complication rate, and pain score for both fluoroscopic and CT-guided guided spinal biopsy were similar. However, radiation dose exposed to patients and doctors were significantly higher in CT group without lead protection. With lead protection, radiation exposed to doctors reduced significantly.

## Effect of Thoracic and Pelvic Anteroposterior Diameters on Spinal Sagittal Alignment

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**Purpose:** This study aimed to analyze the effect of the thoracic anteroposterior diameter (TAPD) and pelvic anteroposterior diameter (PAPD) on global sagittal alignment in asymptomatic patients with normal sagittal alignment.

**Materials and Methods:** The study investigated 2,042 adult patients who visited our hospital with a hip and knee problem without history of symptoms related to the entire spine. Only 57 patients with normal global sagittal alignment (C2–7 sagittal vertical axis [SVA] and C7–S1 SVA of <10 mm) were considered. Whole-spine standing lateral radiographs were obtained to analyze the following parameters: pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), thoracic inlet angle (TIA), T1 slope, cervical spinal parameters (angle of C0–2, C2–7, and C0–7), TAPD, and PAPD. Statistical analysis was performed using the Pearson correlation coefficients and multiple regression analyses.

**Results:** All the parameters showed a normal distribution. TAPD had a significant relationship with TK ( $r=0.458$ ), TIA ( $r=0.677$ ), and C0–2 angle ( $r=0.294$ ) but no significant relationship with T1 slope and other cervical parameters. PAPD had a significant relationship with PI ( $r=0.309$ ) and PT ( $r=0.463$ ) but no significant relationship with LL, SS, and TK. The multiple regression analysis showed that  $TIA=21.974+0.405(TK)+0.188(TAPD)$  ( $p<0.0001$ ).

**Conclusion:** The TAPD and PAPD were associated with the TIA, TK, C0–2 angle, PI, and PT. However, there was no direct correlation with the other cervical parameters,

T1 slope, and LL. The TAPD and PAPD might have indirect effects on cervical and lumbar spinal sagittal alignment.

## Incidence and Complications in Acute Spinal Cord Injury

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**Purpose:** Acute spinal cord injury (ASCI) is a catastrophic event with considerable social and economic consequences. It is necessary to quantify the incidence and complications for identify social impact of ASCI. However, incidence and complications of ASCI in South Korea has not investigated yet. Methylprednisolone is still used worldwide to treat ASCI although it has conflicting results. We aimed to evaluate the incidence, complications, and current status of methylprednisolone therapy for ASCI in South Korea.

**Materials and Methods:** We reviewed the national database of the Korean Health Insurance Review and Assessment Service between 2007 and 2017. To identify patients with ASCI and use of methylprednisolone, the International Classification of Disease, 10th revision codes, medical behavior codes, and examination codes were used. We grouped the patients according to the methylprednisolone therapy received (MP group vs. none-MP group).

**Results:** Incidence was peak between 51–60 years of age for males and 71–80 years of age for females. The male-to-female ratio was 3.4:1. Between 2007–2017, the average incidence per 1,000,000 persons per year was 26.4. Methylprednisolone prescription rate was highest in 2012 (75.7%) and continued to decrease thereafter, lowest in 2017 (40.7%). MP group represented an increase in pneumonia (odds ratio [OR], 1.8; 95% confidence interval [CI], 1.62–2.0), gastrointestinal bleeding (OR, 2.27; 95% CI, 2.22–2.32), and urinary tract infection (OR, 1.68; 95% CI, 1.53–1.84). There were no differences between both groups in wound infection (OR, 0.98; 95% CI, 0.77–1.25). The average length of hospitalization was longer in patients with use of methylprednisolone (26.5 days vs. 24.4 days,  $p<0.05$ ).

**Conclusion:** The average incidence of ASCI for 11 years was 26.4 per 1,000,000 persons per year in South Korea.

The use of methylprednisolone for patients with ASCI is associated with increased risk of complications. The prescriptions of methylprednisolone for ASCI are decreasing in South Korea.

## Predictability of 1-Year Curve Progression in Adolescent Idiopathic Scoliosis Using the Distal Radius and Ulna Classification

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**Purpose:** Determining a child's remaining skeletal growth is crucial for the management of adolescent idiopathic scoliosis (AIS). The distal radius and ulna (DRU) classification for assessment of skeletal maturity has been shown to be superior to conventional methods. However, the observation interval and the timing of treatment intervention using this classification have not yet been determined. This study aimed to investigate whether DRU classification can be a scoliotic progression predictor within one year after observation.

**Materials and Methods:** We reviewed the medical records of 161 patients of AIS who visited our scoliosis outpatient between January 2009 and August 2018, and searched for DRU classification and Cobb angle of main curve. Patients who were treated by brace during the survey period were excluded. In addition, patients with bone maturation according to the DRU classification were excluded, that is, it simultaneously recognized radius grade 11 (R11) and ulna grade 9 (U9). Scoliosis progression was defined as exacerbation of Cobb angle by 6° or more within one year from DRU classification judgment. The relationship between DRU classification and scoliosis progression was determined using statistical study.

**Results:** The final study comprised 66 patients with 71 DRU classification. Both R and U grade showed a significant relationship with the scoliosis progression (R:  $p=0.001$ , U:  $p=0.002$ ), and the grade significantly related to the risk of scoliosis progression was R7 and U6. Scoliosis progression rate within one year and median exacerbation of Cobb angle were as follows: R7: 63.6%, 6°; U6: 52.2%, 6°.

**Conclusion:** DRU classification is a convenient and practi-

cal bone maturity evaluation, and there is a possibility that patients with progressive scoliosis can be found at an early stage. Especially in R7 and U6, there is a possibility that scoliosis may progress in a short period of time, and it is necessary to follow up carefully.

## Changes in Sagittal Alignment in Upslope or Downslope: An Insight into Dynamic Spinal Stenosis Symptomatology

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**Purpose:** Classical textbook description of symptomatic spinal stenosis is worsened symptoms while walking on a downslope and improved in upslope posture as a result of respective extension and flexion movements of the lumbar spine with resultant reduction and relative increased spinal canal diameter. However, these dynamic changes and resulting changes in sagittal alignment have not been studied. The aim of study is to analyze the changes in sagittal alignment with downslope and upslope positions to better understand the dynamic changes in the spine related to lumbar spinal stenosis.

**Materials and Methods:** Ten asymptomatic young adults without back pain, spinal disease, or surgery were recruited. Whole body biplanar images were obtained at level ground standing, standing on 20° downslope and 20° upslope using an adjustable slant board. Sagittal parameters included spinopelvic parameters (lumbar lordosis [L1–S1], thoracic kyphosis [T5–12], pelvic tilt, sacral slope, pelvic incidence), lower limb parameters (posterior pelvic shift, knee flexion angle), and global balance parameters (sagittal vertical axis, C2-hip axis) were measured and evaluated.

**Results:** The lumbar alignment did not have significant changes in both downslope and upslope settings. Main compensatory changes occurred in the lower lumbar segments at L5/S1. and L5/S1 The balancing mechanism in downslope setting were different in each individual but the net outcome was to maintain a balanced spine with little change in global alignment. The balancing mechanism in upslope setting favors translation of global alignment forward as evident by increased C2-hip axis angle, sagittal vertical axis, C2–C7 sagittal vertical axis, and sacral slope,

along with decreased thoracic kyphosis.

**Conclusion:** This study suggests that overall balance and posture, especially lumbar lordosis, do not change with different postures. Spinal canal diameters at lower levels may be affected more by dynamic postures than upper levels suggesting that slope-walking mainly affects symptoms relevant to lower lumbar compression.

## Comparison of Percutaneous Vertebroplasty and Bracing for Osteoporotic Vertebral Compression Fractures: The Analysis of Bridging Callus Formation and Sagittal Alignment

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**Purpose:** Bone-healing capability and alignment restoration after percutaneous vertebroplasty (VP) are not completely understood. Hence, this study aimed to evaluate callus formation, vertebral height restoration, and sagittal alignment after VP.

**Materials and Methods:** Two hundred and fourteen cases of VPs (48 males, 166 females) for osteoporotic vertebral compression fractures (OVCF) in National Cheng Kung University Hospital between 2013 and 2016 were reviewed and compared with those treated with brace (n=55). Single level OVCFs without previous operation on the target or adjacent vertebrae were included. Age, gender, and bone mineral density were recorded. Preoperative and postoperative radiographs were reviewed.

**Results:** The mean age was 74.98 years old and average T-score was -2.88. Bridging callus formation was identified in 14% 26%, 33%, and 37% of patients within the postoperative 6, 12, 24, and 36 months, respectively. The anterior and middle compression ratio before and after VP for 6 months were preoperative (46.98%, 54.16%); immediate postoperative (36.8%, 44.54%); postoperative 6 months (44.18%, 49.81%). Wedge angles (°) before and after VP for 12 months were preoperative 16.14; immediate postoperative 11.94; postoperative 6 months 13.99; postoperative 12 months 13.88. Bridging callus formation was not correlated with vertebral height or wedge angle

restoration. The thoracic kyphotic and lumbar lordotic angles had no significant difference before and after VP. In comparison with brace group, VP group had significant older age and more vacuum signs. The preoperative anterior and middle compression ratios in VP group were significantly higher than those of brace group. Wedge angle correction was similar in both groups.

**Conclusion:** The current results revealed that about 40 percent of bridging callus can be identified after VP for OVCF within postoperative 3 years, yet this was not related to height or wedge angle restoration. The vertebral height restoration and wedge angles improved postoperatively, but deteriorated gradually. In comparison to brace group, older age, the presence of vacuum sign and greater compression ratio were identified.

## The Characteristic of Radiological Findings for Revision Surgery after Balloon Kyphoplasty

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**Purpose:** To investigate the risk factors for the failure after balloon kyphoplasty (BKP).

**Materials and Methods:** This is a case-control study including 13 patients who needed revision surgery after BKP and 105 patients who underwent BKP. We evaluated the characteristics of radiological findings for revision cases to reveal risk factors. The type of fracture was classified using AO Classification using computed tomography scan. However, since no commonly accepted classification for osteoporotic vertebral fractures exists, we evaluated each fracture condition. Plain X-rays were assessed based on lateral views between the flexion and extension positions before surgery.

**Results:** Regarding baseline characteristics between patients with and without revision surgery after BKP, the mean age was not different between both groups. More males were observed in revision group. Angular motion between flexion and extension position was significantly greater in revision group than BKP group (14.7° vs. 8.6°,  $p=0.001$ ). Wedged angle of vertebral body was similar be-

fore BKP (20.1° vs. 17.6°,  $p=0.264$ ), but the angle after surgery was significantly less in revision group (5.1° vs. 12.2°,  $p<0.001$ ). Diffuse idiopathic skeletal hyperostosis (DISH) was more frequently observed in revision group, but the difference was not statistically significant ( $p=0.093$ ). Posterior element injury, pedicle fracture, and posterior wall injury were not different between the both groups. Split type fracture (AO type 2) was more frequently observed in revision group (23% vs. 2%,  $p=0.009$ ). The odds ratios (ORs) for revision surgery were shown in Table. ORs were adjusted for age, sex, angular motion  $\geq 14^\circ$ , DISH, endplate deficit, and split type fracture. Split type of fracture showed highest OR. Angular motion  $\geq 14^\circ$  increased 6-fold risk for revision surgery.

**Conclusion:** Split type fracture, greater angular motion ( $\geq 14^\circ$ ) and large endplate deficit were risk factors for revision surgery after BKP.

### Intra-operative Neuromonitoring for Spine Surgery in Pregnancy: A Case Report

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**Purpose:** Intra-operative neuromonitoring plays a role of paramount importance in detecting iatrogenic spinal cord and nerve root injury in spine surgery. However, not much is known about its use in pregnancy, especially with regard to its safety as well as effect of pregnancy on monitoring signal.

**Materials and Methods:** A 37-year-old lady at 18 weeks of pregnancy who presented to us with thoracic back pain. She had incomplete neurological deficit of lower limbs (power Medical Research Council [MRC] grade 3–4) and reduced sensation from T5 and below. Her magnetic resonance imaging showed T2 vertebral plana with spinal cord compression. With patient's agreement, circumferential decompression and stabilization of C7–T4 were done with transcranial motor evoked potentials (TcMEP) neuromonitoring. Baseline signal was only recordable from the right lower limb, while there was no lower limbs signal detected immediately post-instrumentation. However, postoperatively there was no worsening of neurology and no induction of labor.

**Results:** One of the main concerns of using intra-operative neuromonitoring in pregnancy is inadvertent induction of labor via stimulated uterine myometrial contraction by TcMEP. Another risk for induction of labor is via hormonal cascade activation. Reports by Ingram and Stock have shown a rise in plasma levels of oxytocin in rat models with electrical stimulus to the forebrain, vagal, and sciatic nerves. Cardiotocography (CTG) can monitor fetal and myometrial activity greater than 20-week pregnancy. However, it's not applicable in our patient. We have limited its frequency and stimulus intensity to minimise its side effects. Lee and his colleagues have concluded successful rate of intra-operative TcMEP captured in MRC 3 and 4 are 28.6% and 72.3%, respectively. This may explain failure of TcMEP record in our case.

**Conclusion:** As our experience, intra-operative TcMEP is safe in this 18-week pregnant lady spinal surgery and have not induce labor.

### Spontaneous Spinal Epidural Hematoma due to Clopidogrel: A Case Study and Review of Literature

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**Purpose:** Spontaneous spinal epidural hematoma (SSEH) associated with anti-platelet drugs is rarely seen and there are less than 10 cases of clopidogrel induced SSEH being reported in the literature. We hereby report two cases of clopidogrel-induced SSEH and discuss what literature has to say on anticoagulant-induced SSEH.

**Materials and Methods:** We report two cases of SSEH who were on clopidogrel and presented with sudden onset paraplegia preceded by severe back pain. Magnetic resonance imaging was done which revealed a space occupying lesion suggestive of an epidural hematoma. Emergent decompressive laminectomy was done within 8 hours of the presentation with excellent clinical outcome.

**Results:** Both patients underwent emergent decompressive laminectomy and evacuation of the extradural space occupying lesion, which was later histologically proven to be a hematoma. After surgery, there was a significant sensory recovery, and 1 week after surgery, patients' weakness

improved and both the patients could walk without any assistance.

**Conclusion:** SSEH is a rare neurosurgical emergency and with the growing trend of anti-platelet prescriptions for prophylactic use, and clinicians should be aware of this serious complication. Correct diagnosis and urgent decompressive surgery with evacuation of the hematoma is imperative for successful recovery if severe neurological deterioration is present.

