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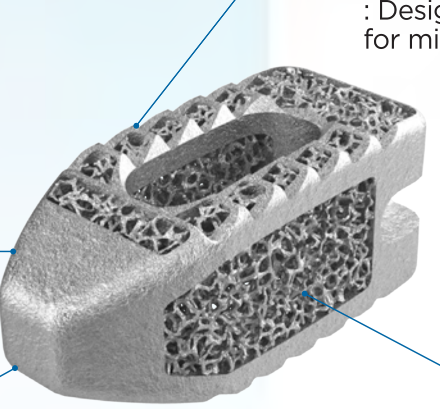

Minimized Sharp Edge

: Designed smooth edge
for minimizing damage

Smooth Wedge-Shaped Design

: Easy Insertion

Bullet-tip Nose

: The nose designed easy to rotational insertion

Interconnected Irregular Porous Structure

: Irregular porous structure provide optimized cellular adhesion and proliferation

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About the Journal

Journal of Korean Society of Spine Surgery is the official journal of Korean Society of Spine Surgery and is published four times year on March 31, June 30, September 30, and December 31. Supplementary abstracts will be published for annual Spring and Fall congress. The Journal is devoted to research and treatment related to the spine surgery and high-quality, ethical, evidence-based spine care, including basic science and clinical investigations. Read the full text of the first ever issue of Journal of Korean Society of Spine Surgery, published on 1 April 1994.

Aims and Scope

Journal of Korean Society of Spine Surgery (J Korean Soc Spine Surg, JKSSS) is an international journal in all fields of basic spine science and spine surgery, including anatomy of the spine, biology, biomechanics and pathophysiology, diagnostic procedures, and neuroscience. The aim of "Journal of Korean Society of Spine Surgery" is to provide an integrated, ethical and balanced view of diagnostic, research and treatment procedures affecting spine specialists worldwide.

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Instructional Course Lecture: Cervical Spine

S001

Upper Cervical Deformities

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Introduction: The upper cervical spine (Occiput-C1-C2) has unique anatomic and biomechanical properties compared to the subaxial cervical spine (C3-C7). Given the less C2-C7 sagittal vertical axis changes, clinical deformity from the upper cervical spine is less prominent than the subaxial or cervicothoracic spine deformities.

Preoperative evaluation

1. Radiographic alignment
   - Normal sagittal alignment of the upper cervical spine is variable and reciprocal to the subaxial cervical spine.
   - In the literature, the occiput-C2 angle is 15–40° but may vary depending on the measurement methods.
   - Chin-brow-vertical angle is an important parameter for fixed cervical deformity, and 10–15° is a recommended angle for most activities of daily living.
   - Preoperative vertical displacement, coronal, and axial malalignment of the upper cervical spine should be evaluated using various imaging studies.
2. Flexibility of the deformity
   - Rigid deformity: when the reduction is achieved with skeletal traction and/or general anesthesia with surgical positioning
   - A fixed deformity will require various types of osteotomy, such as anterior, posterior, etc.
3. Neurological status
   - Myelopathy from spinal cord compression or occipital neuralgia from C2 nerve root compression
   - May originate from segmental instability, bony structure, or inflammatory pannus.

Surgical treatment

1. Fixation: The mainstay is stable and safe fixation of the upper cervical spine, especially for the risk of vertebral artery injury.
   - Occiput fixation: 3 bicortical screw fixation in the midline occiput is a reliable method. A too-anterior plate may cause nonunion; a too-posterior plate increases wound problems.
   - C1 fixation: lateral mass screw using a notch technique or posterior arch screw method. A bicortical screw can provide better pull-out strength.
   - C2 fixation: bilateral pedicle screws, one pedicle screw plus one pars screw, additional translaminar screw for multipoint fixation

2. Intra-articular fusion

- Reliable option to reduce basilar invagination or coronal plane deformity from C1/2
- May use allograft cage for ACDF w/wo BMP or local bone structural graft

3. Osteotomy

- Anterior: via a retropharyngeal approach (in most cases up to the clivus of the occiput), possibly a transoral approach
- Posterior: osteotomy for fixed or ankylosed C1/2 joint

Conclusions: The upper cervical spine deformity may not be as prominent as the cervicothoracic deformity, but should be understood in the context of the entire cervical spine—global spinal balance. More meticulous surgical techniques, including fixation and osteotomy, are required because of the vicinity of the vertebral arteries in the surgical area.

Keywords: Upper cervical spine, Occiput, C1, C2, Cervical deformity

S002

Treatment Strategy for Atlantoaxial Rotatory Fixation (AARF)

Ken Ishii

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Atlantoaxial rotatory fixation (AARF) is one of the most common causes of torticollis in children. Although many acute cases improve spontaneously with conservative

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treatment, prolonged torticollis may result in facet joint deformity and make treatment more difficult. Therefore, accurate diagnosis at the earliest possible stage is essential, as treatment is generally more effective and prognosis is better in the acute phase. In determining the treatment strategy, factors such as age, sex, precipitating events, and clinical findings are considered, in addition to imaging findings obtained from plain radiographs, dynamic CT, and MRI. Among CT findings, important factors include the mobility between C1 and C2 and the presence of bony fusion assessed by reconstructed three-dimensional CT, the presence of facet joint deformity (C2 facet deformity), and the degree of C1 lateral inclination.

We previously reported that C2 facet deformity is a risk factor for recurrence after reduction, and surgical treatment had traditionally been performed in such cases. We also introduced a remodeling therapy in which remodeling of the facet deformity following manual reduction and external fixation was used as a treatment indicator. This method represents the ultimate minimally invasive treatment, and since its development, we have applied it to all indicated cases with favorable clinical outcomes. We have also treated adult-onset AARF using the same strategy. In this lecture, based on our clinical experience, we will present the pathophysiology and treatment strategies for AARF.

Keywords: Atlantoaxial rotatory fixation (AARF), Upper cervical spine, Facet deformity, Pathophysiology, Treatment strategies

S003

Surgical Management of Retrodental Mass Causing Severe Myelopathy

Jin Sup Yeom

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Retrodental soft tissue hypertrophy can be managed with simple C1–C2 fusion in most cases. If the patient does not have quadriparesis, C1–C2 fusion alone followed by observation may be sufficient. In such cases, the mass often regresses spontaneously over time.

However, when the mass causes severe myelopathy or quadriparesis, is fusion alone with observation still appropriate? How long does it take for the mass to regress, if it does so spontaneously? Moreover, can we be certain that regression will occur in all cases? The author has developed surgical strategies for managing retrodental masses associated with severe myelopathy. This lecture will demonstrate these surgical techniques using video presentations.

Keywords: C1-C2, Retrodental mass, Myelopathy, Surgical management

S004

Surgical Strategies for the Management of K-line (–) OPLL Myelopathy

Dong-Ho Lee

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Purpose: Cervical OPLL is a very common cause of cervical myelopathy in Asian populations, and compared with cervical spondylotic myelopathy, it is known to be technically more demanding and associated with a higher rate of complications. In particular, K-line (–) lesions present an additional challenge because both adequate spinal cord decompression and restoration of cervical alignment must be achieved simultaneously. In this lecture, I would like to discuss which surgical strategy may be most appropriate for patients with severe K-line (–) cervical OPLL.

Materials and Methods: I would like to refer to the algorithmic process for determining the surgical treatment of cervical myelopathy recently proposed by myself. This algorithm can be easily applied in clinical practice based on several factors, including the K-line status, number of involved segments, neck pain, segmental instability, and flexibility of the cervical curve. Among these factors, in patients with K-line (–) lesions, important considerations include the number of segments involved by the OPLL, whether the OPLL lesion can be fragmented through discectomy at three segments or fewer, and whether cervical hypo-lordosis or kyphosis can be reduced with posterior instrumentation. Based on these factors, anterior decompression, laminoplasty, laminectomy and fusion, and circumferential procedures can be selectively applied.

Results: For OPLL lesions involving three segments or fewer that can be adequately fragmented, anterior decompression procedures such as ACDF, ACCF, or VBSO should be considered preferentially. In contrast, for continuous or mixed-type OPLL involving more than three levels, laminoplasty may be preferentially considered when the patient has sufficient neck extension capacity. In cases with relatively rigid hypo-lordosis or kyphosis, K-line conversion may be attempted through laminectomy with instrumental reduction. However, when more severe spinal cord compression or kyphotic deformity is present, a circumferential procedure is often unavoidable and may provide the safest surgical option.

Conclusions: The complexity of surgical situations and diversity of treatment methods for K-line (-) OPLL can be effectively managed using an algorithmic approach. Furthermore, surgical techniques that minimize the number of stages and address challenging conditions could enhance treatment outcomes in OPLL.

Keywords: Cervical myelopathy, K-line, Ossification of posterior longitudinal ligament, Vertebral body sliding osteotomy, Surgical treatment

S005

Motion Preserving Surgeries for Cervical Radiculopathy

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Purpose: To review the rationale, advantage, and disadvantage of motion preserving surgeries for cervical radiculopathy based on long-term evidence.

Materials and Methods: Literature review.

Results: Anterior cervical discectomy and fusion (ACDF) is the gold standard for surgical treatment of cervical radiculopathy. However, the drawbacks of ACDF are approach-related complications and fusion-related complications. Especially, adjacent segment pathology in fusion-related complications has been pointed out as a major disadvantage of ACDF. On the other hand, advantages of motion preserving surgeries are preserved range of motion, prevention of adjacent segment pathology, and avoidance of complications related to fusion surgery. Recently, artificial disc replacement (ADR) and posterior foraminotomy (PF) have been popular based on the advantages of motion preserving surgeries. Recent systematic reviews of ADR reported superior clinical outcomes and lower rates of symptomatic adjacent segment degeneration and secondary surgery compared with ACDF. A recent registry study and systematic review reported that more secondary surgeries at the index level occurred in PF compared to ACDF.

Conclusions: Motion-preserving surgeries including ADR and PF have advantages over ACDF. However, ACDF is still the gold standard for surgical management of cervical radiculopathy with advantages of versatility, lordosis restoration, and both indirect and direct decompression. The proper choice of surgical procedures for each patient considering patient factors and proper indications of each surgical procedure is critical for surgical success.

Keywords: ACDF, Artificial disc replacement, Posterior foraminotomy, Cervical radiculopathy, Motion preserving surgery

Instructional Course Lecture: MIS

S006

Surgical Considerations and Long-Term Outcomes of MIS TLIF

Jae Chul Lee

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Minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) is a valuable surgical option for degenerative lumbar disease because it combines the biomechanical advantages of interbody fusion with reduced approach-related soft-tissue injury. Compared with conventional open posterior fusion, MIS TLIF preserves the contralateral musculoligamentous complex, reduces neural retraction, minimizes paraspinal muscle stripping and pressure necrosis,

and may lessen postoperative inflammation, scar formation, and adjacent segment destabilization. These biological and mechanical considerations form the basis for its long-term clinical value.

Appropriate indications are essential. MIS TLIF is particularly suitable for single-level or limited two-level degenerative pathology with unilateral symptoms, segmental instability, low-grade spondylolisthesis, severe foraminal stenosis with disc height loss, recurrent disc herniation with degeneration, and cases requiring direct posterior decompression with fusion. However, its limitations should be recognized in multilevel disease, marked deformity, and situations in which indirect decompression through LLIF or OLIF may be more efficient. In current practice, MIS TLIF remains especially useful at L5–S1 and in patients whose pathology is not ideal for lateral approaches.

Technical success depends on meticulous setup and disciplined execution. Important surgical pearls include prone positioning with a free abdomen, obtaining true AP and lateral fluoroscopic images, docking the tubular retractor accurately, and working through a unilateral corridor with the microscope to maintain depth perception. High-speed burrs, angled curettes, and careful endplate preparation are critical, while safe cage placement and percutaneous pedicle screw fixation require attention to trajectory, avoidance of facet violation, and prevention of guidewire-related complications. In smaller Asian patients, the skin incision is often appropriately placed about 2.5–3 cm from the midline.

Long-term data support the durability of MIS TLIF. In a 10-year follow-up study, fusion rates improved over time from 77.1% at 1 year to 91.4% at 5 years and 94.3% at 10 years, while clinical improvement was maintained. Nevertheless, radiological adjacent segment degeneration increased gradually and reached 50.0% at 10 years, with worse ODI and leg pain in affected patients. In a larger long-term survival analysis, the 10-year incidence of adjacent segment pathology requiring surgery was 6.1% after MIS TLIF versus 16.4% after open PLIF, and open PLIF carried an approximately threefold higher hazard of revision surgery. Age ≥ 65 years was an independent risk factor.

MIS TLIF remains a technically demanding but reliable and durable procedure for selected patients with degenerative lumbar disease. When supported by proper patient selection, meticulous surgical technique, and an understanding of its limitations and learning curve, it can provide effective decompression, solid fusion, and favorable long-term outcomes.

S007

Experience with Indirect Decompression, Single Position Surgery and Emerging Technologies for Lateral Lumbar Interbody Fusion

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The University of Hong Kong

Anterior or lateral interbody fusion surgery has the benefit of a minimally invasive approach whilst providing a direct visualization of the disc space and inserting larger grafts for increased fusion rates. It is especially useful for deformities whereby minimally invasive techniques can reduce surgical trauma whilst correcting the alignment better. Indirect decompression is also feasible with these interbody fusion techniques as ligamentotaxis can be achieved with correction of the disc space collapse or spondylolisthesis. Surgical throughput can be further improved with single-position surgery techniques. Both lateral and prone positions allow for cage and screw insertion in the same position. With the assistance of the surgical robot, efficiency of the procedure is further enhanced with simultaneous surgery and improved accuracy. Combining these three aspects of lumbar surgery together, improved efficacy, accuracy and safety in deformity correction surgery can be achieved through a minimally invasive approach.

S008

How to Avoid and Manage the Complications of Endoscopic Decompression and Discectomy

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Endoscopic decompression and discectomy are rapidly expanding techniques in modern spine surgery, offering the promise of effective neural decompression with less

tissue disruption than conventional open or microscopic procedures. Nevertheless, the minimally invasive nature of these operations should not obscure the reality that their complications can be technically demanding, difficult to recognize early, and occasionally catastrophic. The complication profile of endoscopic surgery is strongly influenced by a restricted visual corridor, dependence on continuous saline irrigation, altered anatomical orientation, and a steep learning curve. These features make prevention and early recognition more important than delayed rescue. The broader ESS literature has already highlighted that bleeding, durotomy, neural injury, infection, and technical failure remain relevant concerns even in experienced hands.