### A Prospective Randomized Trial Comparing Radiation Exposure of Fluoroscopic versus Computerized Tomography-Guided Percutaneous Transpedicular Core Needle Spinal Biopsy

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**Purpose:** This study evaluated radiation exposure of fluoroscopic and computerized tomography (CT)-guided transpedicular biopsy to patients and different body parts of the doctors with and without lead shield.

**Materials and Methods:** A prospective randomized trial was performed in 60 patients divided into fluoroscopic and CT-guided spinal biopsy groups. Transpedicular approach was done with 8G core biopsy needle. Demographic data, biopsy level, spinal diagnosis, and diagnostic accuracy were evaluated. For doctors, optically stimulated luminescence dosimeters (OSLDs) were placed at glabella, neck (thyroid cartilage level), chest (sternomanubrial joint level), pelvis (symphysis pubis level), and both hands. Radiations measured represent radiation exposure to lens, thyroid gland, breasts, gonads, and hands, respectively. OSLDs were placed inside and outside of lead shields. For patients, dosimeters were placed 15 cm away from biopsy level along spinal axis.

**Results:** There was no significant difference between the demographic data, biopsy level, spinal pathology, and diagnostic accuracy of both methods. Radiation dose exposed to patients and doctors was approximately 26 times and 2 times higher in CT group, respectively, compared to fluoroscopy group without lead protection. Lead shield significantly reduced the radiation exposure of doctors to

approximately 2 to 8 times. Without lead shield, area with the highest radiation exposure was non-dominant hand for CT group and pelvis (gonads) for fluoroscopic group. With lead protection, the area with the lowest radiation exposure was neck (thyroid gland) for both groups.

**Conclusion:** Radiation to both patients and doctors were significantly higher in CT group. With the use of lead shields, radiation to doctors was reduced significantly. However, average radiation dosages for both methods were well within recommended dose stated in International Commission on Radiological Protection statement on tissue reaction in 2011.

### The Validation of Ultrasound-Guided Target Segment Identification in Thoracic Spine as Confirmed by Fluoroscopy

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**Purpose:** The aim of this study was to make a comparison between the 12th rib and the spinous process of C7 as a landmark for effective ultrasound-guided target segment identification in the thoracic spine.

**Materials and Methods:** Ultrasonography of 44 thoracic spines was performed and the same procedure was carried out 1 week later again. The target segments (T3–4, T7–8, and T10–11) were identified using the 12th rib (group 1) or the spinous process of C7 (group 2) as a starting landmark. Ultrasound scanning was done proximally (group 1) or distally (group 2) toward the target transverse process and further medially and slightly superior to the target thoracic facet. Then, a metal marker was placed on the T3–4, T7–8, and T10–11 and the location of each marker was confirmed by fluoroscopy.

**Results:** In the total 132 segments, sonographic identification was confirmed to be successful with fluoroscopy in 84.1% in group 1 and 56.8% in group 2. Group 1 had a greater success rate in ultrasound-guided target segment identification than group 2 ( $p=0.001$ ), especially in T10–11 (group 1: 93.2%, group 2: 43.2%;  $p=0.001$ ) and T7–8 (group 1: 86.4%, group 2: 56.8%;  $p=0.002$ ). There intra-rater reliability of ultrasound-guided target segment identification was good (group 1:  $r=0.76$ , group 2:  $r=0.82$ ), showing no difference between right and left sides. Ul-

trasound-guided target segment identification was more effective in the non-obese subjects ( $p=0.001$ ), especially in group 1.

**Conclusion:** Ultrasound-guided detection using the 12th rib as a starting landmark for scanning could be a promising technique for successful target segment identification in the thoracic spine.

## Short Segment Stabilisation for Thoracolumbar Burst Fracture: Comparison between Open versus Minimally Invasive Technique

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**Purpose:** Minimally invasive stabilization (MIS) allow fixation of thoracolumbar burst fracture percutaneously using multiple stab incisions. It avoids dissection of posterior spinal elements which can further destabilize the spine. This is a retrospective study comparing the results between open and MIS techniques.

**Materials and Methods:** Patients suffering from traumatic thoracolumbar burst fracture (A3 and A4 under AO thoracolumbar injury classification) treated with Universal Spine System (either conventional or MIS) were recruited. Exclusion criteria included more than one level of spinal fractures, presence of neurological deficit, pathological fractures, multiple trauma, and patients with previous spinal fractures or surgery. Open technique was performed using mid-line incision with dissection of paraspinal muscles before instrumentation. In both groups, indirect reductions were done by insertion of Schanz screws followed by creating lordosis at fracture site and then distractions. Wedge angle at the fracture levels were measured before the operation, immediate postoperatively, 3 months, and 6 months after the operation. The operative time, blood loss, and length of stay after the surgery were also recorded. Statistical analysis comparing the two groups was performed using SPSS.

**Results:** From 2014 to 2018, short segment stabilizations for thoracolumbar burst fractures were performed in 16 patients. The degree of wedge angle improvements were significantly better in open group (12.0 vs. 10.4,  $p<0.05$ ). Both groups showed partial loss of initial reduction at 6 months (17.5% in open vs 20.1%). However, the opera-

tive time (330 minutes vs. 296 minutes), intra-operative blood loss (285 mL vs. 175 mL), and postoperative length of stay (16.0 days vs. 13.3 days) were significantly lower in the MIS group. One superficial infection was noted. No implant failure was observed in both groups.

**Conclusion:** Short segment stabilization using MIS technique effectively improved the angle of kyphosis as compared with open technique but with less operative blood loss, reduced operative time, and length of stay.

## Sagittal Corrective Force of Minimally Invasive Surgery with Lateral Interbody Fusion and Completely Percutaneous Pedicle Screw Fixation for Adult Spinal Deformity

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**Purpose:** Minimally invasive surgery (MIS) techniques are making a new standard in the treatment of adult spinal deformity (ASD), but it is concerned that the sagittal correction of MIS is insufficient. The purpose of this study was to evaluate the sagittal corrective force of MIS with lateral interbody fusion (LIF) and completely percutaneous pedicle screw (PPS) fixation for ASD based on an assessment of lumbar lordosis angle (LL).

**Materials and Methods:** This study was conducted with 39 patients with ASD undergoing MIS with LIF and completely PPS fixation by a single surgeon in a single institution. The patients with a multilevel bony fusion or a severe malunion were excluded from this study. All patients were divided into two groups by preoperative LL. Twenty-five patients whose preoperative LL was less than 20° were classified in group A, and 14 patients whose it was 20° or more were done in group B. The mean age of the patients was 73 years and 69 years in each group. A mean of 8.1 levels were fused and 7.7 levels were done, respectively. Operative time, intraoperative blood loss, and pre- and postoperative global radiographic parameters, including coronal Cobb angle, LL, pelvic incidence (PI)-LL mismatch, sagittal vertical axis (SVA), and pelvic tilt (PT), were investigated.

**Results:** The average operative time was 413 minutes in

group A and 371 minutes in group B. The average intraoperative blood loss was 519 g and 459 g, respectively. Pre- and postoperative coronal Cobb angle were 48° and 11° in group A and 41° and 11° in group. LL were corrected from -4° to 47° in group A and from 29° to 54° in group B. PI-LL mismatch decreased from 54° to 1° and from 23° to -2°, SVA decreased from 178 mm to 178 to 17 mm and from 84 to -2 mm, and PT was corrected from 37° to 18° and from 27° to 20°, respectively.

**Conclusion:** The ideal corrections were achieved in each group. This MIS technique for ASD has good correction force even in sagittal plane.

## A Novel Surgical Technique: Microscopic Augmented Reality-Assisted Three-Dimensional Navigation during Spinal Surgery

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**Purpose:** Within conventional three-dimensional (3D) navigation methods, surgeons have to alternately watch both the surgical field and the navigation display because the navigation monitor is setup separately from the surgical field during surgery. Therefore, there are potential risks: accidental neurovascular injury, the inaccuracy and inconvenience of navigation surgery, etc. These are some major difficulties for surgeons during conventional intraoperative 3D navigation. Recently, the utilization of augmented reality (AR) technology with Goggles, which displays additional visual information onto the view of the physical surgical field, is considered to be an effective solution. However, it is cumbersome to wear the AR Goggles throughout the entire surgery. In this paper, we present a novel technique using a microscopic AR system other than the use of AR Goggles.

**Materials and Methods:** Our system consists of a surgical microscope (Leica M530/OH6), dual imaging color module (Leica DI C500), multiformat converter (XC1), and a Brain Lab navigation system. The navigation results can be displayed inside the optical view finder of the microscope. We use this system for various kinds of surgeries, especially when inserting screws and when resecting spinal dumbbell tumors.

**Results:** Using this system, surgeons can see the surgical field and navigation display at the same time within the microscopic view finder throughout the entire surgery. Therefore, surgeons can rely on real-time information from this navigation system and perform surgeries safely, accurately, and comfortably.

**Conclusion:** The advantages of an AR microscope over AR Goggles are the steady view and the lack of weight of the AR system on the surgeon's head because the AR system is self-supported by the microscopic stand. Although AR Goggles are considered to be the only choice for AR surgery, we recommend the use of an AR microscope for intraoperative 3D navigation during spine surgery.

## Comparison of Percutaneous versus Open Pedicle Screw Fixation for Treatment of Thoracolumbar Fractures in Hardware Removal Patients

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**Purpose:** To evaluate the safety and usefulness of implant removal in having percutaneous screw fixation (PSF) in thoracolumbar fracture patients

**Materials and Methods:** We analyzed 68 patients (open 43, PSF 25) who had undergone surgery for thoracolumbar fractures. Single segmental unstable burst fracture and flexion-distraction injury were included in the study. In open method patients, implant removal was performed at an average of 11.3 months and in percutaneous method patients, implant removal was performed at an average of 8.6 months. Wedge and local kyphotic angles were measured on plain radiographs. The range of motion of each segment was recorded by flexion-extension lateral radiographs at 3 months after the removal of implants.

**Results:** Patient demographics, mechanisms of injury, fracture morphologies, and the outcomes of index fracture surgery were similar between the two groups (PSF vs. conventional posterior fixation [CPF]). As to perioperative data for fixation, there were significant difference in operation time, blood loss, duration of hospitalization, and PSF group showed a better outcome than that in CPF group ( $p < 0.05$ ). There were no significant differences in wedge angle, local kyphotic angle, and  $\Delta$ kyphotic angle

in postoperative plane X-ray ( $p>0.05$ ). There were no significant differences in wedge angle and local kyphotic angle after implant removal ( $p>0.05$ ). There were significant difference in segmental motion angle ( $p=0.00$ ), and PSF group had higher segmental motion angle better than CPF group (PSF:  $5.9^\circ\pm 3.2^\circ$ , CPF:  $1.7^\circ\pm 1.2^\circ$ ).

**Conclusion:** Compared with CPF, PSF technique for the treatment of thoracolumbar fracture can achieve the similar result of reduction and fixation. After implant removal, PSF can get better segmental motion angles after removal than CPF.

### Comparison between Anterior Instrumentation and Posterior Percutaneous Pedicle Screw Fixation during Single-Level Corpectomy Accompanied by Bi-Level, Anterior Interbody Fusion

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**Purpose:** We evaluated the surgical outcomes of patients undergoing both anterior instrumentation and posterior, percutaneous, pedicle screw fixation during single-level corpectomy accompanied by bi-level, anterior interbody fusion using struts fabricated from autologous iliac bone grafts.

**Materials and Methods:** We retrospectively evaluated 21 patients (eight males, 13 females) treated via single-level corpectomy accompanied by bi-level, anterior interbody fusion. Group 1 ( $n=9$ ) underwent anterior plate/screw fixation, and group 2 ( $n=12$ ) received posterior, percutaneous, pedicle screw fixation. The fusion segment height (FSH) and fusion segment angle (FSA) were measured on lateral X-rays taken preoperatively (Preop), immediately after operation (OP), 3 months postoperatively (PO3M), and 12 months postoperatively (PO12M). The two groups were compared using the independent-samples *t*-test, Mann-Whitney test, or Wilcoxon signed-rank test, as appropriate. We employed multiple regression to detect risk factors for reduction loss after surgery.

**Results:** The mean age of group 1 was  $67.33\pm 11.48$  years and that of group 2 was  $66.17\pm 19.91$  years ( $p=0.877$ ). The mean body mass index of group 1 was  $24.02\pm 4.10$  kg/m<sup>2</sup>, and that of group 2 was  $1.31\pm 2.70$  kg/m<sup>2</sup> ( $p=0.083$ ). The pre-surgery diagnoses were burst fractures in 17 cases, and

instability attributable to nonunion of vertebral fractures in four cases. The height changes ( $\Delta$ FSH values) from OP to PO3M ( $\Delta$ FSH [PO3M-OP]) were  $7.67\pm 4.91$  mm in group 1 and  $10.06\pm 6.90$  mm in group 2 ( $p=0.404$ ). The  $\Delta$ FSH (PO12M-OP) values were  $7.23\pm 3.50$  mm in group 1 and  $10.75\pm 8.27$  mm in group 2 ( $p=0.272$ ). The angle changes ( $\Delta$ FSA values) from OP to PO3M ( $\Delta$ FSA [PO3M-OP]) were  $4.87^\circ\pm 2.34^\circ$  in group 1 and  $10.62^\circ\pm 10.10^\circ$  in group 2 ( $p=0.111$ ); the  $\Delta$ FSA values (PO12M-OP) were  $8.13^\circ\pm 5.59^\circ$  in group 1 and  $10.63^\circ\pm 9.5^\circ$  in group 2 ( $p=0.531$ ).

**Conclusion:** In patients undergoing corpectomy with bi-level fusion, we found no significant difference in surgical outcomes when anterior instrumentation or posterior, percutaneous, pedicle screw fixation was used.

### Cement Volume and Pattern of Distribution in Fenestrated Cement Augmented Screws: Its Relevance with Respect to Preoperative Bone Mineral Density and Functional Outcome

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**Purpose:** Fenestrated screw is an important tool in a surgeon's armamentarium in osteoporotic spine. Yet, there is limited evidence on radiological assessment of these screws as well as on their clinico-radiological outcome. The objective of our study is the assessment of cement volume and pattern of distribution in relation to the bone mineral density (BMD) and functional outcome.