This review focuses on how to avoid and manage complications during endoscopic decompression and discectomy. Major topics include preoperative risk stratification, indication and approach selection, portal planning, irrigation safety, hemostatic control, and management of specific complications such as dural tear, cerebrospinal fluid leakage, neural injury, residual compression, postoperative hematoma, infection, recurrence, and revision-related problems. Mechanistic evidence suggests that cervical epidural pressure can rise significantly during biportal endoscopic decompression, particularly when the epidural space is opened or fluid outflow is restricted, reinforcing the importance of low-pressure irrigation and unobstructed drainage. In addition, recent case-based evidence of intracranial embolism after dural tear serves as a warning that rare intracranial events may occur when cerebrospinal fluid violation and irrigation-related pressure phenomena coexist.

A structured complication-avoidance strategy should therefore include careful case selection, respect for the learning curve, standardized intraoperative checkpoints, predefined conversion criteria, and active postoperative surveillance. Endoscopic decompression and discectomy can be performed safely, but only when surgeons recognize that success depends not merely on smaller incisions, but on precise technique, pressure control, and disciplined complication management.

Keywords: Lumbar spine, Endoscopic decompression, Surgical complications, Dural tear, Endoscopic discectomy

S009

Long-Term Results of Percutaneous Endoscopic Debridement and Drainage (PEDD) for Lumbar Infectious Spondylodiscitis

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Infectious spondylodiscitis of the lumbar spine remains a challenging condition because successful treatment depends on timely diagnosis, identification of the causative pathogen, and appropriate antibiotic therapy based on culture results. However, the diagnostic yield of conventional computed tomography-guided biopsy is often unsatisfactory, and traditional open surgery may increase perioperative morbidity, especially in elderly patients or those with poor general condition.

Percutaneous endoscopic debridement and drainage (PEDD) has emerged as a minimally invasive alternative that offers both diagnostic and therapeutic advantages. Using improved endoscopic instruments and techniques, PEDD enables direct access to the infected disc space, allowing adequate debridement, decompression, drainage, and collection of sufficient tissue specimens for microbiological examination. Compared with conventional biopsy or open surgery, this method may improve pathogen detection while reducing surgical trauma.

In this presentation, we review the long-term clinical results of PEDD in the treatment of lumbar infectious spondylodiscitis. Our experience demonstrates that PEDD can provide a high culture yield, facilitate early identification of offending organisms, and allow prompt administration of sensitive antibiotics. In addition to its diagnostic value, PEDD also contributes to infection control through effective debridement and drainage of the infected lesion. Many patients can achieve satisfactory clinical improvement without the need for extensive traditional surgery.

Based on our long-term observations, PEDD is an effective and practical treatment option for selected patients with lumbar infectious spondylodiscitis. It combines minimal invasiveness with reliable diagnostic capability and meaningful therapeutic benefit. Therefore, PEDD should

be considered as an important alternative prior to more extensive open procedures, particularly in patients in whom reduced surgical morbidity is desirable.

Keywords: Lumbar spine, Infectious spondylodiscitis, Diagnosis, Percutaneous endoscopy, Debridement

S010

Current Evidence and Limitation of Biportal Endoscopic Transforaminal Lumbar Interbody Fusion

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Purpose: Biportal endoscopic transforaminal lumbar interbody fusion (BE-TLIF) has recently emerged as a minimally invasive alternative to conventional lumbar fusion techniques. This lecture aims to provide an overview of the current evidence, surgical advantages, and limitations of BE-TLIF, with a focus on clinical outcomes and technical considerations.

Materials and Methods: In this lecture, we review the currently available literature on BE-TLIF, including retrospective comparative studies and early clinical reports. Key aspects discussed include perioperative outcomes, complication profiles, fusion rates, and technical challenges associated with this procedure.

Results: Accumulating evidence suggests that BE-TLIF provides several meaningful short-term advantages compared to conventional fusion techniques. These include reduced intraoperative blood loss, less postoperative pain, faster functional recovery, and shorter hospitalization. The endoscopic approach allows for direct and magnified visualization of the endplate, which may facilitate more meticulous preparation and potentially reduce the risk of infection through continuous irrigation and minimized soft tissue disruption. Nevertheless, several limitations and concerns have been identified. Continuous irrigation may limit the availability of autologous bone graft and may lead to washout of graft materials, potentially compromising the biological environment for fusion. The relatively narrow and constrained working corridor increases the technical complexity of cage insertion and may predispose to endplate injury, which is a known risk factor for cage subsidence and nonunion. Furthermore, similar to other minimally invasive fusion techniques, the ability to achieve adequate restoration of lumbar lordosis remains limited, particularly in multilevel cases. Although most studies report clinical outcomes comparable to those of conventional posterior fusion, some reports indicate that radiologic fusion rates may be relatively lower, highlighting the need for further technical refinement.

Conclusions: BE-TLIF is a promising minimally invasive fusion technique with distinct advantages. However, challenges related to fusion reliability, minimizing endplate injury, and sagittal alignment restoration remain. Ongoing technical advancements and future high-quality studies are needed to further define its role in spine surgery. Recent advancements, such as the use of 3D-printed large-footprint cages, expandable implants, and multiportal surgical strategies, may help address these limitations. Establishing standardized surgical protocols and accumulating higher-level evidence through well-designed prospective studies and randomized controlled trials with long-term follow-up will be essential to define the optimal role of BE-TLIF in contemporary spine surgery.

Keywords: Biportal endoscopic spine surgery, Meticulous endplate preparation, Continuous irrigation, Fusion rate, Cage subsidence

Instructional Course Lecture: Deformity

S011

Clinical Significance of Sacral Slanting in Patients with Adolescent Idiopathic Scoliosis

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Purpose: To evaluate the clinical significance of sacral slanting in adolescent idiopathic scoliosis (AIS), including its impact on coronal balance, postoperative outcomes after

lumbar curve correction, distal adding-on in Lenke 1A curves, and shoulder balance in Lenke 2A curves.

Materials and Methods: A series of retrospective analyses were conducted using AIS patients who underwent corrective surgery with at least 2-year follow-up. A total of 389 patients were analyzed to determine the incidence and magnitude of sacral slanting and its relationship with coronal balance. Subgroup analyses included 149 patients with structural lumbar curves to assess postoperative balance, 126 patients with Lenke 1A curves to evaluate distal adding-on, and 99 patients with Lenke 2A curves to investigate shoulder balance. Radiographic parameters such as Cobb angle, C7-CSVL, LIV tilt, and sacral slanting angle were measured and correlated using regression analyses.

Results: Sacral slanting was common, with only 37% of patients demonstrating a horizontal sacrum. The mean slanting angle was 3°, and 26% had angles greater than 5°. Sacral slanting significantly influenced coronal balance, with the C7 plumb line shifting toward the direction of slanting. Greater preoperative sacral slanting correlated with postoperative coronal decompensation and reduced centralization and horizontalization of the lowest instrumented vertebra (LIV). In Lenke 1A curves, larger sacral slanting, younger age, and shorter fusion levels were associated with higher rates of distal adding-on, particularly in L4-R type curves. In Lenke 2A curves, sacral slanting was not directly associated with postoperative shoulder imbalance, although compensatory mechanisms such as distal wedging contributed to gradual improvement in balance.

Conclusions: Sacral slanting is a common and clinically significant factor in AIS. It affects coronal spinal balance, influences postoperative alignment after lumbar fusion, and increases the risk of distal adding-on, especially when fusion levels are short. While not directly associated with shoulder imbalance, sacral slanting contributes to compensatory changes over time. Consideration of sacral slanting is important in surgical planning, particularly in determining distal fusion levels.

Keywords: Adolescent idiopathic scoliosis, Sacral slanting, Coronal balance, Distal adding-on, Fusion level

S012

Challenges in Surgical Correction and Balancing of Lenke 5C Curves

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This topic examines the complexities of correcting Lenke 5C curves, a scoliosis subtype often considered straightforward yet prone to significant challenges. Despite perceptions of simplicity, these curves can present difficulties in achieving proper spinal balance. Misjudging curve behavior may result in postoperative imbalance and complications. The discussion emphasizes the importance of recognizing the surgeon’s control in applying precise corrective strategies to optimize surgical outcomes in patients with Lenke 5C deformities.

Keywords: Spine, Scoliosis, Idiopathic, Lenke 5C, Spinal Fusion

S013

Analysis of Apex and Its Importance in Severe Spinal Deformity Correction

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Background and Introduction: Rigid kyphosis correction is a demanding surgery in view of neurological risk, more so if it is of severe degree and located in dorsal and cervicodorsal region. Though column shortening procedures have been advocated, correction of apex by cantilever technique is not ideal and biomechanically substandard. We describe a novel technique and its steps to get true apical correction during VCR for post-tubercular rigid kyphosis of more than 100 degree.

Main Body: Over 27 years, we treated 81 cases of post-tubercular rigid kyphosis of dorsal spine (including cervicodorsal and dorsolumbar junction). According to degree of kyphosis it was grouped into 3 grades. Grade-I

Angle of kyphosis 40-70 degree (13 patients), Grade – II Angle of kyphosis 70 to 100 degree (41 patients) and Grade – III Angle of kyphosis >100 degree (27 patients). In Grade III patients, the apex shifts significantly posterior and almost always remains embedded behind approximating proximal and distal normal vertebra anteriorly. The patients were surgically treated by a posterior midline incision with deeper dissection to bilateral posterolateral zone reaching anterior to vertebral column. After securing minimum three levels proximal and three levels distal fixation and excising the internal gibbus according to the preoperative planning, corrective maneuver was done which consisted of a combination of initial temporary stabilisation and then correction with the help of extending the hinge of table at the apex and cantilevering the rod from one segment to another. In higher degree of deformity (>100 degree) most of the time the end plates of the vertebrae do not become parallel rather remain tilted. There is rather compensatory reduction of proximal kyphosis and distal lordosis. We started using reduction screws in proximal segment and did gradual controlled posterior pivotal sagittal correction (in intermittent dynamic compression mode) with broad dynamic anterior hinge (using stationary angled spreader in distraction mode). This technique was used even in patients having deformity with deficit in 11 patients of grade III. Out of 27 cases of Grade III, in 10 patients cantilever technique was used. In 4 of these, apex of deformity remained tilted. The use of reduction screws (17 patients) made the procedure smooth and controlled with the feasibility of correction of tilt at the apex. Average correction achieved was 86.7%. There were two cases of proximal segment toppling in Grade II which were revised. 1 patient who had pre-operative deficit deteriorated neurologically.

Conclusions: High magnitude rigid kyphosis even with neurodeficit can be corrected with an anterior dynamic broad hinge in a controlled distraction mode and gradual controlled posterior pivotal sagittal correction with intermittent compression mode thus resulting in true apical correction.

Keywords: Kyphosis, Tuberculosis, Neurodeficit, Dorsal spine, Biomechanical

S014

Hip-Spine Syndrome

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This lecture reviews hip–spine syndrome, a condition where hip and lumbar spine disorders may coexist and interact biomechanically and clinically. Because hip and spine share overlapping nerve supply and function as a single kinetic unit, pain patterns often overlap, making diagnosis challenging. Hip–spine syndrome is classified into simple, complex, and secondary types. In simple cases, symptoms are clearly attributable to either the hip or spine. Complex cases involve both structures with unclear pain sources, often requiring diagnostic injections or nerve root blocks. Secondary hip–spine syndrome occurs when pathology in one region (e.g., hip osteoarthritis or spinal deformity) secondarily alters biomechanics and causes symptoms in the other. Careful clinical differentiation is important for favorable outcome. Hip-origin pain typically presents as groin or anterior thigh pain, worsened by hip rotation, with restricted internal rotation and positive hip provocation tests. Spine-origin pain more commonly radiates below the knee, is associated with neurological signs, worsens with prolonged sitting, and may show nerve tension signs. Imaging is supportive but rarely diagnostic on its own. Diagnostic injections play a key role: intra articular hip injections have high specificity for hip pathology, while selective nerve root blocks, facet injections, and electrophysiological studies help localize spinal pain generators. Other regional causes such as sacroiliac joint pain, piriformis syndrome, and vascular or pelvic pathology must also be excluded. Management should begin with non surgical treatment. When surgery is required in complex cases, the more symptomatic structure is generally treated first. If hip and spine symptoms are equally severe, total hip arthroplasty (THA) is often preferred initially, as it may improve back pain and spinopelvic mechanics. Evidence suggests many patients experience resolution of low back pain after THA. There is increased risk of dislocation and revision after THA in patients with spinal stiffness or prior spinal fusion. Preoperative assessment of spinopelvic alignment and motion is essential. Surgical strategies include adjusting acetabular cup orientation

beyond traditional "safe zones," using larger femoral heads or dual mobility implants, and favoring posterior approaches in high risk patients. From the spine perspective, preserving motion and minimizing fusion length are key. Decompression alone is often sufficient for lumbar stenosis and stable degenerative spondylolisthesis, with outcomes comparable to fusion but fewer complications. Long spinal fusion is reserved for severe deformity, sagittal imbalance, or deformity driven symptoms.

Keywords: Overlapping symptoms, Injections, Less fusion

S015

Adult Lumbar-TL Spinal Deformity: When Is It Appropriate to Stop Short of Sacrum/Pelvis

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Adult spinal deformity (ASD) surgery frequently involves long-segment fusion constructs, with extension to the sacrum and pelvis; this is considered necessary to achieve durable sagittal alignment and prevent distal junctional failure. However, fusion to the pelvis is associated with significant morbidity, including high rates of pseudarthrosis, implant-related complications, and loss of lumbosacral motion. This presentation evaluates whether fusion to the pelvis is always required and explores a new strategy for preserving the lumbosacral junction in selected patients.

A review of the literature demonstrates that while fusion to the sacrum provides superior correction of sagittal imbalance, it is associated with substantial complication rates, including pseudarthrosis rates approaching 24% and implant-related pain requiring removal in up to 22% of patients. Furthermore, degeneration at L5–S1 is common when stopping constructs proximal to the sacrum, raising concerns regarding long-term durability.

The presentation introduces a novel two-stage surgical strategy aimed at preserving motion segments at the lumbosacral junction. This technique involves temporary distal fixation using percutaneous S2AI screws, followed by removal after achieving correction and stability. In a preliminary series of patients undergoing this approach, radiographic outcomes demonstrated maintenance of sagittal alignment with acceptable correction of Cobb angle, thoracic kyphosis, and sagittal vertical axis, while preserving distal motion segments.

Clinical case examples illustrate successful application of this strategy in younger patients with adult idiopathic deformity, where preservation of one or two distal motion segments may offer functional benefits. However, this approach is not universally applicable. Degenerative deformities, particularly in older patients with significant lumbosacral degeneration, still require fusion to the pelvis to ensure long-term stability.

In conclusion, fusion to the pelvis remains the standard for most degenerative ASD cases. However, in carefully selected younger patients with preserved lumbosacral discs, motion-preserving strategies are feasible and may delay the need for sacropelvic fusion. Early results are promising, but longer-term follow-up is required to determine durability and the eventual need for secondary procedures.

Keywords: Spine, Adult spinal deformity, Lumbosacral junction, Posterior lumbosacral tether, Motion preservation

S016

Automated Computed Tomography-Based Body Composition Analysis and Utility in Risk Stratification for Adult Spinal Deformity Correction – Implications for Proximal Junctional Kyphosis and Complications

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Background Context: Mechanical complications after adult spinal deformity (ASD) correction remain common, particularly proximal junctional kyphosis (PJK) and proximal junctional failure (PJF). Existing preoperative risk assessment relies primarily on demographic, radiographic, and construct-related factors and does not fully capture patient-specific biologic reserve. Computed tomography (CT)-derived body composition may provide objective markers of musculoskeletal reserve and capacity to tolerate correction, but its prognostic value in ASD remains incompletely defined.

Purpose: To utilize automated trained segmentation algorithms to identify and standardize preoperative body composition metrics between computed tomography (CT) scans of the lumbar spine or the abdomen and pelvis (CTAP) in patients with thoracolumbar ASD, and to evaluate the associations between these metrics and mechanical complications after ASD correction.

Study Design: This was a retrospective single-institution cohort study performed at a tertiary academic center.

Patient Sample: Adults undergoing ASD correction with constructs extending from the thoracic spine to the pelvis at a tertiary academic center. Patients with oncologic, traumatic, spastic, juvenile, or infectious deformity etiologies were excluded.

Outcome Measures: PJK, PJF, and distal fixation failure (DFF), as well as preoperative, immediate postoperative, and follow-up spinopelvic alignment parameters measured on standing full-length radiographs.

Methods: Automated CT-based segmentations were performed utilizing the TotalSegmentator “total” and “four tissue types” segmentation tasks, with a customized Python pipeline to extract L3 area-based and L1-5 volumetric body composition metrics. Univariable and adjusted multivariable analyses were utilized for comparisons between groups and associations between body composition measures and outcomes and alignment parameters.

Results: 190 patients were included with median follow-up of 22.5 months (interquartile range (IQR) 15.7–32.0 months). PJK occurred in 78 patients (41.1%), PJF in 44 (23.2%), and distal fixation failure (DFF) in 29 patients (15.3%). Area and volume-based metrics of the same compartment were nearly colinear, indicating adequate representation of volumetric measurements by the area-based representations. Multivariable logistic regression revealed significant association between higher SMI and lower odds of PJF (adjusted OR, 0.65; 95% CI, 0.42–0.99; $P = 0.049$). No other body composition metrics were significantly associated with PJF or PJK. Higher L3 subcutaneous fat density was significantly associated with greater odds of DFF, although events were low (adjusted OR per SD, 1.54; 95% CI, 1.06–2.26; $p=0.025$). Lower SMI was significantly associated with greater preoperative pelvic tilt (Spearman $\rho=-0.27$; $p<0.001$), greater PI–LL mismatch ($\rho=-0.24$; $p<0.001$), and greater T1PA ($\rho=-0.27$, $p<0.001$), while higher IMAT-AI was significantly associated with greater immediate postoperative SVA ($\rho=0.26$, $p<0.001$), greater follow-up SVA ($\rho=0.33$, $p<0.001$), and less favorable radiographic correction, including smaller improvements in PI–LL, PT, LL, and T1PA ($\rho=0.20$–0.24; $p\leq0.006$ for each comparison). Lastly, tertile-based risk modeling revealed significant reductions in PJF risk by SMI tertile (adjusted OR, 0.93 per cm^2/m^2; LRT $p=0.038$), while addition of SMI to a clinical-only model of PJF improved discrimination from a C statistic of 0.652 to 0.709, with significant improvement in model fit ($\chi^2=4.32$, $p=0.038$).

Conclusions: Preoperative CT-derived body composition provides clinically meaningful information not captured by standard ASD risk factors alone. Lower L3 SMI was independently associated with PJF and improved PJF risk stratification beyond clinical variables, whereas lower SMI and higher intramuscular adiposity were associated with less favorable deformity compensation and postoperative alignment. Automated body composition phenotyping may therefore serve as a scalable adjunct to preoperative risk assessment in ASD surgery. This is the first study of its kind.

Keywords: Adult spinal deformity, Intramuscular adipose tissue, Sarcopenia, Skeletal muscle index, Automated segmentation, Proximal junctional failure

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S017

Preoperative VBQ Score and Early Cage Subsidence After Endoscopic Lumbar Interbody Fusion: A Propensity Score–Matched Comparison with TLIF

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Purpose: To compare 12-month symptom improvement

and implant-related complication rates between TLIF and endoscopic lumbar interbody fusion (EndoLIF), and to evaluate whether MRI-based vertebral bone quality (VBQ) modifies early cage subsidence risk. We hypothesized that EndoLIF—limited by working corridor, visualization, and implant trajectory—may be more sensitive to technical factors (endplate preparation, cage angle/size), increasing subsidence risk and potentially reducing indirect decompression.

Materials and Methods: This retrospective single-center study identified patients undergoing TLIF or EndoLIF for lumbar degenerative disease. Propensity score matching generated comparable cohorts (20 TLIF vs 20 EndoLIF; 1:1). VBQ was calculated on preoperative non-contrast T1-weighted MRI as the median L1–L4 vertebral body signal intensity normalized to CSF at L3. Outcomes at 12 months included VAS and ODI improvement and complication events: cage subsidence (defined as ≥2 mm cage subsidence and/or disc height decrease compared with immediate postoperative imaging), pedicle screw loosening/pullout, restenosis, and infection.

Results: Both groups showed meaningful improvement in VAS and ODI at 12 months without an apparent between-group difference. Cage subsidence occurred in 6/20 (30%) EndoLIF and 2/20 (10%) TLIF patients. In EndoLIF, subsidence clustered in patients with high VBQ (>3.2): 5/9 (55.6%) vs 1/11 (9.1%) with VBQ ≤3.2. In TLIF, subsidence also occurred only in the high-VBQ subgroup: 2/8 (25.0%) vs 0/12 (0%) with VBQ ≤3.2. Other complications (screw loosening/pullout, restenosis, infection) were infrequent and comparable between cohorts.

Conclusions: Higher preoperative VBQ (>3.2) identifies patients at increased risk of early cage subsidence, with a more pronounced signal in EndoLIF. Although symptom relief at 12 months is generally achieved, high-VBQ patients undergoing EndoLIF may require technique/implant modifications (e.g., strategies to increase cage footprint) and targeted bone-health optimization to mitigate subsidence and preserve indirect decompression.

Keywords: Lumbar spine, Lumbar degenerative disease, Vertebral bone quality (VBQ) score, Endoscopic lumbar interbody fusion (EndoLIF), Transforaminal lumbar interbody fusion (TLIF), Cage subsidence

S018

Clinical and Radiologic Outcomes of Biportal Endoscopic vs Microscopic Decompression for Lumbar Spinal Stenosis with Low-Grade Spondylolisthesis: A Pooled Analysis of Randomized Controlled Trials

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Purpose: Posterior decompression for lumbar spinal stenosis may be associated with postoperative segmental instability and progression of spondylolisthesis. While microscopic minimally invasive decompression has been reported to preserve spinal stability in selected patients with low-grade spondylolisthesis, evidence regarding the stability-preserving effect of biportal endoscopic decompression remains limited. This study aimed to compare clinical and radiologic outcomes between biportal endoscopic decompression and conventional microscopic decompression, with particular focus on slip progression and segmental instability.

Materials and Methods: Data were pooled from two prospective randomized controlled trials, and a predefined subgroup of 120 patients with lumbar spinal stenosis who underwent decompression surgery was included for the present analysis. Patients were treated with either biportal endoscopic decompression (n=60) or microscopic decompression (n=60). Each group was further stratified according to preoperative spondylolisthesis grade (Grade 0 or I). Clinical outcomes were assessed using the visual analog scale (VAS), Oswestry Disability Index (ODI), and EQ-5D. Radiologic parameters included listhesis percentage, segmental lordosis, lumbar lordosis, instability ratio, and disc height index. Longitudinal changes and between-group differences were analyzed using linear mixed-effects models incorporating group, time, and group-by-time interaction.

Results: Both surgical groups demonstrated significant postoperative improvement in all clinical outcomes, with no significant differences between biportal endoscopic and microscopic decompression. Within each surgical group, no significant clinical or radiologic differences were observed

between Grade 0 and Grade I patients. Radiologically, patients with Grade I spondylolisthesis in both groups showed a tendency toward increased listhesis over time; however, no significant group-by-time interaction was identified between surgical techniques. Importantly, this radiologic progression was not significantly associated with deterioration of clinical outcomes. Complication rates were low and comparable between the two groups.

Conclusions: Biportal endoscopic decompression provides clinical and radiologic outcomes comparable to those of conventional microscopic decompression in patients with lumbar spinal stenosis. Although slip progression may occur over time in patients with low-grade spondylolisthesis, its magnitude and clinical impact were limited and did not differ according to surgical technique. These findings suggest that biportal endoscopic decompression is a stability-preserving, minimally invasive alternative for lumbar spinal stenosis with low-grade spondylolisthesis.

Keywords: Lumbar spinal stenosis, Biportal endoscopic decompression, Microscopic decompression, Low-grade spondylolisthesis, Segmental stability

S019

Efficacy and Safety of Various Graft Choices in OLIF

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Purpose: To compare radiologic and clinical outcomes among different biologic graft materials—demineralized bone matrix (DBM), Chinese hamster ovary (CHO)–derived recombinant human bone morphogenetic protein-2 (rhBMP-2), and Escherichia coli–derived rhBMP-2—in patients undergoing oblique lumbar interbody fusion (OLIF).

Materials and Methods: This retrospective study included patients who underwent OLIF with a minimum follow-up of 12 months. A total of 99 patients were analyzed, including 36 patients in the DBM group (48 operated levels), 33 patients in the CHO-derived rhBMP-2 group (Infuse®, Medtronic; 47 levels), and 30 patients in the E. coli–derived rhBMP-2 group (Novosis®, CG Bio; 41 levels). Fusion status was assessed at 12 months using postoperative computed tomography and graded according to the modified Bridwell classification. Subsidence and clinical outcomes were also evaluated.

Results : Overall fusion (Bridwell grade I–II) was achieved in 95.8% of DBM levels, 95.7% of CHO-derived rhBMP-2 levels, and 95.1% of E. coli–derived rhBMP-2 levels, with no significant difference among the groups. However, fusion grade distribution differed among graft types. Bridwell grade I fusion was observed in 50.0% of DBM levels, 87.2% of CHO-derived rhBMP-2 levels, and 68.3% of E. coli–derived rhBMP-2 levels. Bridwell grade III nonunion was uncommon and was observed in a small number of cases in each group, while no Bridwell grade IV nonunion was identified. Subsidence occurred in 60.4% of DBM levels, 27.7% of CHO-derived rhBMP-2 levels, and 43.9% of E. coli–derived rhBMP-2 levels, with a significant difference among the groups. All groups demonstrated significant postoperative clinical improvement, with comparable clinical outcomes and complication profiles.

Conclusions: In OLIF, all graft materials demonstrated high fusion rates and comparable clinical outcomes. CHO-derived rhBMP-2 showed a higher proportion of complete fusion and a lower incidence of subsidence, followed by E. coli–derived rhBMP-2, while DBM also provided acceptable radiologic outcomes. Graft selection should therefore be individualized based on patient's risk profile and surgical goals.

Keywords: Oblique lumbar interbody fusion, Bone morphogenetic protein-2, Demineralized bone matrix, Fusion rate

S020

Predictive Factors of MIS Decompression in Lumbar Spinal Stenosis with Degenerative Lumbar Scoliosis

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Purpose: Degenerative lumbar scoliosis commonly coexists with lumbar spinal stenosis and is a significant source of pain and disability. Although decompression combined with fusion can effectively treat both spinal stenosis and deformity, it is associated with a considerable risk of morbidity in elderly patients. Minimally invasive decompression emerged as a less invasive alternative, but outcomes remain inconsistent.

This study aims to identify factors associated with poor outcomes following decompression alone in degenerative scoliosis patients with lumbar spinal stenosis.

Materials and Methods: This retrospective cohort study analyzed patients with lumbar spinal stenosis and degenerative deformity who underwent minimally invasive lumbar decompression at Seoul St. Mary's Hospital between January 2013 and May 2025. Inclusion criteria included preoperative coronal Cobb angle >10°, one- or two-level microtubular, uniportal, or biportal endoscopic decompression, and more than 3 months of follow-up. Patients with prior or concomitant fusion, tumor, infection, trauma, or adolescent idiopathic scoliosis were excluded. Demographic, operative, clinical, and radiographic data were collected. Clinical evaluation included symptoms, back and leg pain (NRS), and functional disability using the ODI. Radiographic evaluation included coronal Cobb angle, spinopelvic parameters, and coronal deformity patterns. Poor outcome was defined as postoperative ODI >22, NRS back pain >3, or NRS leg pain >3. Univariable and multivariable regression identified factors associated with poor outcomes after decompression alone.

Results: A total of 35 patients were included, with a mean age of 69.9±10.1 years, 77.1% females, with a mean follow-up time of 3.4 years. Microscopic decompression was performed in 39.5%, unilateral biportal endoscopy in 15.8%, and uniportal endoscopy in 44.7%. ODI improved significantly by 23±19.2 points, with substantial reductions in back and leg pain (all p<0.01). No significant progression was observed in sagittal listhesis, PI-LL mismatch, coronal or sagittal SVA, or Cobb angle. Lateral listhesis showed a small change without clinical significance. On univariate analysis, a higher age-adjusted CCI, decompression on the convex side of the curve, neurogenic claudication, and preoperative PI-LL mismatch were associated with worse outcomes. Multivariate analysis demonstrated that convex-side surgery remained the only independent predictor of poor postoperative outcome (p=0.029).

Conclusions: MIS decompression alone provides significant clinical improvement without meaningful deformity progression in selected patients with lumbar spinal stenosis and degenerative scoliosis. However, decompression on the convex side of the curve was independently associated with poor outcomes, highlighting the importance of careful case selection.