**Materials and Methods:** Thirteen patients with at least 6-month follow-up were analysed. They were evaluated in the form of computed tomography (CT) scan, and parameters like cement morphology and zone and pattern of distribution were assessed. The cement distribution in the vertebrae was divided into four zones on the axial CT cuts: anterior 1/3rd, middle 1/3, and posterior 1/3rd of vertebral body and the pedicle. Pattern of distribution was defined as concentrated or scattered. The leakage pattern was divided into anterolateral, posterolateral, and canal leakage. The relationship among BMD, volume, and pattern of cement distribution was studied, and patients were clinically evaluated by comparing the preoperative and

follow-up Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores.

**Results:** Mean age of patients was 69 years with a mean follow-up of 14 months. Out of 92 screws, 84 (91.3%) had cement in the safe zone (1&2), 7 (7.6%) had in zones 1–3, and only 1 (1%) had cement in zone 1. Concentrated cement distribution had higher BMD value than scattered distribution ( $p=0.027$ ). Preoperative mean ODI & VAS scores improved significantly ( $p<0.001$ ). Mean cement volume occupancy (3.66%) did not correlate with the mean improvement of VAS (65.5%,  $r=-0.068$ ), ODI (43.14%,  $r=-0.088$ ), or preoperative BMD value ( $r=-0.007$ ). 7 screws had cement leakage in the anterolateral zone.

**Conclusion:** Fenestrated screws are safe in osteoporotic spine. The volume of cement is independent of the BMD and functional outcome. However, the pattern of distribution relates well with the BMD.

## Multifidus Muscle Changes after Biportal Endoscopic Spinal Surgery: Magnetic Resonance Imaging Evaluation

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**Purpose:** The authors used magnetic resonance imaging (MRI) to assess the radiological status of the multifidus muscle (MF) after biportal endoscopic spinal surgery (BESS) and evaluated the extent of MF injury and atrophy.

**Materials and Methods:** T2-weighted signal intensity MRI was performed 3 times: preoperatively, postoperatively (within 3 days of surgery), and during follow-up. We measured the MF cross-sectional area (CSA) on both sides ipsilateral and contralateral and recorded BESS operative times. On entire patients analysis, the association between the last follow-up time and change in MF, and between the operative time and the change, were analyzed. For between-group comparisons, patients were divided into three groups, I, II, and III, by the timing of the last follow-up after BESS (within 2 weeks, 2 to 4 weeks, and after 4 weeks). MF changes were recorded.

**Results:** The operative time correlated significantly with the percentage change in the T2 signal intensity ratios of both the ipsilateral and collateral sides ( $p<0.01$ ). At the last follow-up, the T2 signal intensity ratio of the ipsilateral side had decreased in group III ( $p=0.002$ ). The per-

centage change in this signal intensity ratio was smallest in group III ( $p=0.004$ ). I found no significant difference in the T2 signal intensity ratios of the contralateral sides of the three groups ( $p>0.01$ ). The MF CSA did not differ significantly on either side.

**Conclusion:** The MF tended to recover in several months. The author found no significant MF atrophy after BESS; the CSA did not change. We conclude that MF changes after BESS correlated with operative time, and was reversible.

## Minimally Invasive Surgery Transforaminal Interbody Fusion versus Minimally Invasive Surgery Lateral Interbody Fusion: A Retrospective Study for Early Degenerative Lumbar Spondylolisthesis

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**Purpose:** There is recent increase popularity in extreme lateral interbody fusion (XLIF) as a new minimally invasive surgery (MIS) option. Direct comparison to its MIS counterpart approach, the transforaminal lumbar interbody fusion (TLIF), have been done in several studies; however, our study emphasise bias reduction as surgery is done by a single surgeon in a single centre. The aim of this study was to comparatively study the effectiveness and safety between the direct decompression approach via MIS TLIF and the indirect decompression via XLIF in patients with single level, early lumbar spondylolisthesis.

**Materials and Methods:** A single centre, retrospective cohort study involving a total of 38 patients underwent surgical intervention between 2010 and 2013 for degenerative disc disease of lumbar spine at single L4/L5 level. Eighteen patients were treated with MIS TLIF and 20 patients were treated with XLIF.

**Results:** The XLIF group showed shorter duration of surgery ( $p=0.03$ ) length of hospital stay ( $p=0.03$ ) and intraoperative blood loss ( $p=0.03$ ). Radiologically, disc height significantly improved postoperatively in the XLIF group ( $p=0.01$ ), and foramina height increment was also higher in the XLIF group ( $p=0.06$ ). Clinically, back pain and leg pain improved in 85% of patients in the XLIF group and 78% in the TLIF group. Despite resolving within 6 months of surgery, hip flexion weakness was isolated to the XLIF

group only (40%). There was one case of dural tear and surgical site infection in the TLIF group respectively and none in the XLIF group. Clinical outcome 6 months post-operatively is similar in both groups based on the Oswestry Disability Index.

**Conclusion:** XLIF shows comparable clinical outcomes in resolution of back pain and radiculopathy to conventional MIS TLIF with better perioperative efficiency and safety.

## A Minimally Invasive Surgical Strategy for Thoracic Metastatic Tumor Accompanied with Neurologic Compression

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**Purpose:** The purpose of study is to evaluate the feasibility, efficacy, and safety of minimally invasive pedicle screws fixation (MIPS) combined with percutaneous vertebroplasty (PVP), minimally invasive neurologic decompression, and partial tumor resection for treating thoracic metastasis with epidural involvement and neurologic symptoms.

**Materials and Methods:** Eighteen patients with a mean age of 53.2 years (range, 31–72 years), who sustained single-level thoracic vertebral metastasis and neurologic compression underwent the procedure of MIPS (The minimal-access in a paraspinalis muscle-splitting approach was performed to insert pedicle screws into the vertebrae under direct vision and two rods of the appropriate size were placed over the pedicle screws through subcutaneous soft tissues and muscles) combined with PVP, minimally invasive decompression, and partial tumor resection through mini posterior midline approach. The mean prognostic score was 7 (range, 6–7 points) according to Tomita scoring system.

**Results:** The mean length of the midline incision was  $3.1 \pm 0.3$  cm. There was a mean blood loss of 150 mL (range, 70–600 mL). Clinical follow-up was available for 17 patients in this study ranging from 12 to 16 months (mean time, 14.2 months) and other one patient died 8 months after surgery. The Visual Analog Scale score significantly dropped from 9 (range, 7–10) before operation to 3 (range, 2–4;  $p < 0.001$ ) immediately after the operation and to 1 (range, 0–1;  $p < 0.001$ ) at 1-year follow-up. Improvement of paraplegia was observed after surgery in all patients. Spine

stability was observed in all of surviving patients during follow-up.

**Conclusion:** MIPS combined with PVP, minimally invasive decompression, and partial tumor resection is a good choice of surgical treatment for thoracic metastatic tumor accompanied with neurologic compression.

## Minimally Invasive Lateral Access Corpectomy for a Solitary Renal Cell Carcinoma Spinal Metastasis: A Case Report

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**Purpose:** Spinal metastases can present with neurological symptoms due to cord compression which often requires urgent surgical decompression and fixation. However, the posterior spinal approach has limitations in cord decompression. We describe our institution's experience of a thoracic 12 corpectomy done via a minimally invasive retropleural approach for a patient with a metastatic spinal tumour.

**Materials and Methods:** A 63-year-old presented with a 1-month history of worsening atraumatic back pain with lower limb radicular pain and weakness. Magnetic resonance imaging showed a T12 pathological fracture with vertebral body retropulsion causing cord compression. A computed tomography abdomen scan showed a heterogeneous enhancing mass in the superior pole of the right kidney, suspicious of a renal cell carcinoma.

**Results:** He underwent initial posterior pedicle screw instrumentation from T10 to L2 and a T12 bilateral laminectomy with right T12 pedicle bone biopsy, followed by a minimally invasive lateral access T12 corpectomy. His weakness improved and he had subsequent radiation therapy, chemotherapy, and a right nephrectomy with good recovery.

**Conclusion:** Minimally invasive lateral access retropleural approach can be considered in metastatic spinal tumour cases with cord compression as it allows for circumferential decompression while avoiding risks of anterior spinal surgery.

## Outpatient 1, 2, or 3 Level Anterior Cervical Discectomy and Fusion Procedures Have Similar Complication and 30-Day Readmission Rates Compared to Overnight Stay: Analysis of 284 Patients in the Public Healthcare Setting

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**Purpose:** To assess the safety and efficacy of day surgery for 1, 2, or 3 level anterior cervical discectomy and fusion (ACDF) at a single Canadian institution.

**Materials and Methods:** A retrospective review of the inpatient spine surgery database of a single Canadian institution over 13 years was performed to compare the complication and readmission rates of patients undergoing day surgery or short-stay ACDF. Regression analysis was used to assess outcomes at 2 months and 2 years post-surgery with the Neck Disability Index.

**Results:** One hundred and forty-three patients underwent ACDF with the intention to treat (ITT) as a day surgery procedure, with 130 admitted for short stay (24 hours). The day surgery cohort included 73 single-level, 51 two-level, and 19 three-level patients. The short stay cohort included 55 single-level, 45 two-level, 29 three-level, and 1 four-level procedures. Six patients (4%) with the ITT as day surgery were admitted for overnight stay or longer (range, 2–21 days). Intra-operative dural tear was reported in eight patients (5.8%) in the day surgery group (four required admission), compared to four patients (3.1%) in the short stay group (odds ratio [OR], 1.81; 95% confidence interval [CI], 0.53–6.2;  $p=0.5$ ). One patient (0.7%) in the day surgery group suffered a permanent postoperative neurological deficit compared to 0 patient in the short stay group ( $p=1$ ). Three patients (2.1%) in the day surgery group and two patients (1.5%) in the short stay group required readmission within 30 days (OR, 1.36; 95% CI, 0.22–8.3;  $p=1$ ). Regression analysis showed no significant differences in the 2-month and 2-year outcomes post-ACDF between groups ( $p=0.796$ , 0.315, respectively) after accounting for total number of levels.

**Conclusion:** Day surgery ACDF for 1, 2, or 3 levels does not have a significantly higher rate of complications, readmission within 30 days, or differences in short- and long-term outcomes when compared to overnight stay. This provides evidence that day surgery ACDF is a safe and

effective treatment option in the public healthcare setting.

## Effects of Lowest Instrumented Vertebra for Non-instrumented Lumbar Curve in Thoracic Adolescent Idiopathic Scoliosis

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**Purpose:** Unfixed lumbar segments and coronal off-balance are sometimes prominent after the correction of thoracic adolescent idiopathic scoliosis (AIS). How the correction of thoracic curve affects for them is not known well. The lower instrumented vertebra (LIV) may play a role to control the unfixed lumbar segments and coronal off-balance. The aim of this study is to examine how the correction of LIV affects the unfixed lumbar curve and coronal balance in thoracic AIS.

**Materials and Methods:** Eighty consecutive patients with corrective surgery for Lenke 1 and 2 AIS were examined retrospectively. Measurements were LIV angle from the orthogonal line drawn upper instrumented vertebra to LIV (LIV angle for construct), major Cobb angle, non-instrumented lumbar Cobb angle, L4 tilting angle (L4 tilt), and coronal balance (central sacral vertical line [CSVL]–C7 plumb line [C7PL]) using up-right whole spine radiographs at preoperation, postoperation, and 2 years after the correction. LIV rotation was measured by computed tomography. The values of correction coefficient about LIV in the radiological parameters and background data were examined.

**Results:** Postoperative LIV rotation showed the correlation with L4 tilt ( $r=-0.511$ ,  $p<0.0001$ ). Postoperative LIV angle for construct correlated with postoperative non-instrumented lumbar Cobb angle ( $r=0.573$ ,  $p<0.0001$ ). Postoperative LIV rotation together with postoperative major-Cobb angle affected CSVL–C7PL ( $r=0.517$ ,  $p<0.0002$ ).

**Conclusion:** LIV rotation was a unique driver for the change of L4 tilt. Non-instrumented lumbar Cobb angle could be controlled by LIV angle for construct. CSVL–C7PL was affected by the combination of LIV rotation and major Cobb angle. Discordance of correction of major Cobb angle and LIV rotation would occur coronal off balance.

## Biomechanical Study of Posterior Pelvic Fixations in Vertically Unstable Sacral Fractures: An Alternative to Triangular Osteosynthesis

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**Purpose:** To investigate the relative stiffness of a new posterior pelvic fixation for unstable vertical fractures of the sacrum.

**Materials and Methods:** To simulate a vertically unstable fractured sacrum, 12 synthetic pelvic models were prepared. In each model, a 5-mm gap was created through the left transforaminal zone (Denis zone II). The pubic symphysis was completely separated and then stabilized using a 3.5-mm reconstruction plate. Four each of the unstable pelvic models were then fixed with two iliosacral screws, a tension band plate, or a transiliac fixation plus one iliosacral screw. The left hemipelvis of these specimens was docked to a rigid base plate and loaded on an S1 endplate by using the Zwick Roell z010 material testing machine. Then, the vertical displacement and coronal tilt of the right hemipelves and the applied force were measured.

**Results:** The transiliac fixation plus one iliosacral screw constructions could withstand a force at 5 mm of vertical displacement greater than the two iliosacral screw constructions ( $p=0.012$ ) and the tension band plate constructions ( $p=0.003$ ). The tension band plate constructions could withstand a force at 5° of coronal tilt less than the two iliosacral screw constructions ( $p=0.027$ ) and the transiliac fixation plus one iliosacral screw constructions ( $p=0.049$ ).

**Conclusion:** This study proposes the use of transiliac fixation in addition to an iliosacral screw to stabilize vertically unstable sacral fractures. Our biomechanical data demonstrated the superiority of adding transiliac fixation to withstand vertical displacement forces.

## Full Endoscopic Multilevel Decompressive Laminectomy for Cervical Spondylotic Myelopathy: Technical Report-

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**Purpose:** Laminoplasty or laminectomy and fusion has been widely accepted for the treatment of cervical spondylotic myelopathy (CSM) due to ossification of posterior longitudinal ligament (OPLL). However, some disadvantages have also been recognized and there have been various attempts to resolve it. Endoscopic decompressive laminectomy which has less postoperative pain and muscle injury, could be an alternative method for patients with moderate cervical stenosis and preserved cervical lordosis. The purpose of this study is to report the pilot study case of endoscopic dome laminectomy for the treatment of CSM.