Keywords: Degenerative lumbar scoliosis, Lumbar spinal stenosis, Minimally invasive spine surgery, Decompression alone, Risk factors

S021

Hidden Blood Loss in Full-Endoscopic Lumbar Decompression Compared with Biportal Endoscopic and Microscopic Decompression for Single-Segment Lumbar Stenosis

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Purpose: Endoscopic spine surgery (ESS) is well known to minimize trauma to anatomical structures and reduce surgical burden, leading to rapid recovery. ESS is generally known to have less perioperative blood loss (PBL) due to lower surgical injury and excellent visualization. However, it is difficult to estimate the amount of intraoperative blood loss in ESS because of continuous saline irrigation and blood infiltration into soft tissues and dead spaces. Hidden blood loss (HBL), caused by extravasation into potential compartments or hemolysis, may induce increased total blood loss (TBL) and postoperative complications related to bleeding. In addition, HBL has been reported to account for a substantial portion of the TBL in ESS. Despite several previous studies regarding HBL in ESS, to our knowledge, no study has evaluated HBL in full-endoscopic lumbar decompressive surgery via interlaminar approach such as full-endoscopic unilateral laminotomy and bilateral decompression (FE-ULBD). The purpose of this study was to assess the HBL in FE-ULBD compared to the biportal endoscopic ULBD (BE-ULBD) and open microscopic ULBD (OM-ULBD).

Materials and Methods: A retrospective analysis was performed for patients who underwent single-level FE-ULBD, BE-ULBD, or OM-ULBD for lumbar central canal and/or lateral recess stenosis at a single institution. We collected data on demographics, comorbidities, smoking status, operative details, perioperative complications, and laboratory data including preoperative coagulation function and pre- and postoperative hemoglobin (Hb) and hematocrit (Hct).

Results: A total of 93 patients were identified, consisting of 34 patients in the FE-ULBD group, 32 in the BE-ULBD group, and 27 in the OM-ULBD. Comparison of baseline characteristics and preoperative laboratory data showed no significant differences among groups. The amount of PBL, including TBL, visible blood loss, and HBL, differed significantly among groups. Post hoc analysis demonstrated that FE-ULBD had significantly lower TBL than both BE-ULBD and OM-ULBD ($p=0.024$ and $p<0.001$, respectively). The HBL in FE-ULBD was significantly lower than in OM-ULBD ($p=0.020$), and although not significantly, also lower than in BE-ULBD ($p=0.052$). There were no significant differences in clinical outcomes among groups.

Conclusions: This study demonstrated that FE-ULBD was associated with significantly less TBL than both BE-ULBD and OM-ULBD, and significantly lower HBL than OM-ULBD. FE-ULBD would be a viable option with less PBL and acceptable clinical outcomes as decompressive surgery for lumbar spinal stenosis.

Keywords: Lumbar spinal stenosis, Endoscopic spine surgery, Full-endoscopic, Unilateral laminotomy and bilateral decompression, Hidden blood loss

Free Paper: MISS (2)

S022

Infective Spondylodiscitis After Full Endoscopic Lumbar Discectomy - A Single Center Retrospective 10 Year Analysis

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Purpose: Infective spondylodiscitis following a lumbar discectomy is a rare complication. Full endoscopic lumbar discectomy is a minimally invasive technique emerging as a favored technique for lumbar disc surgery in the last couple of decades. The use of irrigation fluid and radiofrequency ablators add to the possible sources of intraoperative contamination. There is a paucity of information on post-operative discitis after endoscopic disc surgery in the literature. The purpose of this study is to analyse the incidence, clinical characteristics and results of infective spondylodiscitis after endoscopic lumbar discectomy at our center.

Materials and Methods: A retrospective analysis of all the full endoscopic lumbar discectomy surgeries performed at our center over the past 10 years was done. Incidence, risk factors, comorbidities, clinical presentation, laboratory parameters and radiological features of the cases which developed post-operative infective spondylodiscitis were analysed. The parameters were compared to the published literature on discitis after microdiscectomy.

Results: The study found that there were six cases of infectious discitis in over 470 cases of endoscopic discectomy surgeries performed in the past eight years. Five of the six patients had medical conditions that compromised their immunity. Five cases had undergone endoscopic interlaminar approach while one had transforaminal approach. Five patients were diagnosed within the initial eight weeks after index surgery while one patient developed symptoms after 6 months. All the six patients underwent a fusion surgery.

Conclusions: The incidence of post-operative infective spondylodiscitis after full endoscopic discectomy is around one percent, similar to the known incidence after microdiscectomy. Diabetes mellitus and long-term steroid medication have been found to be risk factors for post-operative spondylodiscitis. Appropriate investigations to identify the organism, appropriate anti-microbial therapy and surgical treatment with debridement, stabilization and fusion ensure good healing and outcomes. Improved reporting of complications and larger studies will help characterise the risk factors and microbiological nature of the infective spondylodiscitis after endoscopic discectomy.

Keywords: Infective spondylodiscitis, Endoscopic, Lumbar discectomy, Complication

S023

Biportal Endoscopic Transforaminal Lumbar Interbody Fusion Using an Expandable Cage for Meyerding Grade II or Higher Isthmic Spondylolisthesis: A Comparative Study with the Conventional Open Technique

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Purpose: To compare the clinical and radiological outcomes of biportal endoscopic transforaminal lumbar interbody fusion (BE-TLIF) with conventional open TLIF in patients with Meyerding grade II or higher isthmic spondylolisthesis.
Materials and Methods: This retrospective study included 67 patients who underwent single-level TLIF for Meyerding grade II or higher isthmic spondylolisthesis between March 2019 and March 2024 (open TLIF [n=32] and BE-TLIF [n=35]). An expandable titanium cage containing recombinant human bone morphogenetic protein-2 was used. Clinical outcomes were assessed using the Visual Analog Scale (VAS) for back and leg pain, Oswestry Disability Index (ODI), and the EuroQol-5 Dimension index (EQ-5D). Radiological parameters included disc height, foraminal height, anterior translation, segmental lordosis, lumbar lordosis, spinopelvic parameters, and fusion rates based on the Bridwell classification at 12 months postoperatively.
Results: Both groups exhibited significant postoperative improvements in all clinical parameters, with no significant differences at 12 months. Fusion rates were 91.4% and 87.5% in the open TLIF and BE-TLIF groups, respectively. Clinically significant cage subsidence (>2 mm) occurred in 5.7% of BE-TLIF versus 18.8% of open TLIF cases (p=0.14). BE-TLIF was associated with significantly shorter operative times (206.1±33.7 vs. 236.7±59.2 min, p=0.027) and hospital stays (12.91±5.15 vs. 16.97±4.78 days, p=0.020). The overall complication rate was 14.3% in the BE-TLIF group and 25.0% in the open TLIF group (p=0.25).
Conclusions: BE-TLIF is a feasible and effective alternative to conventional open TLIF for Meyerding grade II or higher isthmic spondylolisthesis, achieving comparable clinical and radiological outcomes with shorter operative times and hospitalization.
Keywords: Biportal endoscopic spine surgery, Transforaminal lumbar interbody fusion, Isthmic spondylolisthesis, Minimally invasive spine surgery, Expandable cage

S024

Beyond the Microscope: Is Endoscopic Discectomy the Next Gold Standard for Lumbar Disc Herniation?

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Purpose: This systematic review and meta-analysis aimed to compare endoscopic discectomy (ED) with microdiscectomy (MD) for lumbar disc herniation (LDH), evaluating patient-reported outcomes, perioperative parameters, and complications to determine if ED could replace MD as the gold standard.
Materials and Methods: Following PRISMA guidelines, we searched PubMed, Embase, Scopus, and Web of Science (January 2000–June 2025) for randomized controlled trials (RCTs) and prospective cohort studies comparing MD with ED subtypes (transforaminal endoscopic lumbar discectomy (TELD), interlaminar endoscopic lumbar discectomy (IELD), and unilateral biportal endoscopy (UBE)). Outcomes included Oswestry Disability Index (ODI), Visual Analog Scale (VAS) for pain, operative time, hospital stay, complications, and recurrence. Pooled mean differences (MDs) and odds ratios (ORs) were calculated using random-effects models, with subgroup analyses by ED subtype. Risk of bias was assessed using RoB 2.0 and ROBINS-I tools.
Results : Seventeen studies (9 RCTs, 8 cohorts; n=3,115) were included. ED significantly reduced hospital stay (MD: -2.43 days, 95% CI: -3.62 to -1.23, p<0.05) and showed greater short-term ODI improvement (MD: 2.13, 95% CI: 0.58 to 3.67). No differences were observed in operative time, long-term ODI, or VAS scores. ED had lower wound complications but a higher recurrence risk with TELD (OR: ~2.0). High heterogeneity (I^2>95%) and limited long-term data (>2 years) were noted.

Conclusions: Addressing whether endoscopic discectomy will replace microscopic discectomy as the gold standard for lumbar disc herniation, our analysis concludes “not yet”; better designed studies are needed that control for uniform surgical approach (e.g., IELD or UBE) and pathology (e.g., extruded paracentral HNP) in the future. The long history of excellent outcomes with microdiscectomy sets a high bar that endoscopic techniques have now met, but not yet exceeded. Endoscopic techniques offer reduced invasiveness, shorter hospital stays, and fewer wound complications, yet they fall short of supplanting microdiscectomy due to comparable long-term functional outcomes and a doubled re-herniation risk with transforaminal approaches like TELD. Subtype-specific applications (e.g., IELD, UBE) position endoscopy as a viable alternative in select cases; however, microdiscectomy remains the benchmark for safety and efficacy. As techniques evolve and high-quality trial data mature, the balance may gradually tilt toward endoscopic surgery, though for now the evidence supports cautious, selective adoption rather than full replacement.

Keywords: Lumbar disc herniation, Endoscopic discectomy, Microdiscectomy

S025

Novel Endoscopic-Assisted Triple Realignment Strategy for Single-Position OLIF: A New Paradigm for Sagittal Correction and Indirect Decompression

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Purpose: Conventional oblique lumbar interbody fusion (OLIF) often faces limitations in achieving sufficient indirect decompression for severe stenosis and carries mechanical risks during aggressive sagittal correction. We propose a "Triple Realignment Strategy" implemented via endoscopic OLIF (E-OLIF) in a single position. This strategy integrates Anterior Rim Realignment (ARR), Posterior Rim Realignment (PRR), and Facet Release/Fusion (FRF) to simultaneously optimize sagittal alignment and neural decompression while ensuring mechanical safety.

Materials and Methods: The strategy was evaluated using a dual-track approach: (1) Finite element analysis (FEA) to isolate the biomechanical roles of ARR and PRR, and (2) a retrospective clinical series of 15 patients (18 levels) who underwent single-position E-OLIF. Radiographic parameters, including segmental lordosis (SL), central canal cross-sectional area (CSA), and foraminal area (FA), were measured pre- and postoperatively. A split-body analysis was conducted to compare the decompression efficacy (ΔFA) between FRF-executed and non-executed sides.

Results: FEA identified ARR as the main driver for lordosis, though high stress (120.8 MPa) was neutralized by PRR (13.0 MPa). E-OLIF correction matched ACR with lower peak stress (13.0 vs. 58.3 MPa). Clinical outcomes significantly improved ($p<0.05$). The ARR group achieved greater SL restoration (12.0° vs. 3.5°; p=0.051). Side-to-side analysis showed greater FA expansion on the FRF side (38 vs. 20 mm^2; p=0.045) despite baseline parity ($p>0.05$).

Conclusions: The Triple Realignment Strategy in single-position E-OLIF establishes a new surgical paradigm. By utilizing E-OLIF as a precision platform for ARR, PRR, and FRF, this approach effectively overcomes the limitations of traditional lateral fusion, providing a robust and biomechanically safe solution for complex spinal deformities and stenosis.

Keywords: Oblique lumbar interbody fusion (OLIF), Endoscopic decompression (FRF), Anterior column realignment (ARR), Posterior rim realignment (PRR), Finite element analysis

S026

Intraoperative Changes in Modified Coronal Root Angle Following Biportal Endoscopic Lumbar Decompressive Foraminotomy for Lumbar Foraminal Disc Disease

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Purpose: Although paraspinal decompressive foraminotomy and/or discectomy (PDFD) is the gold standard for lumbar

foraminal disc disease, unsatisfactory outcomes occur in 20% of cases. The coronal root angle (CRA) has emerged as a key prognostic factor, with previous evidence suggesting it reflects ventral decompression. This study investigates intraoperative CRA changes during biportal endoscopic PDFD (BE-PDFD) and their correlation with clinical improvement.

Materials and Methods: This retrospective study included 92 patients who underwent BE-PDFD for moderate to severe LFS. Intraoperatively, the modified coronal root angle (mCRA) was defined as the value obtained by adding 90 degrees to the acute angle between the inferior margin of the exiting nerve root and the upper endplate of the caudal vertebra. It was measured immediately after flavectomy (mCRA1) and again after removal of the ventral pathologies (mCRA2). Clinical outcomes were assessed using the Oswestry Disability Index (ODI) preoperatively and at 1 year postoperatively. Patients were stratified into two groups based on whether the ODI improved by ≥13 points compared with the preoperative value, according to the minimal clinically important difference (MCID). Radiographic parameters, including preoperative lumbar lordotic angle (LLA), disc lordotic angle (DLA), and posterior disc height (PDH), were also measured. The relationships between mCRA and other radiographic parameters were analyzed for statistical significance between the two groups.

Results: A total of 89 patients were included in the final analysis. The mean ODI score improved from 59.21 preoperatively to 25.79 at 1 year postoperatively. Patients were categorized into Group A (n=71), who achieved the MCID, and Group B (n=18), who did not. The mean mCRA1 was 120.17° in Group A and 118.25° in Group B, with no statistically significant difference ($p=0.25$). However, the mean mCRA2 was 128.03° in Group A and 122.03° in Group B, demonstrating a statistically significant difference ($p=0.01$). Furthermore, the intraoperative change in mCRA (mCRA1–mCRA2) was 7.86° in Group A and 3.75° in Group B, which was also significant ($p<0.001$). Radiological parameters, including LLA, DLA, and PDH, were comparable between the two groups ($p>0.05$).

Conclusions: Our results indicate that intraoperative changes of mCRA and the mCRA2 were significantly associated with clinical outcomes. These findings suggest the potential utility of mCRA as an intraoperative marker for evaluating the adequacy of direct foraminal decompression.

Keywords: Coronal root angle, Biportal endoscopic, Decompressive foraminotomy, Lumbar foraminal disc disease, Oswestry disability index

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S027

Full-Endoscopic Rhizotomy for Degenerative Lumbar Facet Joint Syndrome: A Systematic Review and Meta-Analysis

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Purpose: This study aimed to evaluate the efficacy and safety of full-endoscopic rhizotomy in patients with degenerative lumbar facet joint syndrome (FJS), using pooled data from clinical studies reporting postoperative outcomes. Degenerative changes, such as osteoarthritis, often lead to facet joint syndrome (FJS). Physical therapy, nerve blocks, and radiofrequency rhizotomy are all common treatments. Full-endoscopic lumbar rhizotomy enables direct visualization and precise ablation of the medial branch nerves. Recent studies have shown significant reductions in pain and disability.

Materials and Methods: A systematic literature search was conducted in PubMed and Scopus databases between January 2000 and March 2025, following PRISMA guidelines. We included studies that reported preoperative and postoperative outcomes of full-endoscopic rhizotomy in adult patients with lumbar FJS. Both randomized controlled trials (RCTs) and observational studies were considered. Risk of bias was assessed using the Cochrane RoB 2 tool for RCTs and ROBINS-I for non-randomized studies. Primary outcomes included changes in pain and disability scores measured by the Visual Analog Scale (VAS) and Oswestry Disability Index (ODI). Meta-analyses were performed using pooled mean differences with 95% confidence intervals.

Results: Fifteen studies involving a total of 1,467 patients were included. The pooled mean improvement in VAS was

−4.53 (95% CI: −4.58 to −4.48), and the mean improvement in ODI was −25.64 (95% CI: −26.02 to −25.26), indicating significant pain and functional improvement after endoscopic rhizotomy. No study reported any severe or permanent complications. Minor complications included transient skin numbness, intraoperative discomfort, and failed sutures. Endoscopic techniques demonstrated lower complication rates (6.67% vs. 30%, p<0.05), although they were associated with a longer operative time than fluoroscopic-guided percutaneous rhizotomy.

Conclusions: Full-endoscopic rhizotomy is a safe and effective treatment for degenerative lumbar facet joint syndrome, offering significant and sustained improvements in pain and disability. While it requires a longer operative time than conventional techniques, its satisfactory clinical outcomes and low complication rates support its use as a minimally invasive alternative.

Keywords: Endoscopic rhizotomy, Lumbar spine, Radiofrequency ablation, Minimally invasive surgery, Systematic review

S028

Is Biportal Endoscopic Decompression Truly Muscle-Sparing? A Quantitative Analysis Using 3-Class MRI Segmentation

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Purpose: To quantitatively evaluate acute paraspinal muscle injury following single-level unilateral biportal endoscopic (UBE) decompression using a 3-class MRI segmentation method and to determine its impact on spinopelvic sagittal alignment.

Materials and Methods: A retrospective analysis was performed on 71 patients who underwent single-level UBE decompression for lumbar spinal stenosis. Preoperative and immediate postoperative MRIs were analyzed using the Multi-Otsu thresholding method to segment the multifidus muscle into three distinct classes: muscle, fat, and other soft tissue (representing edematous connective tissue). Changes in tissue composition and spinopelvic parameters (pelvic incidence minus lumbar lordosis, PI–LL) were assessed. Subgroup analysis was conducted based on preoperative muscle fraction (sarcopenia vs. non-sarcopenia).

Results: Postoperatively, the multifidus muscle fraction significantly decreased by 10.65%p (p<0.001), while the other soft tissue fraction increased by 9.78%p (p<0.001). The fat fraction remained unchanged (p=0.138), indicating that acute muscle loss was replaced by edematous tissue rather than fatty degeneration. Despite these compositional changes, the PI–LL mismatch showed no significant change (p=0.884), with the difference falling within statistical equivalence margins. Notably, the non-sarcopenia group exhibited significantly greater muscle loss compared to the sarcopenia group (11.92%p vs. 4.95%p, p=0.007), suggesting greater iatrogenic injury in patients with higher muscle reserve.

Conclusions: Contrary to the belief that UBE is strictly muscle-sparing, our 3-class segmentation analysis revealed distinct acute muscle injury replaced by edema, especially in patients with high muscle reserve. However, this localized injury did not compromise global sagittal alignment. Thus, UBE should be redefined as an alignment-preserving rather than purely muscle-sparing technique in the acute phase.

Keywords: Unilateral biportal endoscopy, Lumbar spinal stenosis, Paraspinal muscle, MRI, Sarcopenia

S029

Minimally Invasive Spine Surgery for Thoracolumbar Fractures Using Standard Instruments: A Cost–Effective Two–Center Prospective Study

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Background: Minimally invasive spine surgery (MIS) reduces perioperative morbidity compared to open techniques, but its widespread use is limited by the high cost of specialized instrumentation, especially in resource-limited settings.

Objectives: To evaluate the feasibility, outcomes, and cost-effectiveness of MIS pedicle screw fixation using standard surgical instruments for thoracolumbar fractures.

Materials and Methods: A prospective two-center study

was conducted on 18 patients with AO type A1–A4 thoracolumbar fractures without neurological deficit. Pedicle screws were placed percutaneously via small incisions using standard instruments and the rods were introduced subfascially under fluoroscopic guidance. Clinical parameters (operative time, blood loss, hospital stay, pain scores, neurological status, complications) and cost analysis were assessed. Patients were followed for a mean of 9 months (range 6–12).

Results: Mean operative time was 95 minutes (range 80–120), with mean blood loss 120 mL. Hospital stay averaged 4.2 days, VAS pain scores improved from 7.8 preoperative to 2.3 at final follow-up. All patients mobilized within 48 hours. The main intraoperative complication was conversion to open surgery in 2 patients (11%) due to difficult screw trajectory. No neurological deterioration, wound infection or implant-related complications (loosening, breakage, loss of reduction) were observed during follow-up. Cost analysis showed a 40–50% reduction compared to commercial MIS kits.

Conclusions: MIS pedicle screw fixation using standard instruments is a safe, effective and highly cost-efficient alternative for selected thoracolumbar fractures, particularly in resource-limited settings. Larger multicenter studies with extended follow-up are warranted to validate these findings and assess long-term functional outcomes.

Keywords: Minimally invasive surgery, Thoracolumbar fractures, Pedicle screw fixation, Standard instruments, Cost-effectiveness

S030

Factors Associated With Patient Satisfaction One Year After 1–2 Level Minimally Invasive Transforaminal Lumbar Interbody Fusion: The Role of Foraminal Height and Segmental Lordosis

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Purpose: Patient satisfaction is an increasingly important outcome after spine surgery, distinct from pain and function scores. We aimed to identify clinical and radiographic factors associated with patient satisfaction 12 months after 1–2-level minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) for degenerative lumbar disease.

Materials and Methods: We retrospectively reviewed 68 patients (mean age 70.6 years) who underwent 1–2-level MIS-TLIF at a single center (March 2021–March 2024). Satisfaction at 12 months was assessed using the Macnab criteria (Excellent/Good = satisfied; Fair/Poor = dissatisfied). Demographics, comorbidities, neurologic status, radiographic parameters (lumbar lordosis [LL], pelvic parameters), and postoperative intervertebral foraminal height (IFH) on CT were collected. Patient-reported outcomes (ODI, FRI, and 0–10 VAS for back, buttock, and leg pain) were recorded preoperatively and at 12 months. Groups were compared, and multivariable logistic regression identified independent predictors of dissatisfaction.

Results: At 12 months, 55 patients (80.88%) were satisfied and 13 (19.12%) were dissatisfied. Baseline characteristics and perioperative outcomes were similar between groups (all $p>0.10$). The satisfied group had greater postoperative IFH (16.65±2.03 vs. 14.86±1.83 mm, $p=0.005$) and greater lordosis correction (ΔLL 4.29°±7.67° vs. −3.08°±7.78°, $p=0.003$). Fusion and complication rates did not differ. Satisfied patients achieved larger improvements in PROs (e.g., ODI change 20.3±6.8 vs. 7.8±7.8, $p<0.001$). On multivariable analysis, dissatisfaction was independently associated with smaller postoperative IFH (adjusted OR per 1 mm increase 0.58, $p=0.014$), less lordosis correction (adjusted OR per 1° increase 0.87, $p=0.013$), and preoperative cauda equina syndrome (adjusted OR 39.4, $p=0.003$).

Conclusions: After 1–2-level MIS-TLIF, greater postoperative foraminal height and restoration of segmental lordosis are independently associated with higher patient satisfaction at 12 months. Patients with preoperative cauda equina syndrome are at increased risk of dissatisfaction, highlighting the importance of preoperative counseling.

Keywords: Minimally invasive surgery, Transforaminal lumbar interbody fusion, Patient satisfaction, Foraminal height, Lumbar lordosis

S031

Learning Curve for Biportal Endoscopic Transforaminal Lumbar Interbody Fusion (BE-TLIF) in a Junior Endoscopic Spine Surgeon: A Phase-Specific Retrospective Analysis

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Purpose: Biportal endoscopic transforaminal lumbar interbody fusion (BE-TLIF) is an emerging minimally invasive spinal fusion technique with unique technical demands. Understanding its learning curve is essential for improving surgical efficiency and ensuring patient safety, particularly for junior surgeons with prior biportal decompression experience but limited fusion background.
Materials and Methods: We retrospectively analyzed 70 consecutive BE-TLIF levels performed by a single junior surgeon with extensive biportal decompression but limited MIS-TLIF experience (<10 cases). Learning progression was assessed using LC-CUSUM and exponential regression analyses. Operative times were evaluated across six surgical phases, and perioperative and clinical outcomes were compared between groups stratified by LC-CUSUM proficiency.
Results: LC-CUSUM identified procedural competence after 62 levels, while exponential regression demonstrated plateauing at around 43 cases. Phase-specific analysis revealed significant reductions in approach and decompression times, with the greatest improvement in cage insertion (37.1% reduction). Bone grafting time increased with experience, reflecting more meticulous technique. Clinical outcomes, including ODI and FRI scores, improved significantly in both groups, with greater functional recovery and fewer complications observed in later cases.
Conclusions: BE-TLIF demonstrates a phase-specific learning curve, with proficiency achieved after sufficient case volume. Structured training focusing on decompression and cage insertion may accelerate skill acquisition. Comprehensive inclusion of multi-level cases and phase-specific time analysis provides a robust framework for evaluating technical proficiency in endoscopic spine surgery training.
Keywords: Biportal endoscopic transforaminal lumbar interbody fusion, Learning curve, Junior surgeons, Phase-specific analysis, Surgical training

Invited Lecture I

S032

Challenges in Thoracic OPLL Posterior Surgery: Our Two-Stage Strategy

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Beak-type thoracic ossification of the posterior longitudinal ligament (T-OPLL) represents one of the most challenging conditions in spine surgery. Although posterior decompression and fusion are widely used, indirect decompression alone may be insufficient in cases with severe anterior spinal cord compression, particularly in beak-type lesions. Achieving adequate spinal cord decompression while minimizing surgical invasiveness remains a major challenge. In our institute, posterior decompression and instrumented fusion have been performed as the initial surgical procedure for beak-type T-OPLL. To better understand factors associated with surgical outcomes and to determine appropriate surgical timing, we analyzed 71 patients who underwent this procedure using multivariate logistic regression analysis. Negative prone and supine position tests (PST), good preoperative ambulatory status, absence of concomitant T-OPLL, ossification of the ligamentum flavum, and high intensity area in spinal cord on MRI at the same level, intraoperative spinal cord floating (+) confirmed by ultrasonography, and lower estimated blood loss were identified as significant predictors of favorable surgical outcomes. We have developed a two-stage surgical strategy. First, posterior decompression and corrective instrumented fusion are performed to achieve indirect decompression and spinal stabilization with good surgical outcome in most cases. If sufficient neurological recovery is not obtained, a second-stage surgery is performed approximately three weeks

later. In this procedure, we directly resect the OPLL using a posterior approach with our previously reported RASPA method, which enables anterior spinal cord decompression while avoiding a thoracotomy. Recent advances in posterior approaches for anterior decompression have expanded surgical options for thoracic OPLL. In selected patients with beak-type OPLL limited to one or two segments, we have recently adopted primary RASPA as the initial procedure to achieve complete spinal cord decompression in a single stage. Our strategy emphasizes careful patient selection and stepwise surgical decision-making. By combining indirect decompression with the option of direct OPLL resection, this two-stage strategy may help optimize neurological recovery while balancing surgical invasiveness in the treatment of thoracic OPLL.

Keywords: Thoracic spine, Ossification of the posterior longitudinal ligament (OPLL), Posterior decompression and fusion with instrumentation, OPLL resection from posterior approach, Two-stage strategy

Plenary Lecture I

S033

Management of Cervical Spine Deformity: Present and Future

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Introduction: Cervical deformity is a disabling condition and is becoming more important due to the increased number of patients, the aging population, and the higher requirement for quality of life in modern spine surgery. Evaluation and management of cervical deformity will need structural refinement.

Etiologies: The majority of traditional etiologies of cervical deformity were post-laminectomy kyphosis (PLK), chin-on-chest (COC) deformity of ankylosing spondylitis, and dropped head syndrome (DHS) from isolated neck extensor myopathy (INEM). However, the etiologies of cervical deformity have been more variable, including neuromuscular, post-surgical, posterior cervical laminectomy with fusion, laminoplasty, adjacent segment kyphosis to long thoracolumbar fusion, post-radiation treatment, as well as advanced degenerative changes.

Definition and Classification: Given the wide range of normal cervical spine alignment, the definition of cervical deformity remains unclear. Some cervical deformity is within the gray zone between 'degenerative alignment' and significant 'deformity'. The most common criteria used in clinical studies are from the ISSG prospective cervical deformity (PCD) study, but they span a wide spectrum from milder to severe deformities. In addition, there is no criterion of 'severe' cervical clinical deformity requiring corrective surgery. Several classifications have been published based on the primary driver, compensation mechanism, and morphometric phenotypes, but no comprehensive, universal classification system exists.

Surgical Techniques and Strategies: Variable options are being applied, including simple anterior cervical discectomy/corpectomy and fusion, posterior instrumented fusion, traditional posterior column osteotomy, pedicle subtraction osteotomy, anterior osteotomy, etc. Surgical strategies are variable depending on the main driver of the deformity (cervical, cervicothoracic, thoracic, etc.), the flexibility (flexible, rigid, and fixed). Fixed deformity requires osteotomy either from the anterior or the posterior. Thoracic and cervicothoracic drive is mostly approached from the posterior because of the limited anterior access. The subaxial cervical spine is usually approached anteriorly due to the risk of vertebral artery injury. A comprehensive treatment algorithm will be required.

Outcomes, Complications, and Preoperative optimization: The number of cervical deformity patients is dramatically increasing. Age and medical comorbidities are also increasing together. Corrective surgery is more common, but perioperative mortality and morbidities are increasing accordingly. Surgery is challenging due to age, combined medical comorbidities, osteoporosis, and the technically demanding nature of cervical/thoracic osteotomies. Preoperative optimization and improvement of postoperative outcomes will require further studies.