**Materials and Methods:** The patient is a 59-year-old female which complained left upper extremity pain (trapezius shoulder-interscapular-arm-forearm-1, 2, 3, 4, 5th finger), numbness, and tingling for 7 months. The patient also had myelopathy symptoms as hand clumsiness and gait disturbance. Hoffman reflex and finger escape sign was checked through the physical exam. The computed tomography and magnetic resonance imaging (MRI) images revealed a localized type OPLL on the C5 body and severe foraminal stenosis of C6–7 left foramen. The authors performed unilateral endoscopic laminectomy C4–5–6–7 left with C6–7 left foraminotomy. Making sufficient saline outflow and checking the dura pulse during operation are important to prevent neural damage and increase of intracranial pressure.

**Results:** The patient expressed immediate relief of left upper extremity pain, numbness, and tingling. Myelopathy symptoms also improved. Successful decompression was checked through the postoperative MRI.

**Conclusion:** Endoscopic multilevel decompressive laminectomy may be a useful and effective surgical procedure for CSM. Further study is necessary.

## Is Routine Use of a Drain Really Necessary for Extensive Spinal Fusion Surgery?: 50 Consecutive Cases without Drain

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**Purpose:** Contrary to the long-standing belief in the need for a drain in spinal surgery, its usefulness has still been controversial. The purpose of this study was to observe the surgical outcomes of extensive multilevel spinal fusion (EMSF) ( $\geq 3$  levels) without a drain and to evaluate the usefulness of a drain.

**Materials and Methods:** We included 100 consecutive patients with degenerative spinal disease who underwent EMSF surgery (average, 5.5 segments). The participants were divided into two groups by the use of a drain or not; drain group ( $n=50$ ) and no-drain group ( $n=50$ ). We observed various surgical outcomes of EMSF without a drain and compared demographics, comorbidities (hypertension, brain infarct, cardiac disease), anticoagulant use, perioperative surgical and clinical factors, surgical site infection (SSI), revision surgery, and laboratory findings between the two groups. Pedicle subtraction osteotomy was performed in 12.2% of a no-drain group and in 13.7% of a drain group, respectively ( $p=0.826$ ).

**Results:** In the no-drain EMSF surgeries, there was neither newly developed neurological deficit nor reoperation due to hematoma. In the no-drain group, there was one (2.0%) patient who suffered from SSI requiring revision surgery. Time to walk after surgery (4.3 days) and hospital stay (13.0 days) of the no-drain group were faster than those of the drain group ( $p<0.001$ ). The rate of perioperative blood transfusion of the no-drain group (49%) was significantly lower than the drain group ( $p=0.004$ ). No significant differences existed between the two groups in demographics, comorbidities, additional surgery for hematoma evacuation, SSI, and perioperative hemoglobin levels.

**Conclusion:** In 50 extensive multilevel spinal fusion surgeries without the use of a drain, no hematoma-related neurological deficits or reoperations were observed. The no-drain group did not show significantly more frequent postoperative complications than did the drain use group; hence, routine insertion of a drain following extensive multilevel spinal fusion should be reconsidered carefully

## Pathological Fracture of C4 Vertebra Secondary to Lung Adenocarcinoma Metastasis with Concomitant Fungal Spine Infection: A Case Report

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The spine is the most common site of skeletal metastases with the thoracic spine is the most common region involved in spinal metastasis (70%), followed by the lumbar spine (20%), while the cervical region is affected in 10% of the cases. Lung, prostate, breast, renal cell, thyroid, and gastrointestinal carcinomas are the most common tumors that metastasize to the spinal column. The majority of vertebral metastases originate via hematogenous dissemination from primary carcinoma of the breast, lung, or prostate. The most common symptom in cervical metastases is neck pain which occurs in 90% of patients; 50% of cases complain of severe deficit, such as acute weakness that may progress to quadriplegia. The mean survival after diagnosis of vertebral metastasis was 7.1 months. Fungal infections of the spine are relatively uncommon and occur primarily as opportunistic infections in immunocompromised patient. They mostly arise as a result of hematogenous spread from another focus, most commonly the lung. We reported a case of 69-year-old gentleman who had pathological fracture of C4 secondary to lung adenocarcinoma metastasis with concomitant fungal spondylitis. Surgical intervention was done with long course of antifungal treatment; however, due to late presentation of the metastases and concomitant fungal infection, the prognosis is poor.

## Floating Lateral Mass Fracture of Cervical Spine: A Case Report

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Unilateral lateral mass fractures and fracture dislocations

comprise 7% to 16% of sub-axial cervical spine fractures. Most are commonly due to motor vehicle accident. An uncommon and poorly described subset is the 'floating' lateral mass fracture (FLM) with fractures of the adjacent pedicle and lamina. Historic literature has described multiple treatment options including nonoperative management, single level anterior cervical disc fusion, and posterior three level fusion. Due to the relatively uncommon nature of the FLM fracture, little has been written with respect to its presentation, associated injuries, or the optimal management of these injuries. We reported a rare case of floating lateral mass fracture of cervical spine that treated conservatively with sternal-occiput-mandibular immobilizer and neurological outcomes improves by 6 weeks.

## Posterior Mediastinal Mass Mimicking Adolescent Idiopathic Scoliosis: A Case Report

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**Purpose:** To describe a case of dumbbell-shaped mass mimicking adolescent idiopathic scoliosis in a 17-year-old female patient and to alert orthopedic surgeon regarding this condition.

**Materials and Methods:** A 12-year-old girl presented with progressive worsening painless thoracic scoliosis. On examination she was found to be tall and slim with an upper thoracic scoliosis convex to the right. Physical examination revealed thoracic scoliosis with a prominent right rib hump with no neurological deficit. Radiographic examination using Cobb's method showed a right thoracic curve measuring 40° from the superior endplate of T5 to the inferior endplate of T11 and a left lumbar curve measuring 60° from the superior endplate of T12 to the inferior endplate of L4. However, tracing back to her previous plain radiographs taken 5 years ago, we found out a left intrathoracic dumbbell-shaped mass and a documented right-convex scoliosis of 25° Cobb. The thoracic curve was the main structural curve, while the lumbar curve was the compensatory curve. The main structural curve was rigid. Magnetic resonance imaging revealed a soft tissue mass at the apex of the thoracic curve from T4 to T10. These features demonstrated that the mass had an extensive intraspinal component, deviating the cord to the left, and

was continuous with the extra-spinal component with no tumor extension into neural foramina.

**Results:** This report points out that a rigid and unusual curve pattern should alert orthopedic surgeon to conduct further investigation for assumed idiopathic scoliosis. This large posterior mediastinal mass might cause progressive spinal deformity mimicking adolescent idiopathic scoliosis.

**Conclusion:** We report here a case of giant dumbbell-shaped mass that had been erroneously treated for idiopathic scoliosis over several years. The authors recommend a combination of cardio-thoracic, neurosurgery, and orthopedic spine surgery to treat this condition.

## Biomechanical Comparison of Anterior Cervical Plate Systems with Allograft Spacer with Respect to the Screw Insertion Angle and Plate Length

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**Purpose:** We used finite element analysis to investigate load sharing ratio between allo spacer and anterior cervical plate (ACP), which is closely associated with the fusion rate, and to compare the biomechanically stability through peak von Mises stress of allo spacer and yielding risk of peri-screw bone.

**Materials and Methods:** A previously validated intact three-dimensional cervical finite element model was used (C3–C6), and the implant model has implemented on the basis of Cornerstone ASR and ZEVO Anterior Cervical Plate System. Six types of postoperative models (type 1, SP & insert angle 16; type 2, SP & insert angle 32; type 3, MP & insert angle 8; type 4, MP & insert angle 16; type 5, MP & insert angle 32; and type 6, max plate & insert angle 0) were constructed by modifying the intact model to simulate implantation of the devices at C4–C5. The stability of allo spacer and bone was confirmed by measuring the peak von Mises Stress (PVMS).

**Results:** The load sharing ratio of allo spacer was highest in 15% for type 2 in the flexion and 13.7% for type 1, 9.7% for type 3, 9.4% for type 3, and 9.3% for type 5 and type

6. The load sharing ratio of ACP was highest in 92.9% for type 6 in extension. The PVMS of the allo spacer was the highest in 20.9 MPa for type 6 in lateral bending. The yielding risk of bone in screw and bone interface was lowest in 7.2% for type 2 in axial rotation.

**Conclusion:** As the plate is closer to the adjacent disc, the load transferred to the ACP increases, and the risk of stress shielding and screw loosening will be further increased.

### Biomechanical Stress Analysis of Allograft Spacers as a Function of Cortical-Cancellous Ratio and Length in an Anterior Cervical Discectomy/Fusion Model

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**Purpose:** To use finite element model (FEM) analyses to investigate the effects of different designs and the length of cervical spacers on the physical stress on allo spacers and the endplates-vertebral body.

**Materials and Methods:** Stress distribution and risk of subsidence according to type and length of allo spacers under the condition of hybrid motion control, including flexion, extension, axial rotation, and lateral bending, were investigated and analyzed. The detailed FEM of a previously validated, three-dimensional, intact cervical spinal segment model of C3–7, with C5–6 segmental fusion using allo spacers, was used in the present study to evaluate the biomechanical characteristics of the different designs of cervical allo spacers, such as cortical only, cortico-cancellous, and cortical lateral walls with a cancellous center bone.

**Results:** The range of motion in C4–5 and C6–7 was increased in all motion modes in all spacers. Among the three types of cervical allo spacers evaluated, cortical lateral walls with a cancellous center bone demonstrated the highest stress on the anterior superior and the posterior inferior cortical bone as well as the endplate around the posterior margin of allo spacers. The longer length of allo spacers had higher stresses on the allo spacers and the endplates of involved segments.

**Conclusion:** A smaller cortical portion and a longer length of cervical spacers could both be risk factors that cause allo spacer failure and subsidence, especially in the C5–6 segment.

### Cauda Equina Syndrome in an Obese Pregnant Patient Secondary to Double Level Lumbar Disc Herniation: A Case Report and Review of Literature

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**Purpose:** Surgery for lumbar disc herniation during pregnancy poses a significant challenge to the operating surgeon in order to achieve good clinical, maternal, and fetal outcome. Specific precautions need to be undertaken during anesthesia, positioning, and postoperative care. Obesity and double level symptomatic disc herniations during that time are even more complicated.

**Materials and Methods:** We report a 29-year-old primigravida in her 21st week of gestational period, who presented to the emergency department with severe low back pain and excruciating radiculopathy of right lower limb. Clinical examination and magnetic resonance imaging were suggestive of a huge right posterolateral disc extrusion at L3–L4 and L4–L5 with inferior migration at L3–L4 causing severe secondary canal and foraminal stenosis. An integrated multidisciplinary team comprising anesthetist, spine surgeon, obstetrician, and psychiatrist was involved in the preoperative planning and perioperative management of the patient.

**Results:** To our knowledge, the surgical and fetal outcome in such a scenario of cauda equina syndrome during pregnancy, complicated by obesity and double level pathology, is unknown. A double level decompression and discectomy in prone position were done under general anesthesia with adequate precautions. Despite the surgical challenges, the postoperative period was uneventful resulting in immediate pain relief and complete neurological recovery by 4 months and the primiparous mother delivered a 2.7 kg healthy male child.

**Conclusion:** Cauda equina syndrome is a surgical emergency and there should be no reason for delay in intervention even in a pregnant patient. It is essential that the surgical team appraises the situation and inculcates certain

precautions in the perioperative management to achieve good surgical and fetal outcomes.

## Delayed Presentation of Invasive Candidal Vertebral Osteomyelitis Following Non-missile Penetrating Spinal Injury

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**Purpose:** Invasive candidal vertebral osteomyelitis (CVO) is a rare entity, which may go unrecognized due to lack of systemic features. Early diagnosis and prompt management are essential to achieve good outcomes. We describe the typical presentation of CVO and describe the details of its successful management and outcome.

**Materials and Methods:** An unusual case of Non-missile based penetrating injury (NMPSI) with complete prolapse of abdominal contents was initially resuscitated and the lumbar fracture was managed conservatively. Ten weeks later, he started experiencing excruciating low back ache and difficulty in walking. There were no clinical systemic features of infection. However, magnetic resonance imaging (MRI) and computed tomography revealed altered subchondral marrow signal intensity changes on either side of L3–L4 and L4–L5 disc spaces, disc involvement along with the presence of a right paravertebral abscess raising the suspicion of infective lesion. Elevated erythrocyte sedimentation rate values of 53 mm/hr and C-reactive protein of 18 mg/L were further suggestive of infection.

**Results:** Surgical debridement, washout, and instrumented stabilization along with nerve root decompression were performed. Extensive scarring of soft tissues resulting in dural adhesions was noted. Tissue staining of the intraoperative samples showed yeast cells and culture revealed *Candida albicans*. According to the antibiotic sensitivity, fluconazole was started and continued for 6 months. The patient was mobilized on the second day following surgery and was started on a structured rehabilitation program. Immediate postoperative MRI showed adequate nerve root decompression and follow-up MRI demonstrated significant change in signal intensities and good healing of endplates. Neurologically he improved by one grade.

**Conclusion:** CVO unlike other causes of spinal infections

lacks systemic features. Delayed exacerbation of local symptoms following penetrating injuries of spine should arouse suspicion among surgeons regarding the possibility of spinal infections. Surgical debridement and instrumentation are safe in CVO.

## Thoracic Inlet Compression Resulting in Superior Vena Cava Obstruction and Cardiac Asystole in a Case of Severe Cervical Kyphotic Deformity Secondary to Neurofibromatosis

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**Purpose:** Cervical kyphosis in neurofibromatosis type 1 is a comparatively rare clinical finding. Dystrophic neurofibromatosis of upper cervical spine can cause serious complications. Surgical correction has its inherent risks. Stand-alone anterior surgery has failed in severe deformities. Combined anterior reconstruction and posterior shortening are essential to achieve stable fusion after deformity correction.

**Materials and Methods:** In the current study, we described the usefulness of combined anterior reconstruction and posterior shortening for deformity correction of congenital kyphosis associated with neurofibromatosis type 1.

**Results:** A retrospective analysis of computed tomography (CT) and magnetic resonance imaging (MRI) showed severe narrowing of thoracic inlet. After a multidisciplinary team meeting involving anesthetists, otolaryngologists, spine surgeons, and cardiothoracic surgeons, the probable diagnosis of superior vena cava (SVC) obstruction in prone position due to narrow thoracic inlet was made and it was decided to attempt surgical decompression. The medial end of the clavicles along with limited manubrium excision relieved the SVC obstruction and it was possible to position the patient prone. C2–T4 instrumented decompression followed by anterior reconstruction and cervical plating were performed. Postoperative period was uneventful and the final Cobb's angle was only 45°.