Conclusions: Cervical deformity will require further studies on diagnostic criteria, classification, surgical strategies,

and outcome optimization. Multi-centered, international collaborations will be necessary.

Keywords: Cervical deformity, Definition, Classification, corrective osteotomy, Surgical strategy

S034

Lessons from ‘En Bloc’ Resections of Spine Tumors

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Introduction: En bloc resection (EBR) of a spine tumor involves resecting the entire mass, including healthy tissue covering it. It improves local tumor control, reduced recurrences, and improved prognosis. It is challenging in the spinal column due to the spinal cord nerve roots and their proximity to major vascular/visceral structures. However, it dramatically increases surgical complications, perioperative morbidities, and mortalities.

Indications: EBR is indicated for benign aggressive tumors (Enneking 3; GCT, osteoblastoma, chondroblastoma), primary malignant tumors (mostly chordomas, sarcomas), and possible solitary metastasis for limited types of primary (renal, thyroid, etc.).

Surgical Planning

1. Delivery route decision
   - Consider spinal cord, functioning/nonfunctioning nerve root; retractable or resectable?
   - Planes between the adjacent vital structures/major vessels
   - Soft tissue extension – compartmental grading
2. Resection plane
   - Soft tissue coverage: paraspinal muscle, psoas muscle, diaphragm
   - Epidural/foraminal space – space available for tumor delivery
   - Osteotomy planes: laminectomy, pediculectomy, sagittal osteotomy ipsilateral/contralateral
3. Final surgical approach decision
   - Anterior, posterior, A-P, P-A, A-P-A, P-A-P, simultaneous A-P approach etc.

Reconstruction

1. Anterior: structural allograft, a cage (mesh, expandable, titanium, carbon, PEEK, etc.) filled with allograft, vascularized fibular autograft
2. Posterior
   - Preservation of unilateral posterior column if possible
   - Multiple-rod system
   - ‘Roof’ plasty

Outcomes/Complications: Overall complication rates 35~40%, 2~5% of mortality rate, and ~15% of local recurrence rate have been reported.

Conclusions: En bloc resection of a spine tumor is a complex and challenging procedure with a high risk of complications. Appropriate preoperative decision-making, considering risks and benefits, detailed surgical planning, and appropriate techniques are critical.

Keywords: Primary spine tumor, En bloc resection, Anterior column reconstruction, Posterior column reconstruction, Outcomes

Asian Spine Society Session I

S035

Thoracic Ossification of the Ligamentum Flavum

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President of the Philippine Spine Society

The ligamentum flavum, composed of elastic fibers (80%) and collagen fibers (20%), is located in the spinal canal from C2 to S1. In certain conditions related to aging of the ligaments and systemic ossification, the ligamentum flavum, also called the yellow ligament, may ossify, often in combination with ossification of the …posterior longitudinal ligament. Ossification of the ligamentum flavum is a type of ectopic ossification disease of the spinal ligaments, characterized by the transformation of the fibrous tissue within the ligament into bony tissue. This OLF is commonly seen in the lower thoracic spine, which leads to slow and progressive compression of the spinal cord. As the compression becomes significant, it will eventually lead to progressive deterioration of neurological function. Thus, surgical decompression is best managed early.

The most common surgical complications are dural tears and cerebrospinal fluid leaks, commonly seen in the tuberous types. It may also lead to further neurologic deficits, wound infections, and hematoma. Dural tears are mostly a result of dural adhesion and are difficult to repair. Intraoperatively, if it is difficult to perform a full laminectomy, a floating technique is preferred, which may lead to spinal cord expansion.

S036

Minimally Invasive Thoracolumbar Fracture Reduction Techniques with Percutaneous Pedicle Screws

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This topic reviews the minimally invasive reduction techniques for thoracolumbar traumatic fractures, encompassing both fundamental and specialized approaches. Simple methods are discussed for routine traumatic fractures, while additional strategies are highlighted for complex cases such as ankylosed spine fractures, osteoporotic fractures, and AOSpine Type C fracture dislocations.

Keywords: Spine, Fracture, Thoracolumbar, Minimally invasive, Reduction

S037

Current Concepts of Vertebral Body Tethering for Non-Fusion AIS Surgery

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Spinal fusion has been the gold standard for treatment of Adolescent Idiopathic Scoliosis (AIS). However, there are long-term considerations for fusion surgery including early degeneration, back pain and reduced spinal motion. Vertebral body tethering (VBT) is a relatively new surgical option that provides minimally invasive non-fusion correction of AIS. VBT utilizes the Hueter-Volkmann principle in correction of the deformity through growth modulation via tensioning the convexity of the curve. Patients can return to sports much earlier and can maintain the normal disc physiology. Currently, VBT is indicated in patients with flexible deformities and adequate growth remaining. This indication can be stretched to more mature patients in particular in the lumbar spine where mobility is far more important. Modified options like hybrid options and apical fusions can be applied to stiffer curves. VBT is a viable alternative option to fusion in patients who require mobility and want to avoid large open surgery. The two main complications of VBT namely, overcorrection and tether rupture can be minimized with proper indication and execution of the surgery. Although reported tether rupture rates are high, it may not require revision surgery if adequate growth modulation has already occurred.

S038

Spine Injuries of 2025 Earthquake in Myanmar

Thant Zin Naing

Past President of the Myanmar Spine Society

The 2025 Myanmar earthquake resulted in a significant number of musculoskeletal and spinal injuries requiring coordinated orthopaedic trauma management at the Orthopaedic Department, University of Medicine 1 (Yangon), under the supervision of Prof. Thant Zin Naing. This study summarizes the demographic characteristics, injury patterns, treatment timelines, and clinical outcomes of 64 patients managed following the disaster. The cohort included 29 males and 35 females, with the majority of patients aged between 18–55 years (65.4%). Thoracolumbar spine fractures accounted for 35 cases, while 29 patients sustained cervical spine injuries, including cases of central cord syndrome and spinal cord injury without radiographic abnormality (SCIWORA). Multiple associated injuries were observed, including pelvic fractures with distal tibial fractures, floating knee injuries, pelvic fractures with clavicle fractures, and lower limb compartment syndrome, reflecting the high-energy mechanisms typical of earthquake-related trauma. The mean hospital stay was 12.6 days, with a maximum duration of 55 days, particularly among patients with complex spine injuries and open fractures. The average interval

from injury to operative intervention was 4.6 days (range 3–7 days), influenced by logistical constraints and limited critical care resources. Two patient deaths were recorded, including a SCIWORA case and a geriatric patient with trochanteric fracture. Early triage, prompt stabilization, and multidisciplinary collaboration were essential in improving outcomes despite resource limitations. The findings highlight the substantial orthopaedic burden following mass casualty disasters and emphasize the need for strengthened disaster preparedness, standardized trauma pathways, rapid surgical response teams, and resilient healthcare systems to optimize future emergency responses.

Symposium I. MISS: From Theory to Practice in MIS Techniques

Session 1: The Next Frontier of Minimally Invasive Spine Surgery

S039

Next-Generation Osteobiologics for MIS Fusion: rhBMP-2, ABM/P-15, Bioactive Glass and Whitlockite

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Purpose: Minimally invasive and endoscopic spinal fusion (MIS fusion) requires achieving reliable arthrodesis within a constrained grafting space while minimizing iatrogenic tissue injury. This presentation aims to evaluate the clinical rationale and emerging evidence for next-generation synthetic osteobiologics—specifically bioactive glass and whitlockite—and to compare their biological mechanisms and clinical applicability with established agents, including recombinant human bone morphogenetic protein-2 (rhBMP-2) and ABM/P-15.

Materials and Methods: A focused narrative review was conducted integrating current clinical and preclinical evidence on osteobiologics used in MIS and endoscopic lumbar fusion. Mechanistic aspects (osteoinduction, osteoconduction, osteostimulation), safety profiles, and handling characteristics relevant to confined surgical environments were comparatively analyzed among rhBMP-2, ABM/P-15, bioactive glass, and whitlockite. Particular attention was given to dose modulation strategies, carrier systems, ion-mediated signaling, and suitability for irrigation-based endoscopic conditions.

Results: rhBMP-2 provides potent osteoinductive capacity and consistently high fusion rates; however, its use in confined spaces is associated with dose-dependent complications, including radiculitis, soft tissue swelling, and ectopic ossification, necessitating ultra-low-dose strategies with controlled-release carriers. ABM/P-15 (i-Factor), a peptide-based biomimetic agent, enhances cell adhesion and early osteogenesis with a favorable safety profile, reducing the risk of aberrant bone formation and demonstrating suitability in limited spaces. Bioactive glass and whitlockite, representing third-generation synthetic scaffolds, exhibit osteostimulatory effects via sustained ionic release. Bioactive glass releases silicon ions, while whitlockite releases magnesium ions, both of which upregulate osteogenic gene expression and promote bone regeneration. Their injectable putty formulations provide high viscosity and resistance to washout under continuous irrigation, enabling effective filling of irregular and narrow bone defects in MIS environments.

Conclusions: Successful MIS fusion requires a strategic selection of osteobiologics tailored to the surgical microenvironment. While rhBMP-2 and ABM/P-15 offer strong biological potency and cell-mediated safety, bioactive glass and whitlockite provide ion-driven osteostimulation and superior handling properties, making them particularly advantageous in endoscopic and minimally invasive settings. Future directions include patient-specific 3D-printed constructs and composite systems integrating growth factors, which may further advance the paradigm of spinal fusion.

Keywords: Lumbar spine, Spinal fusion, Arthrodesis, Bone substitutes, Minimally invasive surgical procedures

S040

Advanced Implant Design Enabling Minimally Invasive Stability - 3D-Printed Porous Titanium Pedicle Screws and Cage

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Background: Pedicle screw fixation and interbody cage implantation remain fundamental components of modern spinal surgery. However, challenges such as screw loosening in osteoporotic bone, stress shielding, subsidence, and pseudarthrosis persist. The advent of additive manufacturing has enabled the development of 3D-printed porous titanium implants designed to enhance osseointegration, optimize mechanical properties, and improve long-term fixation stability.

Objective: To review the current evidence regarding 3D-printed porous titanium pedicle screws and interbody cages, and to discuss future design directions based on biomechanical, biological and clinical perspectives.

Pedicle Screws: Preclinical and early clinical studies demonstrate that porous titanium screws improve bone in-growth and bone–implant contact compared to conventional solid screws. Biomechanical studies report increased pullout strength, particularly in osteoporotic bone models. Early clinical data suggest reduced rates of radiographic loosening; however, high-level comparative trials remain limited.

Interbody Cages

Porous titanium cages exhibit:

1. Enhanced osteoconductivity
2. Reduced elastic modulus closer to cancellous bone
3. Improved fusion rates in some cohort studies

Compared with traditional PEEK cages, porous titanium designs may promote earlier osseointegration, though subsidence risk remains influenced by endplate preparation and patient bone quality.

Design Considerations

Key design parameters include:

1. Porosity percentage and pore size (optimal range 300–700 μm for bone in-growth)
2. Elastic modulus matching
3. Surface roughness and trabecular-mimicking architecture
4. Lattice structure (diamond vs gyroid vs stochastic)
5. Patient-specific customization potential

Balancing mechanical strength and biological integration remains critical.

Future Directions

Future development may focus on:

1. Patient-specific implants using CT-based modeling
2. Topology optimization to maximize strength-to-weight ratio
3. Biofunctional coatings (e.g., BMP integration, drug-eluting surfaces)
4. Hybrid materials combining porous titanium with bioresorbable scaffolds
5. AI-assisted implant design for individualized load distribution

Long-term randomized clinical trials and cost-effectiveness analyses are needed to establish definitive clinical superiority.

Conclusions

3D-printed porous titanium pedicle screws and cages represent a promising evolution in spinal instrumentation. While early biomechanical and clinical results are encouraging, robust long-term evidence is required. Future innovation will likely integrate advanced manufacturing, biologic enhancement, and personalized surgical planning.

S041

Artificial Intelligence and Robotics in MIS Planning and Execution

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Minimally Invasive Spine Surgery (MIS) has achieved remarkable advancements over the past few decades. Recently, the integration of Artificial Intelligence (AI) and robotic technology has presented a new paradigm, elevating the precision, safety, and reproducibility of surgeries to the next level.

Utilization of AI in the Preoperative Planning Stage

In the field of preoperative image analysis, deep learning-based algorithms can now perform automated classification of spinal segments, grading of intervertebral disc degeneration, quantification of spinal canal stenosis, and automated measurement of spino-pelvic parameters from CT and MRI images with high accuracy. This enhances the objectification of surgical indication judgments and the consistency of determining the surgical scope. Furthermore, machine learning-based predictive models integrate and analyze patients' clinical data, imaging findings, and demographic information. These models are evolving into clinical support tools that assist surgeons' decision-making regarding postoperative outcome prediction, complication risk stratification, and the selection of optimal surgical methods.

Intraoperative Robot-Assisted Systems

Robot-assisted spine surgery systems are currently the most widely applied technology in clinical practice, with representative systems including Mazor X, ExcelsiusGPS, and TiRobot. These systems reproduce pre-planned screw trajectories with high precision and are particularly effective in overcoming the limitations of restricted fields of view and working spaces in an MIS environment. Recently, the application of robotics in endoscopic spine surgery has also been attempted, and research is underway on the manipulation of endoscope holders and intraoperative retractors using robotic arms.

Intraoperative Real-Time AI Assistance

Real-time image guidance systems combining Augmented Reality (AR) and navigation technology supplement the visualization of anatomical structures during MIS procedures. AI-based image recognition algorithms are advancing toward providing visual warnings and guidance to the operator by segmenting and recognizing key anatomical structures and surgical instruments in real time from endoscopic surgical videos. Additionally, the integration of intraoperative neuromonitoring data with AI analysis is gaining attention as a safety system for the early detection of nerve injury risks.

Conclusions: The convergence of AI and robotic technology is substantially contributing to shortening the learning curve, standardizing surgical techniques, and improving surgical precision in MIS spine surgery. However, the accumulation of clinical validation data, cost-effectiveness analysis, and the establishment of optimal collaboration methods between surgeons and technology remain future challenges.

Keywords: Artificial intelligence, Minimally invasive spine surgery, Robotics

Session 2: Endoscopic Spine Surgery in Practice: Key Techniques and Pitfalls

S042

Tips and Pitfalls in Cervical Endoscopic Surgery (Key techniques and pitfalls)

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Background and Introduction: Many spine surgeons now prefer full endoscopic over conventional surgery, given its benefits of minimal tissue injury, less bleeding, improved postoperative pain, and early rehabilitation. It has expanded to cervical foraminotomy (PECF), discectomy (PECD), and posterior decompression (CE-ULBD) with good prognosis. However, radiculopathy from foraminal restenosis must be considered in both open and endoscopic surgery. Complications including hematoma, dural tear, cord contusion, root injuries, and double root misidentification can cause neurologic deficits and prolonged recovery.

Main Body: The adequate range of facet resection in PECF. In PECF, the exiting nerve root must be decompressed from the lateral recess to the lateral margin of the lower pedicle by partial facetectomy. Our study showed the adequate resection range is smaller than previously recommended (resection width: 4.618 mm, remnant ratio: 63.922%). Proper, not excessive, facet resection improves pain without inducing segmental instability or restenosis.

Pitfalls

1. Hematoma collection in epidural space.

Postoperative epidural hematoma is critical, particularly after narrow decompressions (PECD, PECF), as it may extend to superior or inferior segments inaccessible through the original portal. Patients may present with thoracic outlet syndrome-like symptoms. Immediate radiologic detection,

surgical exploration, evacuation, and indwelling drain placement are essential.

2. Nerve root injury due to excessive retraction.

In PECD, acute paracentral disc material is readily extracted. However, far lateral or foraminal discs and chronic hard disc protrusions may require excessive retraction, risking nerve root injury. Adequate resection of the overlying lamina and facet is preferable, leaving the hard disc in place.

3. Misidentification of double root or confluent root.

Confluent nerve roots occur in PECD and PECF at an incidence of 13.6%, highest at C6-7 (16.4%). The ventral branch of a cephalo-cranial confluent root may be mistaken for a bulging disc and pinched or squeezed. When in doubt, medial tracing to the dura mater is required to confirm and avoid injury.

Conclusions: Full endoscopic cervical spine surgery offers clear advantages over conventional approaches. However, surgeons must recognize key pitfalls: excessive facet resection risks instability and restenosis; epidural hematoma requires prompt intervention; nerve root injury can result from forceful retraction; and confluent roots must be carefully identified. Iatrogenic complications may cause neurologic deficits immediately or later. Meticulous neural tissue handling, hemostasis, and vigilant postoperative monitoring are essential.

Keywords: Full endoscopic spine surgery, PECF, PECD, CE-ULBD

S043

Biportal Endoscopic Surgery - Interlaminar Approach

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Purpose: Biportal endoscopic spine surgery has become a major modality in minimally invasive lumbar procedures. The interlaminar approach is widely adopted for decompression and discectomy; however, surgical outcomes are highly dependent on technical sequence, bleeding control, and neural structure protection. This study presents practical technical pearls and avoidable pitfalls based on real operative experience.

Main Body: Portal planning is a critical determinant of surgical quality in endoscopic spine procedures. The cranial portal is placed along the upper laminar margin, and the caudal working portal along the lower laminar margin, maintaining an approximate 2 cm interval to ensure effective triangulation and instrument control. During muscle detachment, tactile confirmation of the lamina followed by rotational elevator movement helps create a safe working plane. Early bleeding usually indicates incorrect layer dissection. For flavectomy, early complete removal of the ligamentum flavum should be avoided. The superficial layer is removed first, while the deep layer is intentionally preserved as a protective barrier to minimize epidural bleeding and reduce the risk of dural injury. Medial facetectomy should be limited to less than 50% of the facet joint. Undercutting rather than vertical burring allows adequate lateral recess decompression while maintaining stability. The true endpoint of decompression is root mobility rather than dural pulsation. Irrigation pressure must be carefully controlled to prevent pressure-related neurological complications. When a pump system is used, pressure should be maintained within approximately 30–40 mmHg; with gravity-based irrigation, ensuring adequate and continuous outflow is essential.

Conclusions: A successful interlaminar approach in biportal endoscopic spine surgery relies not merely on visualization but on strict sequence control. Proper portal positioning, flavum-preserving strategy, minimal root manipulation, and irrigation pressure management are essential to reduce complications and achieve stable clinical outcomes.

Keywords: Biportal endoscopic spine surgery, Interlaminar approach, Key techniques and pitfalls

S044

Biportal Endoscopic Surgery - Far Lateral Approach

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Background and Introduction: Far lateral lumbar lesions involve compression of the exiting nerve root within the foraminal or extraforaminal zone. Conventional microscopic approaches provide a deep and narrow surgical corridor, which may limit adequate decompression and risk excessive

facet resection. At the L5–S1 level, access may be further restricted by the sacral ala and transverse process. Biportal endoscopic surgery offers magnified visualization and flexible instrument handling through separate viewing and working portals, providing a minimally invasive alternative for far lateral pathology.

Main Body: The far lateral biportal approach utilizes an intermuscular plane to directly access the foraminal and extraforaminal regions. With a 30-degree endoscope, clear visualization of the exiting nerve root, including its distal portion beneath the pedicle, can be achieved. Partial resection of the superior articular process and selective discectomy, pediculotomy allow sufficient decompression while preserving midline structures. Even at L5–S1, the approach enables access without extensive disruption of the sacral ala. Continuous saline irrigation and bipolar radiofrequency devices facilitate meticulous hemostasis. Radiologic analysis suggests that a small ipsilateral coronal root angle and lower lumbar level involvement may be associated with unfavorable outcomes, in which case interbody fusion with restoration of disc height should be considered rather than stand-alone decompression.

Conclusions: The biportal endoscopic far lateral approach enables adequate neural decompression with minimal soft tissue disruption and preservation of spinal stability. Careful patient selection and consideration of radiologic risk factors are essential to optimize surgical outcomes.

Keywords: Lumbar vertebrae, Foraminal stenosis, Intervertebral disc herniation, Endoscopic decompression, Biportal endoscopic spine surgery

Invited Lecture III

S045

Management Trend of the Early Onset Scoliosis

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Early onset scoliosis (EOS), defined as scoliosis presenting before 10 years of age, is a heterogeneous and challenging condition with potentially life threatening consequences if untreated, particularly due to impaired thoracic and lung development. Management is complex because disease etiology, progression rate, age, and growth potential vary widely, and no single standard treatment fits all patients. The primary goals are to control or improve spinal deformity while preserving spinal and thoracic growth, especially during the rapid growth periods before age 5 and at puberty.

Normal thoracic and lung development is critical in EOS care. Adequate thoracic length is required to support lung growth and pulmonary function, most of which occur before 8 years of age, with the most critical phase before age 5. Severe deformity can restrict thoracic volume, reduce alveolar development, and lead to long term respiratory compromise. Treatment must be individualized. Observation is appropriate for mild, non progressive curves, particularly some infantile idiopathic or selected congenital cases. Serial casting is a key early intervention for very young children with progressive idiopathic scoliosis; when it started early, it can correct deformity, delay or avoid surgery, and reduce later complications. Bracing may help in selected cases but is limited by compliance and effectiveness in very young children or rigid curves. For progressive or severe EOS, growth friendly surgical strategies are central. Distraction based systems, particularly traditional growing rods and magnetically controlled growing rods (MCGR), allow continued spinal growth while controlling deformity but are associated with high complication rates, repeated interventions, and diminishing returns over time. MCGR reduces unplanned surgeries but introduces risks such as mechanical failure and metallosis. Other growth-preserving approaches include VEPTR for thoracic insufficiency syndrome, guided-growth techniques such as the Shilla procedure, and compression-based systems (e.g. vertebral body tethering) mainly for older children. Each has specific indications, benefits, and limitations. Definitive fusion or tethering is generally reserved for children older than 10 years old. Overall, optimal EOS management requires tailored decision-making, balancing deformity control and growth preservation, complication risk, and long-term pulmonary health, with shared decision-making involving families.

Keywords: Diversity, Growth, Tailor-made, Pulmonary, Complications

Free Paper: MISS (4)

S046

Comparison of Transforaminal Endoscopic Lumbar Foraminotomy (TELF) in Patients with Degenerative Scoliosis and Patients with Normal Alignment

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Introduction: Transforaminal endoscopic lumbar foraminotomy (TELF) is a well-described method of treating foraminal stenosis. However, there is little literature examining the usage of TELF to treat foraminal stenosis in patients with degenerative scoliosis. TELF is an attractive option for such patients as it results in less blood loss, shorter recovery time and lower infection rates compared to fusion surgery. However, TELF neither corrects the deformity nor alters the natural history of the disease. Therefore, the outcomes of TELF in patients with degenerative scoliosis may be worse than those without deformities. This study aims to compare the outcomes of TELF in these two groups of patients.

Methods: This is a retrospective study of 19 patients who underwent TELF from July 2012 to April 2015. Eight patients had degenerative scoliosis and 11 were without scoliosis. VAS and ODI scores were collected at 3 months postoperatively. Patient outcomes were graded as excellent, good, fair, and poor using a modified MacNab's criteria.

Results: Both groups had significant improvements in back pain, leg pain and ODI scores postoperatively. There were no differences between the two groups when comparing the pre-operative and post-operative back pain, leg pain and ODI scores. The majority of patients rated their outcomes as excellent or good.

Conclusions: The short-term outcomes of TELF in patients with degenerative scoliosis are comparable to those without scoliosis. Improvements in back and leg pain after surgery are expected. We recommend it as a palliative treatment for patients who are unable to undergo major surgery.

S047

O-arm Navigation–Assisted Biportal Endoscopic Spine Surgery for Extremely Migrated Lumbar Disc Herniation: A Case Series

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Purpose: Extremely migrated lumbar disc herniation with massive extrusion remains a significant technical challenge in minimally invasive spine surgery, particularly in endoscopic procedures, due to limited visualization, distorted anatomical landmarks, and difficulty in precise localization of far-migrated disc fragments. In biportal endoscopic spine surgery (BESS), incomplete removal of migrated or remnant disc material may result in inadequate decompression and persistent symptoms. This study aimed to evaluate the technical feasibility and reproducibility of O-arm navigation assisted BESS for extremely migrated lumbar disc herniation, defined as far-migrated or massively extruded disc fragments.

Materials and Methods: We retrospectively reviewed a consecutive case series of three patients with extremely migrated lumbar disc herniation, including far-migrated or massively extruded disc fragments, who underwent biportal endoscopic spine surgery assisted by intraoperative O-arm based navigation. O-arm navigation was selectively utilized to localize far-migrated disc fragments and remnant disc material, guide targeted bone removal, and confirm the adequacy of neural decompression in surgically distorted anatomical fields.

Results: In all three cases, far-migrated and massively extruded disc fragments, including remnant disc material, were successfully identified and completely removed under navigation guidance. Adequate decompression of the neural elements was achieved without intraoperative or postoperative complications. All patients demonstrated marked improvement in radicular symptoms following surgery, and postoperative imaging confirmed complete removal of the migrated disc fragments with sufficient neural decompression.

Conclusions: This case series demonstrates the technical feasibility and reproducibility of O-arm navigation–assisted biportal endoscopic spine surgery for extremely migrated lumbar disc herniation. O-arm based navigation may be a useful adjunct in BESS for selected challenging cases involving far-migrated or massively extruded disc fragments, where precise localization of disc pathology is critical for achieving complete decompression.
Keywords: O-arm navigation, Biportal endoscopic spine surgery, Extremely migrated lumbar disc herniation, Massive disc extrusion, Minimally invasive spine surgery

S048

Safety and Utility of Ultrasonic Tools in Biportal Endoscopy

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Purpose: Biportal endoscopic spine surgery (BESS) enables effective posterior spinal decompression through independent visualization and working portals; however, laminar thinning and undercutting adjacent to the dura remain technically demanding within a confined fluid-based endoscopic environment. Ultrasonic surgical tools, which utilize high-frequency mechanical vibration for selective tissue fragmentation with minimal thermal and mechanical transmission, have emerged as potential adjuncts to improve safety during endoscopic decompression. This study evaluates the safety and procedural utility of ultrasonic surgical instruments during lamina-focused decompression in biportal endoscopic spine surgery.
Materials and Methods: Patients undergoing biportal endoscopic decompression procedures in which ultrasonic surgical tools were utilized for laminar work were analyzed. Ultrasonic instruments were employed for laminar thinning, undercutting of the medial facet–laminar junction, controlled removal of residual laminar bone, and resection of hypertrophied ligamentum flavum following adequate bony decompression. Intraoperative parameters assessed included precision and controllability of laminar bone removal, preservation of dural integrity, maintenance of endoscopic visualization, and instrument maneuverability through the working portal. Safety endpoints included dural tears, neural injury, thermal tissue damage, excessive bleeding, and the need for conversion to conventional high-speed burrs or mechanical instruments. Postoperative neurological status and procedure-related complications were documented.
Results: Ultrasonic surgical tools enabled controlled and incremental laminar thinning with minimal transmission of mechanical force to the underlying dura. Precise undercutting facilitated safe exposure of the ligamentum flavum and neural elements while maintaining a clear endoscopic field due to reduced bleeding and limited bone debris. No ultrasonic instrument–related dural tears, neural injuries, or thermal complications were observed. The independent working portal in BESS allowed optimal angulation and stable manipulation of ultrasonic instruments during laminar decompression.
Conclusions: Ultrasonic surgical instruments demonstrate a favorable safety profile and significant procedural utility for lamina-focused decompression in biportal endoscopic spine surgery. Their ability to provide controlled bone removal, minimize mechanical stress on neural structures, and preserve endoscopic visualization enhances operative precision and safety. Ultrasonic technology represents a valuable adjunct in BESS, particularly in anatomically constrained regions or areas with dural adherence.
Keywords: Biportal endoscopic spine surgery, Ultrasonic surgical instruments, Laminar decompression, Minimally invasive spine surgery, Dural safety

S049

Feasibility of the Pedicle Medial Line and Inferior Vertebral Upper Endplate as Portal Landmarks for Uniportal Endoscopic Lumbar Laminectomy

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Purpose: The laminar–superior articular process (SAP) junction has been proposed as a reliable anatomical landmark for uniportal endoscopic laminectomy in the lumbar spine. Although this landmark is consistently identifiable on

computed tomography, its visualization on intraoperative fluoroscopy using a C-arm (OEC9800; GE Healthcare, USA) is often unclear, particularly in patients with degenerative changes or obesity. Therefore, this study aimed to evaluate a fluoroscopy-based portal landmark defined by the pedicle medial line and the upper endplate of the inferior vertebral body and to assess its feasibility as a practical guide for uniportal endoscopic laminectomy.

Materials and Methods: Lumbar spine radiographs and CT images of 100 adult patients without prior spinal surgery were retrospectively reviewed. The laminar–SAP junction was operationally defined and identified on coronal reconstructed CT images at the L3–4, L4–5, and L5–S1 levels. Linear distances from the pedicle medial line and from the upper endplate of the inferior vertebral body to the laminar–SAP junction were measured at each segment. Interobserver and intraobserver reliability were assessed using intraclass correlation coefficients.