**Conclusion:** Cervical kyphosis and thoracic lordosis is a deadly combination and may result in severe thoracic inlet obstruction (TIO), especially while positioning the patient prone. We recommend the usage of preoperative CT and MRI in such cases to look for TIO and address it

by adequate decompression before embarking on surgery.

## Surgical Outcomes of Instrumented Posterior Lumbar Interbody Fusion in Patients with Rheumatoid Arthritis under Current Pharmacotherapies

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**Purpose:** To compare the clinical and radiographic results of posterior lumbar interbody fusion (PLIF) for lumbar degenerative disorders between patients with rheumatoid arthritis (RA) under current pharmacotherapies and those without RA.

**Materials and Methods:** Eighty patients who underwent PLIF with instrumentation of less than two segments and followed up for 3 years were divided into the RA group (n=16) and the non-RA group (n=64). All patients in the RA group had an onset of RA after 1999 and fulfilled the American Rheumatism Association criteria for RA. Radiographic results were evaluated by fusion rate and loss of correction. Radiographic adjacent segment disease (ASD) was also evaluated as development of spondylolisthesis >3 mm, development of intervertebral angle at flexion >5°, and decrease in disc height >3 mm. Clinical outcomes were evaluated by the Japanese Orthopedic Association (JOA) score for neurological status and perioperative complications.

**Results:** RA patients' mean disease duration was 8.5 years and mean Disease Activity Score–C-reactive protein was 2.4. Thirteen patients (81.2%) were administered methotrexate and 7 (43.7%) were also administered biological agents. No significant difference was found in loss of correction, though fusion rate in the RA group (85.7%) was significantly lower than in the non-RA group (98.7%) ( $p=0.029$ ). The incidence of radiographic ASD was significantly higher in the RA group (62.5%) than in the non-RA group (23.4%) ( $p=0.005$ ). Postoperative JOA score in the RA group was significantly lower than in the non-RA group. There was no significant difference in perioperative complications between the groups.

**Conclusion:** This study demonstrated both clinically and radiographically poor surgical outcomes of instrumented

PLIF in RA patients. Most notably, the incidence of radiographic ASD was quite high in RA patients. Therefore, careful attention should be paid to RA patients even if the disease activity was well controlled under current pharmacotherapies.

## Relationship between the Progression of Kyphosis in Thoracolumbar Osteoporotic Vertebral Compression Fractures and Magnetic Resonance Imaging Findings

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**Purpose:** To examine the relationship between the progression of a kyphotic deformity and the magnetic resonance imaging (MRI) findings in conservatively treated osteoporotic thoracolumbar compression fracture patients.

**Materials and Methods:** This study categorized the patients who underwent conservative treatment among those patients who underwent treatment under the suspicion of a thoracolumbar compression fracture from January 2007 to March 2016. Among them, this retrospective study included 89 patients with osteoporosis and osteopenia with a bone density of less than -2.0 and single vertebral body fracture. This study examined the magnetic resonance images of anterior longitudinal ligament or posterior longitudinal ligament injury, superior or inferior endplate disruption, superior or inferior intravertebral disc injury, the presence of low signal intensity on T2 weighted images, and bone edema of intravertebral bodies in fractured intravertebral bodies.

**Results:** In cases where the superior endplate was disrupted or the level of bone edema of the intravertebral bodies was high, the kyphotic angle, wedge angle, and anterior vertebral compression showed remarkably progression. In the case of damage to the anterior longitudinal ligament or the superior disc, only the kyphotic angle was markedly prominent. On the T2-weighted images, low signal intensity lesions showed a high wedge angle and high anterior vertebral compression. On the other hand, there were no significant correlations among the posterior longitudinal ligament injury, inferior endplate disruption, inferior disc injury, and the progression of kyphotic deformity and ver-

tebral compression.

**Conclusion:** An osteoporotic thoracolumbar compression fracture in osteoporotic or osteopenic patients, anterior longitudinal ligament injury, superior endplate and intra-vertebral disc injury, and high level of edema in the MRI were critical factors that increases the risk of kyphotic deformity.

## Surgical Outcomes for Late Neurological Deficits after Long Lumbar Instrumented Fusion for Degenerative Lumbar Diseases

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**Purpose:** To report cases with late neurological deficits after long instrumented lumbar fusion.

**Materials and Methods:** The inclusion criteria were (1) previous posterior long lumbar instrumented fusion, (2) thoracic myelopathy caused by adjacent segment pathologies, and (3) no previous history of myelopathy before surgery. Four males and nine females were identified in our institute. Except one patient who underwent anterior surgery only, 12 patients underwent posterior decompression and instrumented fusion was extended. The minimum follow-up period after revision surgery was 1 year (mean, 4.5 years).

**Results:** At the time of revision surgery, the mean age of all patients was 71.5 years (range, 58–82). Before revision surgery, upper instrumented vertebra was L2 in two patients, L1 in six, D12 in two, D11 in one, and D10 in two. All patients presented paraparesis due to cord compression at the supra-adjacent levels. Neurological deficits developed on average at 4.9 years (range, 0.5–15 years) after previous lumbar instrumented fusion. Interestingly, three patients showing neurological deficits within post-operative 1 year underwent iliac screw fixation. The mean duration of neurological deficits was 4.5 weeks (range, 1–12 weeks). However, 11 patients except two patients with acceptable pelvic incidence (PI)–lumbar lordosis (LL) ( $0.1^\circ$  and  $-7.1^\circ$ ) had severe PI–LL mismatch ( $31.1^\circ \pm 15.6^\circ$ ; range,  $14.8^\circ$ – $62.2^\circ$ ). The most common pathology compressing spinal cord was severe adjacent disc degeneration and subsequent canal stenosis (seven patients). Supra-adjacent segmental fractures occurred in three elderly

patients and they had additional pathologies at the fractured level. In other three patients, huge herniated disc at the adjacent level compressed spinal cord. Nine patients underwent perioperative major complications. The mean days of hospitalization were 49.1 days (range, 17–85 days).

**Conclusion:** Late neurological deficits can develop with various pathologies at the supra-adjacent levels. Sagittal parameters and iliac screw fixation might be associated with supra-adjacent segment pathology. Surgical outcomes were not favorable and perioperative complications were quite frequent.

## Multilevel Disc Sparing Pyogenic Vertebral Osteomyelitis Mimicking Neoplasm

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**Purpose:** Vertebral osteomyelitis is a cause of back pain, most commonly caused by pyogenic or granulomatous infection. It is typically associated with the involvement of the intervertebral disc and adjacent vertebral body. The diagnosis is difficult due to its insidious start and indolent course. We report a case of tumour mimicking pyogenic vertebral osteomyelitis in our center.

**Materials and Methods:** A 50 years old lady with no known medical illness presented with the complaint of upper back pain with worsening of both lower limbs weakness for the past 3 months. Her blood investigations were unremarkable with only slight raised in total white blood cell and erythrocyte sedimentation rate (ESR). High dose of intravenous cloxacillin was started. Magnetic resonance imaging showed multilevel thoracic metastatic deposits with cord compression. Stabilisation and decompression surgery was done 2 weeks later. There was an intraoperative biopsy suggestive of pyogenic infection. All cultures were negative. Patient showed significant improvement after commencement of antibiotics and was discharged well from ward after completion of 2 months of intravenous cloxacillin.

**Results:** Pyogenic vertebral osteomyelitis usually presents with combined infection of disc and vertebral bodies. Atypical presentations include sparing of endplate and disc. Some may involve only one vertebral, one vertebral

with adjacent disc, or normal disc between two involved vertebrae. Pseudotumour appearance with multilevel vertebral involvement and normal intervening discs is usually seen in spine metastases or atypical presentation of tuberculous infection which rarely seen in pyogenic vertebral osteomyelitis. Early commencement of antibiotics and surgical stabilisation and decompression achieves a better prognosis, shorter hospitalization period, and subsequent significant improvement in kyphotic deformity and quality of life.

**Conclusion:** High index of suspicion needed when dealing with spine infection as patient usually comes with vague symptoms and blood investigations and radiological imaging may be misleading. Early antibiotic treatment and surgical intervention are vital in patient's recovery.

### Surgical Treatment of Osteoporotic Vertebra Compression Fracture at Thoracolumbar Levels: Only Pedicle Screw Constructs with Polymethyl Methacrylate Augmentation

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**Purpose:** To investigate the radiological efficacy of polymethyl methacrylate (PMMA) augmentation of pedicle screw operation in osteoporotic vertebral compression fractures (OVCF) patients.

**Materials and Methods:** Twenty OVCF patients, who underwent only posterior fusion using pedicle screws with PMMA augmentation, were included in the study. The mean follow-up period was 15.6 months. The demographic data, bone mineral density (BMD), fusion segments, number of pedicle screws, and amount of PMMA were reviewed as medical records. To analyze the radiological outcomes, the radiologic parameters were measured as the time serial follow-up (preoperation, immediately postoperation, postoperative 6-week, 3-month, 6-month, and 1-year follow-up).

**Results:** A total of 20 patients were examined (16 females [80%]; mean age,  $69.1 \pm 8.9$  years). The average BMD was  $-2.5 \pm 0.9$ . The average cement volume per vertebral body was 6.3 mL. The mean preoperative Cobb angle of focal kyphosis was  $32.7^\circ \pm 7.0^\circ$  and was improved significantly to  $8.7^\circ \pm 6.9^\circ$  postoperatively ( $p < 0.001$ ), with maintenance of

the correction at the serial follow-up, postoperatively. The Cobb angle of instrumented kyphosis, wedge angle, and sagittal index showed similar patterns. In addition, the anterior part of fractured vertebral body height averaged  $11.0 \pm 5.0$  mm and was improved to  $18.5 \pm 5.7$  mm postoperatively ( $p = 0.006$ ), with maintenance of the improvement at the 3-month, 6-month, and 1-year follow-up.

**Conclusion:** The reinforcement of pedicle screws using PMMA augmentation may be a feasible surgical technique for osteoporotic vertebral compression fractures. Moreover, it appears to be appropriate for improving the focal thoracolumbar/lumbar kyphosis and is maintained well after surgery.

### Effective Conservative Treatment in Massive Bilateral Gluteal Abscess due to Sacral Tuberculosis

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**Purpose:** Sacral tuberculosis is a spinal infection characterized by bone destruction, pathologic fracture, abscess, and deformity. Sacral tuberculosis is usually caused secondary to lumbar spine tuberculosis with direct spread of infection, but the incidence of sacral tuberculosis without the spreading of infection from the lumbar region was rarely found in this decades. The tuberculosis total treatment was implemented as a treatment basis for tuberculous spondylitis, with multimodal approach to treat the patients by looking at all aspects of the disease which the treatment goals are to eradicate the infection and prevent spinal deformity. The concept of tuberculosis total treatment does not emphasize surgery alone but including the conservative treatment also.

**Materials and Methods:** We collected data of a patient with sacral tuberculosis who were admitted to Cipto Mangunkusumo Hospital in 2016 and were diagnosed with sacral tuberculosis by pathology anatomy with core biopsy sample. Patient was given anti-tuberculosis chemotherapy, and the outcome was measured by clinical and laboratory findings, also radiological evaluation.

**Results:** Basic treatment alone by alternative 1 total treatment procedure with category 1 World Health Organization anti-tuberculosis chemotherapy (Isoniazide, Rifampicin, Ethambutol, Pyrazinamide) on a massive bilateral

gluteal abscess due to sacral tuberculosis in patient resulted a good response in germs eradication with clinical improvement seen from loss of pain and swelling on both buttocks, laboratory improvement with declined erythrocyte sedimentation rate and C-reactive protein value, and from radiological evaluation demonstrates resorption of massive gluteal abscess.

**Conclusion:** This case report describes sacral tuberculosis which rarely found in the global, which often mischaracterized as a bone malignancy in the early course of the disease. And the treatment must be based on the patient's problems to decide whether conservative, operative, or combination of both is the best choice for the patient.

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### Risk Factors for Immediate Endplate Injury after Minimally-Invasive Lateral Lumbar Interbody Fusion

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**Purpose:** To identify risk factors for immediate endplate injury (EpI) after minimally-invasive lateral lumbar interbody fusion (MIS-LLIF)

**Materials and Methods:** One hundred and eighty-six patients underwent MIS-LLIF and posterior instrumentation for degenerative lumbar diseases with one-staged or two-staged manner between 2012 and 2017. All surgeries were performed with the same manner by a single surgeon. Age, sex, body mass index, and bone mineral density were recorded. On preoperative standing X-ray, coronal disc angle, and each sagittal disc angle in neutral, flexed, extended positions were measured. Also, anterior and posterior disc heights were measured on lateral neutral X-ray. Other radiographic parameters including osteophyte formation, Kellgren-Lawrence grading, facet degeneration grading, and endplate sclerosis were assessed. EpI was recorded on immediate postoperative X-ray. All parameters were analyzed statistically regarding endplate injury at each disc level.

**Results:** Three hundred and seventy-four discs underwent MIS-LLIF in 186 patients and 104 levels (27.8%) showed EpI. Among them, 92 had single-side injury and 12 had both-side injury. One case with two adjacent EpI showed

vertebral body fracture leading to early revision. The incidences were similar for each level. When periodic analysis was performed for each 100 levels, and the incidences were steady from the first period to the last one. Multivariate regression analysis demonstrated that sagittal disc angle in extension was correlated with EpI ( $p=0.024$ ). The receiver operating characteristic curve analysis demonstrated that the optimal cutoff value of sagittal disc angle in extension was  $4.3^\circ$ .

**Conclusion:** The incidence of EpI was 27.8% and showed steady tendency. The smaller sagittal disc angle in extension was correlated with EpI. Immediate postoperative EpI seemed not to be procedure-related, but to be patient-related. When performing MIS-LLIF, spine surgeons should check X-ray thoroughly and pay more attention to cases with sagittal disc angle in extension less than  $4.3^\circ$ .

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### Investigation of the Patients Who Were Not Satisfied with Lumbar Surgery at an Early Stage: The Follow-up Rate and Patient Satisfaction at 1 Year after Lumbar Surgery

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**Purpose:** Follow-up rate of patients who were not satisfied at an early stage after lumbar surgery and patient satisfaction at 1 year were compared with those of patients who were satisfied at an early stage.

**Materials and Methods:** In this study, 392 patients who underwent lumbar surgery were enrolled. To evaluate patient satisfaction, an original questionnaire was evaluated around 1 month after surgery. Among 392 patients, 26 patients who answered not satisfied were selected as subject. As control, sex-age-surgical procedure matched 52 patients who answered satisfied were selected. The patients who were not satisfied at early stage after surgery were classified as group A and the patients who were satisfied were classified as group B. Follow-up rate and patient satisfaction using an original questionnaire were evaluated at 1 year after surgery and compared between two groups.

**Results:** Follow-up rate was 73.1% (19 patients and 26 patients) in group A and 94.2% (49 patients and 52 patients) in group B ( $p<0.01$ ). Among group A, 19 patients completed the 1-year follow-up and among group B, 44

patients completed. In group A, 68.3% (13 patients and 19 patients) answered satisfied (1: satisfied or 2: moderately satisfied) and 89.8% (49 patients and 52 patients) answered satisfied (1: satisfied or 2: moderately satisfied) in group B.

**Conclusion:** Follow-up rate of the patients who were not satisfied at an early stage was 73.1% at 1 year. Among the patients who were not satisfied at an early stage after lumbar surgery, 68.3% were satisfied at 1 year.

## Correlation Study Between buttoning Sign and Severity in Patients with Degenerative Cervical Myelopathy

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**Purpose:** Degenerative cervical myelopathy (DCM) is defined as dysfunction of the spinal cord by extrinsic compression that caused by degenerative diseases of the cervical spine. Hand dysfunction from DCM strongly affects patient's daily living. Difficulty buttoning the button is common main complaint of DCM patients. Purpose is to define the correlation of the time for buttoning the button and severity of DCM patients that evaluated by using the modified Japanese Orthopaedic Association Scale (mJOA).

**Materials and Methods:** Forty-five DCM patients were divided into mild, moderate, and severe groups by mJOA score. All patients were asked to perform buttoning the button, then time consumption was recorded. Spearman rank correlation coefficient was used to study the correlation between time for buttoning and severity groups of DCM patients.

**Results:** There were 19 patients in mild group, 19 patients in moderate group, and seven patients in severe group. The correlation of time consumption to perform buttoning the button and mJOA score was moderate negative relationship ( $r=-0.65$ ,  $p<0.001$ ). The correlation of time consumption to perform buttoning the button and motor dysfunction score of the upper extremities in mJOA score was strong negative relationship ( $r=-0.72$ ,  $p=0.0002$ ).

**Conclusion:** For these preliminary results, time to perform buttoning the button significantly has moderate negative

correlated with mJOA score but significantly strong negative correlated with motor dysfunction score of the upper extremities in mJOA score.

## Correlation between Non-specific Chronic Low Back Pain and Psychosocial Factor in Elderly Patients over the Age of 75 Years: A Multicenter Questionnaire Study

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**Purpose:** To investigate the correlation between non-specific chronic low back pain (NCLBP) and psychosocial factor in elderly patients over the age of 75 years using patient-based questionnaire.

**Materials and methods:** One hundred and eighty patients who suffered from NCLBP were enrolled in this study. Clinical outcomes were evaluated by the VAS for low back pain (LBP), the EuroQol-5D (EQ-5D), and the Japanese Orthopaedic Association back pain evaluation questionnaire (JOABPEQ). Social factors were evaluated by the rate in utilization of long-term care insurance and the rate in improvement of life environment. Psychological factor was evaluated by the Brief Scale for Psychiatric Problems in Orthopaedic Patients (BS-POP), and patients were divided into two groups: psychological (P) group and normal (N) group according to the score of the BS-POP.

**Results:** The mean VAS for LBP was  $55.8 \pm 16.0$  mm and the mean score of the EQ-5D was  $0.622 \pm 0.148$ . There were significant positive correlations between the subscale for social life disturbance ( $r=0.55$ ,  $p<0.01$ ) or mental health problem ( $r=0.67$ ,  $p<0.01$ ) in the JOABPEQ and the score of EQ-5D. The rate in utilization of long-term care insurance was 19.4% and in improvement of life environment was 28.3%. For the sub-analysis between the P group and the N group, no significant difference was found in the

clinical outcomes, though the rate of social factors in the P group were higher than in the N group.

**Conclusion:** There was a significant correlation between psychological disorders related to NCLBP and physical deconditioning, and the NCLBP patients with psychological disorders may be severely dependent. It is necessary for elderly patients to improve the approach to NCLBP treatment on the basis of life environment.

## Polyetheretherketone Cage in Minimally Invasive Transforaminal Lumbar Interbody Fusion Subsidence Incidence, Risk Factors, and Clinical Outcomes

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**Purpose:** The minimally invasive transforaminal lumbar interbody fusion (TLIF) is a currently popularized as safe and effective procedure to achieve a circumferential fusion. Cage subsidence after posterior lumbar interbody fusion (PLIF) has been reported by several authors. However, there are few reports describing clinical and radiological results of polyetheretherketone (PEEK) cage subsidence after minimally invasive transforaminal lumbar interbody fusion (TLIF).

**Materials and Methods:** A total of 124 consecutive patients who had undergone minimally invasive TLIF using PEEK cage with minimum follow-up of 1 year were included in this study. Clinical evaluation was performed by the analysis of Visual Analog Scale score and Oswestry Disability Index. They were radiologically evaluated at the postoperative, 1-month, 3-month, 6-month, 1-year, and last follow-up radiographs and computed tomography scans (when available). Cage subsidence was diagnosed, if the cage sank into the adjacent vertebral body by 2 mm or more compared with previous radiographs. Logistic regression analysis was conducted to explore relations between these variables and cage subsidence.

**Results:** Sixteen cases (12.9%) of cage subsidence were found in this study. Cage subsidence occurred within  $7.2 \pm 8.5$  months (range, 1–24 months). There were no significant differences between subsidence group and non-subsidence group for the evaluation of clinical outcomes. For radiological evaluation, there were no significant dif-

ferences between two groups except level of fusion. The odds ratio for the significant risk factors were 1.950 (95% confidence interval, 1.001–4.224) in L5–S1 level.

**Conclusion:** Our study of the PEEK cage subsidence in minimally invasive TLIF showed a favorable subsidence rate compared with other methods. The incidence of cage subsidence was statistically higher L5–S1 level compared with other lumbar levels. Further studies and analysis of multiple correlation are needed to determine mechanism of these subsidence.

## Magnetic Resonance Imaging Signal-Intensity Change at the Stage of Fresh Vertebral Fracture

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**Purpose:** Magnetic resonance imaging (MRI) signal intensity is often used to predict complications of vertebral fracture, namely pseudoarthrosis and progression of vertebral collapse. However, the change in signal intensity with time has not been reported; hence, we investigated MRI signals of fresh vertebral fractures to assess such signal-intensity changes.

**Materials and Methods:** We retrospectively investigated MRI signal intensity using images taken within 1 month of fresh vertebral fractures in 70 patients. The patients were divided into groups according to the time images were taken: 0 to 10 days (early), 11 to 20 days (middle), and 21 to 30 days (later). Signal intensity was classified as confined or diffuse low-signal intensity on T1–WI and confined or diffuse low or confined high signal intensity on T2–WI. For the 15 patients who had an MRI twice within a 1-month-interval, the difference in signal intensity change was also investigated.

**Results:** The rates of confined low signal intensity were 41%, 13%, and 13%, and those of diffuse low-signal intensity were 59%, 87%, and 87% on T1–WI (early, middle, and later periods, respectively). The rates of the signal intensities on T2–WI were as follows (early, middle, and later periods, respectively): normal, 19%, 6%, and 0%; confined low, 40%, 41%, and 63%; confined high, 24%, 29%, and 0%; and diffuse low, 17%, 24%, and 37%. Diffuse low pattern occurrence increased with time on T1–WI

and T2–WI. When MRI scans taken twice within a month interval were compared, more than half of the MRI signals were changed, and all of them became low-intensity diffuse signals on both T1–WI and T2–WI.

**Conclusion:** The MRI signal intensity of the fresh vertebral fractures changed with time. MRIs taken later tend to show diffuse low signal on both T1–WI and T2–WI even in the images taken at the stage of fresh vertebral fracture.

## Expanded Indication and Application of Minimal Invasive Direct Lateral Interbody Fusion

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**Purpose:** We introduce minimal invasive direct lateral interbody fusion (DLIF), one of lateral retroperitoneal transpsoas approach including advantages of anterior and posterior surgery, and present about application and indication of DLIF.

**Materials and Methods:** Case 1: A 78-year-old female had severe central and foraminal stenosis on L2–3–4–5. First, DLIF was performed from L2 to L5. After DLIF surgery, patient's symptom improved. And then, only posterior fixation was done. Case 2: A 86-year-old female had the degenerative scoliosis and severe central and foraminal stenosis on L3–4–5. First, DLIF was performed from L3 to L5. After DLIF surgery, patient's symptom improved. And then, posterior decompression and posterior fixation were done. Case 3: A 70-year-old male had the pseudoarthrosis on L4–5. On past history, the patient was operated by L2 anterior corpectomy and mesh cage insertion and posterior fusion from T12 to L5 because of L2 burst fracture. DLIF was performed L4–5. After DLIF surgery, patient's symptom improved. Case 4: A 75-year-old female had the infective spondylitis on L3–4. Lateral retroperitoneal transpsoas curettage and drainage using DLIF system were performed, and then, posterior fixation were done.

**Results:** The application and indication of DLIF have been expanded to degenerative disc disease, spinal stenosis, degenerative scoliosis, nonunion, trauma, infection, spondylolisthesis, etc. based on the technical development. However, severe spinal stenosis, vascular abnormality, significant spondylolisthesis, previous retroperitoneal

surgery, and severe collapsed disc space were contraindication.

**Conclusion:** DLIF merges the advantages and covers the disadvantages of anterior and posterior surgery. Additionally, DLIF can be minimized bleeding by smaller incision and lessen the pain after surgery. However, approach-related complication and L5–S1 approach were remained obstacles though many efforts including surgery checking the passage of lumbar plexus in psoas muscle with neuro-monitoring.

## Cortical Bone Trajectory Pedicle Screws to Treat Lumbar Pyogenic Spondylodiscitis

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**Purpose:** To assess the efficacy of a cortical bone trajectory pedicle screw (CBT-PS) for the treatment of lumbar pyogenic spondylodiscitis.

**Materials and Methods:** Eight patients with single segment lumbar pyogenic spondylodiscitis were analyzed. At first, anterior debridements and interbody fusions were performed with autogenous strut bone grafts, followed by posterior fixations and fusions with CBT-PS. The lordotic angles of operated levels were checked at the preoperative, postoperative, and final follow-ups. Visual Analog Scales (VAS) were checked at the preoperative and final follow-ups.

**Results:** Lesion sites were found at four L3–4, three L4–5, and one L2–3. Follow-ups were held at 26.13±8.23 months. The lordotic angles at preoperative, postoperative, and final follow-ups were 12.13°±3.09°, 14.63°±3.16°, and 12.75°±3.99°, respectively. There were significant differences between results from the preoperative-postoperative and postoperative-final follow-ups. There was no difference in the preoperative-final follow-up. There was a significant difference between the VAS at the preoperative and final follow-ups (8.13±0.83 and 2.38±0.92, respectively). Complete bony unions were observed at the final follow-up in all cases.

**Conclusion:** The advantages of using a CBT-PS for lumbar pyogenic spondylodiscitis included the ability to minimize damage from the screw for both the posterior struc-

ture damage and the operated anterior area to prevent instability and deformity, and to achieve rigid bone union. CBT-PS is a potential surgical option for pyogenic spondylodiscitis.

## Strategy of Lumbosacral Instability

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**Purpose:** L5/S interbody fixation tend to have more trouble cases than upper level fixation, especially multilevel fixation including lumbosacral. However, lower two level degenerations sometimes occur and the choice of lumbosacral fusion may be difficult. Particularly, in the cases with L5 radiculopathy, it is often difficult to choose L4/5 fixation, L5/S fixation, or nerve root decompressions. This study aims to assess the cases with or without L5/S fusion and to know which is better procedure L4/5/S fusion or L4/5 fusion and L5/S decompression.

**Materials and Methods:** We assigned 17 operation cases and followed up longer than 1 year. We preformed L4/5 interbody fusions. Nine cases were L5/S fusion (transforaminal lumbar interbody fusion, TLIF) that the mean age was 68 years (range, 25–86 years) and mean follow-up period was 1 year 8 months (range, 1–3 year). 8 cases were L5/S decompression without fusion that the mean age was 57 years (range, 46–68 years), mean follow-up period was 1.1 year (range, 1.5–3 years). Eight cases of L5/S were muscle preserving interlamina decompression without fusion (n=4) and foraminal decompression (n=4). Outcome measures included the assessment of bone union, the change of L1 to sacral spondylolisthesis, range of motion in flexion and extension, and disc height and disc generation from 1 year after surgery.

**Results:** In L5/S fusion group, five cases (56%) had bone union both L4/5 and L5/S, and the remaining four cases did not have bone unit neither L4/5 nor L5/S. Two cases worsened L3/4 spondylolisthesis and L3/4 disc degeneration occurred for three cases. No cases changed range of motion in flexion and extension and disc height. In L5/S decompression group, seven cases (86%) had bone union at L4/5. One case worsened L3/4 spondylolisthesis but no cases degenerated post-surgical intervertebral disc change. No cases changed range of motion in flexion and extension

and disc height. Either case did not need reoperation.

**Conclusion:** This study shows lower two level fusion tend to delayed union. Furthermore, avoiding lower two fixations is better for adjacent level disorder.

## Variations in Matrix Metalloproteinase Expression by Disc Location in Patients with Sequestered Lumbar Disc Herniation

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**Purpose:** To evaluate variations in matrix metalloproteinase (MMP) expression levels according to the disc location in patients with sequestered lumbar disc herniation.

**Materials and Methods:** The sequestered and contained disc materials were removed from seven patients with sequestered lumbar disc herniations. The materials from the contained discs were classified into group 1 and those of the sequestered discs into group 2. Immunohistochemistry tests were conducted for the tissues of both groups. The expression levels of MMP-1, 3, and 13 were checked using a fluorescence microscope. The amount of expression of each MMP was calculated using the percentage of expressed cells and analyzed statistically.

**Results:** In the histological study, increased expression of MMP-1, 3, and 13 was found in group 2. In the statistical analysis after the quantification of MMP expression, the expression of all MMPs was found to have increased significantly in group 2 ( $p < 0.05$ ).

**Conclusion:** The increased expression of MMP-1, 3, and 13 indicated that the inflammation and degeneration processes, and the spontaneous resorption by the surrounding tissues were more active in the sequestered disc group than in the contained disc group.

## Do Thoracic Inlet Parameters Predict Pulmonary Dysfunction in Thoracic Kyphoscoliotic Deformities?: A Cross-Sectional Analysis

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**Purpose:** Kyphoscoliotic thoracic curves cause pulmonary dysfunction and reduction in thoracic cage volumes resulting in early respiratory failure. This study aims to analyze the predictive effect of thoracic inlet dimensions on pulmonary dysfunction with varying curve magnitude and thoracic cage parameters.

**Materials and Methods:** Eighty patients excluding patients younger than 8 years, with congenital cardiopulmonary disease, curves less than 30°, and all lumbar curves were divided into three groups based on Cobb's angle 31°–50°, 51°–80°, and >80°. Two thoracic inlet indices (TII) were measured in magnetic resonance imaging, anatomical at manubrium level (TII A) and at the innominate crossing (TII I) compared with 20 age-matched controls. Correlation analysis of TII with pulmonary function (forced expiratory volume in 1 second [FEV1]/forced vital capacity [FVC]) and thoracic cage parameters was done.

**Results:** Mean age was 14.91 years and the etiology included congenital deformity in 34 patients (42.5%) and AIS in 32 patients (40%). Mean Cobb's angle was 69.8°±14.96°. Mean TII A was 3.72±0.91 (maximum 7.35 in group 3 and minimum 1.84 in group 1); mean TII I was 3.27±1.64. In controls, mean age was 12.94 years, mean TII A was 3.23±0.43, and TII I of 3.39±0.52. Mean FEV1 was 70.5±11.1, mean FEV1/FVC of 1.05±0.03 with moderate restrictive pattern in group 3 congenital curves ( $p<0.001$ ) as compared to mild impairment in group 2. Moderate to severe respiratory dysfunction was observed in TII I >5.6 in group 3 curves with thoracic hypokyphosis. Curve apex between T1–T4 had a significant correlation with worsening pulmonary function test and curve angle. Transverse thoracic diameter, hemithorax height, and rib–apex distance were weak predictors.

**Conclusion:** TII >5.6 compared to age-matched controls was found to be a strong predictor of pulmonary impairment in proximal thoracic curves >80°. The probability is weak with height of hemithorax on convex side, rib–apex

distance, and thoracic diameter.

## A Child with a Rare Extraosseous Extension and Pathologic Fracture from a Vertebral Hemangioma: A Case Report

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**Purpose:** We present a case of a pathologic vertebral fracture and encroachment into the spinal canal from a vertebral hemangioma in a 13-year-old boy.

**Materials and Methods:** The case was reported and literature was reviewed.

**Results:** The original approach of embolization followed by an anterior-posterior resection and stabilization through a costotransversectomy had to be converted intraoperatively to a combined anterior and posterior approach secondary to excessive bleeding.

**Conclusion:** Because of the hypervascularity and the extensive nature of aggressive vertebral hemangiomas, surgeons attempting procedures similar to the case described herein must be prepared to adapt to the circumstances when preoperative embolization is not totally effective. Surgical technique, proper anesthesia, and patient clotting capacity are important factors to consider.

## Analysis of Radiologic Risk Factors for Progression of Early Degenerative Lumbar Scoliosis

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**Purpose:** This study was to determine the radiologic risk factors associated with the progression of early degenerative lumbar scoliosis.

**Materials and Methods:** Fifty-one patients having early degenerative lumbar scoliosis with Cobb angle between ≥5° and <15° were reviewed. Subjects (18 men and 33 women; mean age, 60.6 years) were observed for a mean period of 13.7 years. The radiological evaluation included

(1) direction of the scoliosis, (2) apical vertebra level, (3) rotation grade of apical vertebra, (4) lateral listhesis, (5) disc index, (6) osteophyte difference, (7) wedging angles in upper and lower disc, and (8) the relationship between the interest line and L5 vertebra. Subjects were divided into two groups depending on progression of Cobb angle  $\geq 15^\circ$  at the final follow-up, and their risk factors were analyzed.

**Results:** During the follow-up period, the mean Cobb angle was increased  $10.9^\circ$  from  $8.9^\circ$  to  $19.8^\circ$ . The progression of Cobb angle having greater than  $15^\circ$  developed in 17 patients (33.3%) at the final follow-up. The initial baseline of lateral listhesis, disc index, and wedging angles in upper and lower disc were significantly different between the group with progression of Cobb angle  $\geq 15^\circ$  and the group with progression of Cobb angle  $< 15^\circ$ . In the multiple logistic regression analysis, only the wedging angles in upper and lower disc of apical vertebra showed significant relationship with curve progression (odds ratio, 1.55;  $p=0.030$ ).

**Conclusion:** Asymmetrical change in upper and lower disc of apical vertebra is a substantial factor in predicting the progression of early degenerative lumbar scoliosis.

## Lumbar Epidural Varix Causing Radicular Pain: A Case Report and Differential Diagnosis of Lumbar Cystic Lesions

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**Purpose:** We report a case of acute lumbar radicular pain caused by an epidural varix. We also review the similarities and differences among the magnetic resonance imaging (MRI) characteristics of varying cystic lesions.

**Materials and Methods:** A 36-year-old woman presented with a 10-day history of severe radiating pain in the right medial calf area. The symptoms occurred spontaneously and the patient had no prior history of lumbar spine or sciatic problems. Lumbar MRI revealed a cystic lesion in the ventral epidural space posterior to the right L4 body appearing as hyperintense on T2-weighted imaging scans and hypointense with thin rim enhancement on T1-weighted imaging scans. The differential diagnosis of

this lesion included a herniated disc, perineural or facet synovial cyst, abscess, hematoma, and malignancy. After detailed assessment of the MRI characteristics and clinical manifestations, we strongly suspected that this lesion was an epidural varix.

**Results:** An L3–L4 laminotomy was performed, and the mass was located in the ventral epidural space. We observed that the epidural varix was causing compression of the dural sac and right L4 nerve root. The engorged vein was gradually coagulated using bipolar electrocautery several times to prevent massive bleeding. This coagulated epidural varix was removed and its histopathology was confirmed. The patient's symptoms improved immediately following surgical removal. Postoperative MRI showed that the lesion was completely removed. The patient was followed postoperatively for 10 months and remained symptom free.

**Conclusion:** Physicians will benefit from increased awareness of epidural varices as a cause of lumbosacral radicular pain and the associated radiologic findings supporting differential diagnosis. In particular, careful interpretation of MRI scans may help ensure proper diagnosis of an epidural varix versus other cystic lesion.

## A Correlation Study of Standing Magnetic Resonance Imaging Findings and Multilevel Stenosis Symptoms

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**Purpose:** Spinal stenosis has shown improved clinical correlation with findings of standing magnetic resonance imaging (MRI). However, the impact of multilevel stenosis was unknown. We assessed the clinical relationship of dural sac cross sectional area (DSCA) and multilevel stenosis in this prospective study.

**Materials and Methods:** Sixty-eight patients with neurogenic claudication were included to undergo a 0.25-T MRI exam performed in supine and standing positions. Clinical features including body mass index (BMI), duration, walking distance, leg pain Visual Analog Scale, Chinese Oswestry Disability Index, and 12-item Short-Form Health Survey were assessed. DSCA of the most constricted and the next stenotic levels were measured and correlated with each feature by correlation coefficients ( $r$ ).

The number of stenosis levels with DSCA  $\leq 75$  mm<sup>2</sup> and the presence of spondylolisthesis were studied.

**Results:** Standing MRI diagnosed 22% more cases of multilevel stenosis than supine MRI. Dynamic narrowing of dural sac on standing happened in multilevel stenosis as in overall spinal stenosis ( $r=0.88$ ,  $p<0.0001$ ). DSCA at the most constricted level was smaller on standing MRI than on supine MRI ( $r=0.79$ ,  $p<0.0001$ ). This is also true the next stenotic level ( $r=0.69$ ,  $p<0.0001$ ). Shorter walking distance correlated with smaller DSCA in either single-level stenosis ( $r=0.44$ ,  $p=0.005$ ) or multilevel stenosis ( $r=0.45$ ,  $p=0.014$ ). The minimal DSCA associated with BMI ( $r=-0.44$ ,  $p=0.018$ ) and duration of symptom ( $r=-0.41$ ,  $p=0.027$ ) only in multilevel stenosis patients. Smaller DSCA in the next stenotic level correlated with worse leg pain ( $r=-0.41$ ,  $p=0.027$ ). Patients with multilevel stenosis showed less disability ( $r=-0.27$ ,  $p=0.025$ ) despite having smaller DSCA than patients with single-level stenosis ( $p<0.0001$ ).

**Conclusion:** Standing MRI is efficient to uncover multilevel stenosis with limited walking ability. The significant correlations of BMI, duration, and less functional disability with multilevel stenosis reflect the dural-sac adaptation capability for chronic compression. Since the next stenotic level associated with radicular leg pain, better-defined diagnosis of multilevel stenosis influences surgical outcome.

## Biportal Arthroscopic Discectomy for High-Grade Migrated Lumbar Disc Herniation

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**Purpose:** Although endoscopic procedures for lumbar disc herniation have improved greatly and offers many advantages, its application in herniated disc with migration is still challenging and technically demanding. The purpose of this study was to determine feasibility of biportal arthroscopic discectomy for removal of high-grade migrated disc herniation.

**Materials and Methods:** A retrospective review was performed on 131 patients who had undergone biportal arthroscopic discectomy under the diagnosis of lumbar herniated disc. According to preoperative magnetic resonance imaging findings, disc herniation was classified into five zones based on the direction and distance from

the disc space. Patients were divided into two groups: high-grade migration group and low-grade or non-migration group. Operation time was compared between two groups. Clinical outcomes were assessed by Oswestry Disability Index (ODI), Visual Analog Scale (VAS), and modified Macnab criteria.

**Results:** There were five high-grade up, four low-grade up, 49 disc level, 51 low-grade down, and 22 high-grade down patients; making high-grade group 27 patients and low-grade group 104 patients. Demographic data of two groups showed no significant difference. Operation time between the two groups were not different significantly (60.74 minutes vs. 65.63 minutes,  $p>0.05$ ). Satisfactory results were obtained in all cases in both groups. There was no significant difference between two groups in ODI, VAS, and Macnab criteria.

**Conclusion:** Biportal arthroscopic discectomy can be effective for high-grade migrated lumbar disc herniation with no longer operation time and satisfactory clinical outcomes.

## Minimally Invasive Lateral Lumbar Interbody Fusion for Clinical Adjacent Segment Pathology: A Comparative Study with Conventional Posterior Lumbar Interbody Fusion

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**Purpose:** Minimally invasive techniques have been increasingly applied for spinal surgery. No report has compared lateral lumbar interbody fusion (LLIF) with conventional posterior lumbar interbody fusion (PLIF) for clinical adjacent segment pathology (ASP). The purpose of this study is to evaluate the clinical and radiological efficacies of minimally invasive LLIF for clinical ASP.

**Materials and Methods:** Forty patients undergoing LLIF with posterior fusion (hybrid surgery) were compared with 40 patients undergoing conventional PLIF (posterior surgery). The radiological outcomes including indirect decompression in hybrid surgery group, and clinical outcomes such as the Oswestry Disability Index (ODI) and Visual Analog Scale (VAS) were assessed. Postoperative

major complications and reoperations were also compared between the two groups.

**Results:** Correction of coronal Cobb's angle and segmental lordosis in the hybrid surgery were significantly greater postoperatively ( $2.8^\circ$  vs.  $0.9^\circ$ ,  $p=0.012$ ;  $7.4^\circ$  vs.  $2.5^\circ$ ,  $p=0.009$ ) and at the last follow-up ( $2.4^\circ$  vs.  $0.5^\circ$ ,  $p=0.026$ ;  $4.8^\circ$  vs.  $0.8^\circ$ ,  $p=0.016$ ) compared with posterior surgery. Regarding indirect decompression of the LLIF, significant increases in thecal sac ( $83.4 \text{ mm}^2$  vs.  $113.8 \text{ mm}^2$ ) and foraminal height ( $17.8 \text{ mm}$  vs.  $20.9 \text{ mm}$ ) were noted on postoperative MRI. Although postoperative back VAS ( $4.1$  vs.  $5.6$ ,  $p=0.011$ ) and ODI ( $48.9\%$  vs.  $59.6\%$ ,  $p=0.007$ ) were significantly better in hybrid surgery, clinical outcomes at the last follow-up were similar. Moreover, intra-operative endplate fractures developed in 17.7% and lower leg symptoms occurred in 30.0% of patients undergoing hybrid surgery.

**Conclusion:** Hybrid surgery for clinical ASP has advantages of segmental coronal and sagittal correction, and indirect decompression compared with conventional posterior surgery. However, LLIF related complications such as endplate fracture and lower leg symptoms also developed. LLIF should be performed considering advantages and approach related complications for the clinical ASP.

## Novel Radiographic Parameters for the Assessment of Total Body Sagittal Alignment in Adult Spinal Deformity Patients

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**Purpose:** To develop and validate novel radiographic parameters that better describe total body sagittal alignment (TBSA).

**Material and Methods:** One hundred and sixty-six consecutive operative spinal deformity patients were evaluated using full-body stereoradiographic imaging. Seven TBSA parameters were measured and then correlated to six commonly used spinopelvic measurements. TBSA measures consisted of four distance measures relating

the cranial center of mass (CCOM) to the sacrum, hips, knees, and ankles, and three angular measures relating the CCOM to the hips, knees, and ankles. Furthermore, each TBSA parameter was correlated to patient-reported outcome (PRO) scores using the Oswestry Disability Index (ODI) and Scoliosis Research Society-22 (SRS-22) instruments. Thirty patients were randomly selected for inter- and intra-observer reliability testing of the TBSA parameters using intra-class correlation coefficients (ICC).

**Results:** All TBSA radiographic parameters demonstrated strong linear correlation with the currently-accepted primary measure of sagittal balance, the C7 sagittal vertical axis ( $r=0.55-0.96$ ,  $p<0.001$ ). Moreover, five of seven TBSA measures correlated strongly with ODI and SRS-22 total scores ( $r=0.42-0.51$ ,  $p<0.001$ ). Inter- and intra-observer reliability for all TBSA measures was good to excellent (inter-rater ICC= $0.70-0.98$ , intra-rater ICC= $0.77-1.0$ ).

**Conclusions:** In spine deformity patients, novel TBSA radiographic parameters correlated well with PROs and with currently-utilized spinal sagittal measurements. Inter- and intra-rater reliability was high for these novel parameters. This is the first study to propose a reliable method for measuring head-to-toe global spinal alignment.

## Dengue Fever with Intraspinal Hematoma

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**Purpose:** Dengue is an arboviral disease transmitted by *Aedes* sp. mosquitoes. A wide spectrum of illness is observed, ranging from dengue fever to dengue shock syndrome. Haemorrhagic complications due to thrombocytopenia can result in various neurological sequelae. Apart from these, intraspinal hematoma are rare and those associated with dengue fever are still rarer. We report a case of dengue fever with spontaneous spinal hematoma.

**Materials and Methods:** A 62-year-old lady with underlying diabetes melitus presented with moderate grade fever with arthralgia for 5 days. On admission, patient complained of bilateral lower limbs weakness and numbness. On examination, patient was found to have Medical Research Council power grade 0 from L2-L5 with sensory lost from L1 onwards for 3 days. The knee and ankle reflexes were absent and anal tone was lax with reduce

perianal sensation. Magnetic resonance imaging (MRI) spine showed spinal hematoma at the level of T11 to L1. A diagnosis of acute intraspinal hematoma at T11–L1 was made. Patient underwent emergency posterior decompression with laminectomy of L1. Currently postoperative 5 months, patient is currently under spine rehabilitation, however still no recovery in neurological deficit.

**Results:** Early diagnosis of spontaneous intraspinal hematoma is crucial to planning of surgical decompression. Domenicucci and his colleagues revealed that the outcomes are poor in 58% of the cases. The outcome depends on preoperative comorbidities, time to surgery, and neurological deficit. In patients with neurology and imaging evidence, surgery to decompress the hematoma is the best treatment. Domenicucci and his colleagues said that functional recovery is good if the condition was treated prior to development of irreversible neurological deficits. This case had significant preoperative neurological deficits and despite best efforts, the outcome remain poor.

**Conclusion:** Acute spontaneous intraspinal hematoma is rare but should be kept in one's thought in patients with dengue hemorrhagic fever. A MRI should be used to establish the diagnosis and outcomes are guarded and elaborate patient counseling preoperatively should be done.

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## A Novel Surgical Technique for the Treatment of Thoracic Myelopathy Caused by Ossification of Ligamentum Flavum

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**Purpose:** This study aimed to introduce a novel surgical technique for thinning, peeling, and carving to remove the ossification ligamentum flavum (OLF) nidus for the treatment of thoracic myelopathy caused by OLF.

**Materials and Methods:** Thoracic myelopathy caused by OLF was diagnosed in 36 patients using plain radiography, three-dimensional computed tomography, and magnetic resonance imaging from January 2009 to January 2016. The lamina and the lower and the upper facet joint of the involved segment were thinned with a bigger neuro drill (diameter=3.5 mm). The shell was so thin that the feeding blood vessels of the dura can be seen clearly. Secondly, the thinned shell was peeled off with the curette piece by piece. The upper facet joint and the

OLF nidus were carved by the smaller neuro drill (diameter=2.5 mm), and the thinned bony nidus compressing the spinal cord was removed finally. Spinal cord monitoring (somatosensory evoked potential and motor evoked potential) was performed intraoperatively in all cases. The operating time and blood loss were recorded during the operation. The modified Japanese Orthopedic Association (m-JOA) scoring system was used to assess the neurological status before the operation and in the follow-up. The 36-item Short-Form Health Survey was also used to assess the general health status.

**Results:** Among 36 cases with OLF, three were single level, nine were double level, and 14 were multilevel. Of the 65 ossified segments in this study, 15 (23.0%) were located in the upper thoracic spine (T1–4), eight (12.3%) were located in the midthoracic spine (T5–8), and 42 (64.6%) were located in the lower thoracic spine (T9–L1). The mean operating time was  $145 \pm 32$  minutes, and the mean intraoperative blood loss was  $280 \pm 48.6$  mL. The neurological status improved during follow-up (mean=46.1 months) from a preoperative mean m-JOA score of  $5.39 \pm 1.52$  to  $8.97 \pm 1.22$  points ( $t=18.39$ ,  $p<0.05$ ). The neurological function recovery rate ranged from 28.6% to 100%.

**Conclusion:** Thinning, peeling, and carving were used in our technique as being effective and safe, and the proposed surgical method is a reasonable choice

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## Topical Use of Tranexamic Acid in Reducing Blood Loss during Lumbar Spinal Surgery: A Retrospective Case Control Study and Low Cost Strategy

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**Purpose:** Spinal surgeries are associated with significant blood loss leading to perioperative anaemia and increased need for allogenic transfusion. Perioperative topical tranexamic acid (TXA) use can reduce bleeding and transfusion requirements in major spine surgeries, but evidence proving its effectiveness is lacking. In this study we investigated the hypothesis that topical TXA reduces perioperative blood loss in patients undergoing major spine procedures.

**Materials and Methods:** We conducted a retrospective non-randomized case-control study of adults undergoing

single level transforaminal lumbar interbody fusion (TLIF) surgery done by senior author at tertiary care spine center. Study period was from November 2017 to October 2018. TXA as routine was used during May 2018 to October 2018 whereas control group was from November 2017 to April 2018. In the TXA group, wound surface was soaked with TXA (1 g in 100 mL saline solution) for 3 minutes after exposure, after decompression and before wound closure. In the control group, same volume of normal saline was used. The intraoperative and postoperative blood loss, drain at 24 and 48 hours, operative time, and removal time of drainage tube between the two groups were compared using 2 sample *t*-test. Other variables such as preoperative blood parameters and comorbid conditions, were compared across groups and associations with outcome variables were checked using Pearson's correlation coefficient.

**Results:** Two hundred and fifty patients who underwent single level TLIF were enrolled. One hundred and seventy-five received TXA (TXA group) and 75 received normal saline (control). Mean intraoperative blood loss and operative time in control group were  $783.33 \pm 332.71$  mL and  $4.48 \pm 1.58$  hours compared to TXA group,  $410.57 \pm 189.72$  mL and  $2.99 \pm 0.79$  hours, respectively. The mean 24-hour drain was  $167.10 \pm 53.38$  mL and  $107.03 \pm 44.37$  mL for control and TXA group, respectively. Intraoperative blood loss of control group was statistically higher than TXA group ( $p < 0.0001$ ).

**Conclusion:** Topical TXA is cost effective solution for hemostasis in spine surgeries, especially in developing nations.

## Can Cervical Spine Lateral Radiograph Replace Whole-Spine Lateral Radiograph for the Evaluation of Cervical Sagittal Alignment?

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**Purpose:** Standing whole-spine lateral radiograph (WLR) is used to evaluate cervical sagittal balance. However, T1-slope, a key factor influencing balance, is frequently obscured by the shoulder and trunk. Recommended hands-on-clavicle position in WLR affects T1-slope, head position, and cervical lordosis. This study compared

standing cervical lateral radiographs with arms extended to the side (CLR) with WLR in the hands-on-clavicle position. We considered whether CLR can be used instead of WLR to evaluate cervical sagittal alignment.

**Materials and Methods:** We retrospectively reviewed radiographic data of 60 consecutive adult patients (38 males, 22 females; mean age,  $55.6 \pm 1.3$  years) who presented with only neck pain (without radiculopathy or myelopathy). Every patient underwent standing CLR and WLR. The following were measured and analyzed: visibility of T1 slope, T1 slope, C7 slope, C0–C2 Cobb angle (CAC0–C2), C2–C7 Cobb angle (CAC2–C7), and cervical sagittal vertical axis (cSVA).

**Results:** Visibility of the T1 slope was significantly lower with than with CLR (28% vs. 83%,  $p = 0.049$ ). The mean CAC2–C7 on WLR was significantly less lordotic than on CLR ( $11.2^\circ \pm 9.2^\circ$  vs.  $14.3^\circ \pm 11.3^\circ$ ,  $p = 0.01$ ). The mean cSVA was more translated posteriorly on WLR than on CLR ( $9.9 \pm 18.9$  mm vs.  $15.0 \pm 13.4$  mm,  $p = 0.04$ ). However, there was no significant difference in T1 slope, C7 slope or CAC0–C2 between CLR and WLR.

**Conclusion:** This study showed that standing CLR could provide better visualization of the upper endplate of T1 without any difference in the T1 slope compared to that on using standing WLR. Therefore, it would not be necessary to perform repeated WLR for evaluation of cervical sagittal alignment unless there are accompanying thoracolumbar spine lesions on initial examination.

## Preoperative Halo Skeletal Traction for Treatment Severe Scoliosis

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**Purpose:** The surgical treatment of severe scoliosis is challenging and carries substantial risks. To reduce this risk, surgeons can applied preoperative halo-skeletal traction (HST). The safety and effect of deformity correction through HST prior to definite fusion surgery have been proven. However, little is known with respect to the duration of traction and factor related correction rate of HST.

**Materials and Methods:** A total number of 60 patients applied preoperative HST and followed by surgery for the management of severe scoliosis. We retrospectively reviewed clinical and radiographic data. We measured the

correction rate of HST every week and analyzed the change over time. Also, We analyzed the related factors by dividing into two groups depending on the correction rate after HST: low correction group A and high correction group B.

**Results:** A total number of 54 patients treated by preoperative HST followed by posterior fusion and instrumentation. Mean of the Cobb angle improved from  $96.9^{\circ} \pm 14.7^{\circ}$  preoperatively to  $63.3^{\circ} \pm 12.2^{\circ}$  post-traction and  $32.49^{\circ} \pm 11.5^{\circ}$  postoperatively. The major coronal curve corrected 28.2% (change in curve per week/total change in curve), respectively 28.2% at 1 weeks (n=59), 34.0% at 2 weeks (n=58), 33.8% at 3 weeks (n=41), and 32.2% at 4 weeks (n=13). There was a statistically significant difference in traction first and second week (1st,  $p < 0.001$ ; 2nd,  $p < 0.001$ ; 3rd,  $p = 0.244$ ; 4th,  $p = 0.082$ ). In group B were low height (154.9 cm vs. 144.4 cm,  $p = 0.029$ ), low weight (49.1 kg vs. 39.4 kg,  $p = 0.017$ ), high traction/body weight ratio (0.41 vs. 0.47,  $p = 0.025$ ), and more halo-femoral traction (0 vs. 6,  $p = 0.018$ ).

**Conclusion:** In severe scoliosis, safe and effective correction was obtained through preoperative HST. Traction of at least 2 weeks is considered to be necessary to achieve optimal traction. The factors involved in higher correction than the original curvature flexibility were height, weight, traction weight, and traction method. When trying to apply a HST on a rigid severe scoliosis, considering these factors will help.

## Comparison of Clinical and Radiological Outcomes between the Unilateral Biportal Endoscopic Posterior Foraminotomy and Microscopic Posterior Foraminotomy

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**Purpose:** Minimally invasive endoscopic posterior cervical foraminotomy for the treatment of cervical radiculopathy has become increasingly popular. However, the results and prognosis of endoscopic posterior cervical foraminotomy were still poorly studied, and the comparative study on the endoscopic and microscopic approach was very limited. In this study, we hypothesized that the endoscopic approach showed similar clinical results when compared with microscopic surgery and that the risk of complica-

tions and adverse events were less.

**Materials and Methods:** In this study, we conducted a retrospective study of 60 patients, who underwent posterior cervical foraminotomy from March 2015 and January 2018. The patients were divided into two groups according to the surgical methods. Thirty patients underwent endoscopic cervical foraminotomy and 30 patients microscopic cervical foraminotomy. We compared the outcomes between the two groups in terms of operative time, amount of bleeding, duration of hospitalization, use of analgesics, reduction of postoperative pain, postoperative neurological improvement, serum creatine kinase, postoperative radiologic results, and complications.

**Results:** Operative time was shorter in endoscopic group, but did not reach statistical significance ( $p = 0.835$ ). The prevalence of postoperative bleeding, length of hospital stay, postoperative analgesic use, reduction of postoperative pain level, serum creatine kinase, radiographic changes in disc height, and segmental angle in flexion/extension were significantly lower in the endoscopic group than in the microscopic group. The postoperative improvement in neurological symptoms was significantly improved after surgery in both groups, and there was no significant difference between the two groups.

**Conclusion:** This study shows that the endoscopic posterior cervical foraminotomy had advantages in terms of amount of bleeding, pain control, hospital stay, muscle injury, and radiologic improvement than microscopic cervical foraminotomy. However, additional studies on long-term prognosis are needed.

## How Does Long Thoracolumbar Surgical Correction of Adult Spinal Kyphotic Deformity Affect Total Body Sagittal Alignment and Lower Extremity?: Using Full Body Radiograph with EOS

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**Purpose:** The purpose of this study was to elucidate the

correlation of lower extremity compensatory parameters with novel parameters indicating the overall compensatory response using the full body radiograph. In addition, lower extremity compensation was evaluated according to the degree of deformation occurring after surgery.

**Materials and Methods:** Adult spinal deformity patients who had undergone long thoracolumbar fusion were evaluated consecutively. The present study assessed the correlation of preoperative and postoperative changes of lower extremity compensation with the other parameters. Also analysis of variance was used for comparing final postoperative lower extremity radiographic parameters among patient cohorts divided by the degree of deformity correction following surgery.

**Results:** Overall, 103 patients were recruited. The mean age was 54.5 years and the average number of fused vertebrae was 13.3. Preoperative and postoperative SF changes correlated with all angular spinopelvic parameters but not with distant parameters including the C7 sagittal vertical

axis (C7SVA) and cranial sagittal vertical axis (CrSVA) ( $p<0.001$  to  $p=0.001$ ). Preoperative and postoperative SFT changes correlated with all parameters evaluated ( $p<0.001$  to  $p=0.046$ ) except for the knee CrSVA (CrSVA-K). On comparison of final postoperative SF and SFT across matched spinopelvic parameters cohorts, all patient cohort groups manifested a statistically different final SFT or SF, which decreased as the degree of deformation increased ( $p<0.001$  to  $p=0.023$ ), except for final SF with the patient cohort stratified by the C7SVA.

**Conclusions:** The SFT results indicate that preoperative and postoperative changes in knee compensation correlated well with previously accepted spinopelvic parameters and also with total body sagittal alignment, except for CrSVA-K. At the final follow-up, lower extremity radiographic parameters significantly changed gradually as the degree of deformation increased, except when the cohort was stratified by the C7SVA values.