Results: The mean age of the patients was 66±15.93 years, including 52 men and 48 women. The lamina–SAP junction was indistinct on intraoperative C-arm fluoroscopic images in 12 cases (12%). On C-arm posteroanterior images, the mean distance between the SAP and the pedicle medial line was 5.80±1.93 mm at L3–4, 5.30±2.33 mm at L4–5, and 5.46±2.62 mm at L5–S1. The mean distance from the SAP to the upper endplate of the inferior vertebral body was 5.08±3.60 mm at L3–4, 7.85±3.27 mm at L4–5, and 5.02±3.59 mm at L5–S1. Interobserver and intraobserver reliability were moderate to good agreement (ICCs=0.60–0.78). The intersection of these two fluoroscopic reference lines reliably corresponded to the anatomical zone appropriate for endoscopic access, providing a predictable entry point for bone work during uniportal endoscopic laminectomy.

Conclusions: Although the laminar–SAP junction remains a valid anatomical landmark, fluoroscopy-guided portal placement based on the pedicle medial line and the upper endplate of the inferior vertebral body provides a more practical and clinically useful landmark for uniportal endoscopic laminectomy.

Keywords: Lumbar spine, Uniportal endoscopy, Laminectomy, Portal landmark

S050

Wound-Related Outcomes Following Endoscopic Versus Microscopic Lumbar Discectomy: A Post Hoc Analysis of Two Randomized Controlled Trials

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Purpose: Wound complications remain a significant concern following lumbar spine surgery. Endoscopic techniques theoretically offer advantages in wound outcomes due to smaller incisions and reduced tissue trauma. However, direct comparative evidence using validated scar assessment tools remains limited. This study aimed to compare wound complication rates and scar-related outcomes between endoscopic and microscopic lumbar discectomy.

Materials and Methods: This was a post hoc analysis of pooled data from two prospective randomized controlled trials conducted at a tertiary referral center. Patients with single-level lumbar disc herniation were randomly allocated to either uni- or biportal endoscopic lumbar surgery (Group E, n=110) or conventional microscopic surgery (Group M, n=110). The primary outcome was the incidence of wound complications within 12 months, including surgical site infection, wound dehiscence, and prolonged drainage. Secondary outcomes included Patient and Observer Scar Assessment Scale (POSAS) scores at 3, 6, and 12 months, incision length, and wound-related healthcare costs. Fisher's exact test and Haldane-Anscombe correction were used for statistical analysis.

Results: Wound complications occurred in 10 patients (4.5%) overall, all exclusively in the microscopic group (0% vs 9.1%, p=0.0016). Complications included surgical site infection (n=4), wound dehiscence (n=4), and other wound problems (n=2). The odds ratio for wound complications in microscopic versus endoscopic surgery was 23.1 (95% CI: 1.34–399.1). Mean incision length was significantly smaller in the endoscopic group (22.8±15.3 mm vs 64.4±28.7 mm,

p<0.001). POSAS total scores were consistently lower (better) in the endoscopic group at all time points, with significant differences at 12 months (5.9±1.4 vs. 7.2±3.1, p=0.019). Mean wound-related costs were significantly lower in the endoscopic group (0 KRW vs 36,400 KRW, p=0.002).

Conclusions: Endoscopic lumbar discectomy demonstrated significantly lower wound complication rates, smaller incisions, superior scar outcomes, and reduced wound-related costs compared to microscopic surgery. These findings support the wound-related benefits of endoscopic techniques and may influence surgical decision-making, particularly for patients at higher risk of wound complications.

Keywords: Endoscopic spine surgery, Wound complications, Surgical site infection, Scar assessment, POSAS, Minimally invasive surgery, Lumbar discectomy

Free Paper: Lumbar (1)

S051

Risk Factors for Hidden Blood Loss After Oblique Lumbar Interbody Fusion

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Purpose: Hidden blood loss (HBL) constitutes a substantial proportion of total blood loss following spinal surgery and may contribute to postoperative anemia and delayed recovery. Although oblique lumbar interbody fusion (OLIF) is considered a minimally invasive procedure with reduced visible blood loss, data regarding HBL and its associated risk factors remain limited and inconsistent. This study aimed to identify preoperative and perioperative risk factors for hidden blood loss after OLIF while minimizing the influence of posterior procedures.

Materials and Methods: A retrospective analysis was conducted on patients who underwent OLIF for degenerative lumbar disease between January 2023 and December 2024. To minimize the confounding effect of posterior instrumentation, only perioperative data up to postoperative day (POD) 2 were included. Patient blood volume was calculated using the Nadler formula, and total blood loss was estimated based on hematocrit changes according to the Gross method. Hidden blood loss was defined as total blood loss minus measured blood loss, including estimated blood loss and drainage volume. Linear regression analysis was performed to identify independent risk factors for HBL. Additional subgroup analyses were conducted based on age (≥70 years), estimated blood loss (EBL ≥150 mL), operative level, and operative time. A threshold of HBL >400 mL was used for grouping analysis.

Results: A total of 50 patients were included. Mean total blood loss was 0.70±0.29 L, and mean hidden blood loss was 440.2±269.9 mL, accounting for a substantial proportion of total blood loss. The mean hemoglobin decrease by POD 2 was 2.38±1.12 g/dL. Linear regression analysis identified alcohol use and renal disease as independent risk factors for increased hidden blood loss. Patients aged ≥70 years showed significantly higher total blood loss. Interestingly, lower estimated blood loss during surgery was associated with a higher likelihood of excessive hidden blood loss, suggesting underestimation of actual blood loss. Radiologic parameters and operative time were not significantly associated with hidden blood loss. Hemoglobin loss showed a significant correlation with hidden blood loss.

Conclusions: Hidden blood loss represents a clinically significant component of perioperative blood loss following OLIF. Alcohol use and renal disease were identified as independent risk factors, while advanced age and low intraoperative estimated blood loss were associated with higher hidden blood loss. Awareness of these risk factors may help surgeons better anticipate postoperative anemia and optimize perioperative blood management strategies in OLIF patients.

Keywords: Oblique lumbar interbody fusion, Hidden blood loss, Perioperative anemia, Risk factors, Minimally invasive spine surgery

S052

3D Printed Pedicle Screw: Porosity Range for Bone-Like Porous Structures to Ensure Sufficient Structural Stability

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Purpose: With the recent increase in the incidence of degenerative spinal diseases such as osteopenia and osteoporosis due to the aging population, lumbar interbody fusion is becoming more widely performed. However, complications such as nonunion, pedicle screw loosening, and breakage are frequently reported. Despite growing clinical interest in porous titanium pedicle screws utilizing 3D printing technology to address these issues, systematic evaluation of their biomechanical performance and stability remains inadequate. This study aimed to identify the porosity range that ensures sufficient structural stability by evaluating the mechanical behavior of 3D printed porous titanium pedicle screws with bone-like porous structures under physiological loading conditions.

Materials and Methods: To simulate osteopenia and osteoporosis, bone mineral density was reduced by 17.5% and 35%, respectively. A validated finite element model of the lumbar spine (L1–L5), including pelvis, sacrum, coccyx, and major ligaments, was used to simulate one-, two-level fusion constructs with symmetrically placed TLIF cages and pedicle screws inserted using the inward technique. The screw design consisted of a dense inner region and a porous outer region with porosities of 60%, 70%, and 80%. Physiological moments—7.5 Nm in flexion, extension, lateral bending, and axial rotation—combined with a 400 N follower load were applied to reproduce spinal motion. Peak von Mises stress (PVMS) was calculated across porosity configurations and compared against porosity-dependent yield strengths (230 MPa at 60%, 60 MPa at 70%, and 20 MPa at 80%) to assess the risk of screw failure.

Results: In the dense inner region, the PVMS ranged approximately from 59–167 MPa, 61–176 MPa, 63–183 MPa at 60%, 70%, and 80% porosity, respectively. In the porous outer region, the PVMS was approximately 15–39 MPa, 10–30 MPa, and 8–23 MPa at 60%, 70%, and 80% porosity, respectively. Although PVMS in the dense inner region increased with rising porosity, only the 60% configuration consistently remained within safe mechanical limits under a conservative safety factor of 3, while 70% and 80% porosities exceeded allowable thresholds and demonstrated stress concentration in multilevel fusion conditions.

Conclusions: These findings indicate that 60% porosity provides an optimal balance between mechanical integrity and stress distribution, offering sufficient biomechanical stability while supporting the concept of biologically favorable porous structures. This study provides an essential preliminary guideline for designing 3D-printed pedicle screws and underscores the need for future preclinical and clinical validation.

Keywords: 3D-printed pedicle screw, Porous structure, Mechanical integrity, Structural stability, Bone mineral density

S053

Outcomes of Open TLIF vs. MISS TLIF (Hybrid) for the Treatment of Spondylolisthesis: A Comparative Study

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Purpose: To compare the clinical and radiological outcomes of Open TLIF versus MISS TLIF (Hybrid) in patients with spondylolisthesis, focusing on surgical efficiency, functional recovery, and complication rates. Spondylolisthesis remains a primary indication for spinal fusion, with Transforaminal Lumbar Interbody Fusion (TLIF) being a gold standard approach. While traditional open TLIF provides excellent visualization and decompression, it is often associated with significant paraspinal muscle stripping and blood loss. Minimally Invasive Surgery (MISS) TLIF, specifically the hybrid technique, has been developed to achieve similar

stability and fusion rates while minimizing surgical morbidity and accelerating postoperative recovery.

Materials and Methods: A prospective comparative study was conducted on 60 patients diagnosed with spondylolisthesis. The participants were divided into two equal groups: Group A (n=30) underwent traditional Open TLIF, and Group B (n=30) underwent MISS TLIF (hybrid technique). Clinical outcomes were assessed using the Visual Analog Scale (VAS) for back and leg pain, and the Oswestry Disability Index (ODI) for functional status. Radiological parameters, including fusion rate and disc height maintenance, were evaluated via X-ray and CT scans at 3, 6, and 12-month follow-up intervals. Perioperative data such as operative time, blood loss, and length of hospital stay were also recorded.

Results: Patients in the MISS TLIF group (Group B) demonstrated significantly lower intraoperative blood loss and shorter hospital stays compared to the Open TLIF group (Group A). While both groups showed significant improvements in VAS and ODI scores at the 12-month follow-up, the MISS TLIF group reported lower pain scores in the early postoperative phase (1–3 months). Radiological assessment showed comparable fusion rates between both cohorts. Complications such as surgical site infections were lower in the MISS TLIF group, although operative time was initially longer during the learning curve phase.

Conclusions: Both Open and MISS (Hybrid) TLIF are effective in achieving spinal stability and relieving symptoms in spondylolisthesis. However, MISS TLIF offers superior benefits regarding reduced tissue trauma, less blood loss, and faster early-stage functional recovery. It serves as a highly effective alternative to traditional open surgery, particularly for patients prioritizing a quicker return to daily activities.

Keywords: MISS TLIF, Spondylolisthesis

S054

Impact of Listhesis on One-Year Vertebral Compression Progression in Elderly Patients Aged 70 Years or Older

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Purpose: To investigate whether the presence of listhesis is associated with progressive vertebral body compression over time in elderly patients aged 70 years or older.

Materials and Methods: We retrospectively analyzed patients aged ≥70 years who were treated for vertebral compression fractures and had available radiologic follow-up data. Vertebral body compression rates were measured at the initial presentation, 6 months, and 1 year. Compression progression was defined as the difference between the 1-year and initial compression rates (Δ1-year compression). Patients were stratified according to the presence of listhesis. Compression progression and refracture rates at 6 months and 1 year were compared between the groups. Multivariable linear regression analysis was performed to evaluate the independent association between listhesis and compression progression after adjusting for age, sex, and body mass index (BMI).

Results: A total of 107 patients aged ≥70 years were included, of whom 20 (18.7%) had listhesis. Compression progression at 6 months did not differ significantly according to listhesis status (p=0.134). At 1 year, patients with listhesis demonstrated a greater increase in vertebral compression compared with those without listhesis, showing a trend toward significance in unadjusted analysis (p=0.081). In multivariable analysis, listhesis was independently associated with greater 1-year compression progression after adjustment for age, sex, and BMI (p=0.031). Sex was also identified as an independent predictor of compression progression (p=0.003), whereas age and BMI were not. No significant differences were observed in refracture rates at either 6 months or 1 year between patients with and without listhesis.

Conclusions: In elderly patients aged 70 years or older, the presence of listhesis is independently associated with progressive vertebral body compression at 1 year. These

findings suggest that listhesis may contribute to delayed structural deterioration of vertebral compression fractures in older populations, even when early compression progression and refracture rates are comparable.

Keywords: Listhesis, Vertebral compression fracture, Elderly, Compression progression, Lumbar spine

S055

Comparison of Total and Hidden Blood Loss Between BE-TLIF and Tubular Based MIS-TLIF: A Hematocrit-Based Retrospective Study with Learning Curve Effects

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Purpose: The purpose of this study was to compare total blood loss (TBL) and hidden blood loss (HBL) between biportal endoscopic transforaminal lumbar interbody fusion (BE-TLIF) and tubular-based minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) using hematocrit-based calculations. The research question addressed whether BE-TLIF demonstrates superior hemostatic control compared to MIS-TLIF when accounting for learning curve differences between established and newly developed techniques.

Materials and Methods: This retrospective study included 72 patients who underwent single-level lumbar fusion. Thirty-six consecutive BE-TLIF cases (June 2023–July 2025) were compared with 36 early-period MIS-TLIF cases (2016–2021) to ensure comparable learning curve stages. TBL was calculated using Nadler's and Gross's formulas based on hematocrit changes. HBL was derived by subtracting estimated blood loss and drainage from TBL. Both groups were subdivided into first and second halves to evaluate the trajectory of the early learning phase.

Results: BE-TLIF underwent more additional adjacent-level decompression procedures and longer operative times. However, BE-TLIF showed consistently lower TBL at immediate postoperative (0.42 vs. 0.62 L, p=0.001) and maximum calculated loss time points (0.87 vs. 1.05 L, p=0.025). HBL was similar between groups (0.32 vs. 0.43 L, p=0.262), suggesting that reduced TBL in BE-TLIF results from decreased intraoperative bleeding rather than postoperative extravasation differences. Learning curve analysis showed BE-TLIF had significant TBL reduction between the first and second halves, while MIS-TLIF showed no differences. No patients required transfusion in either group.

Conclusions: Despite longer operative times and more extensive adjacent-level decompression procedures, BE-TLIF results in significantly lower TBL. HBL was comparable between techniques, indicating that BE-TLIF's hemostatic advantages are achieved through improved intraoperative control. Early learning curve effects significantly impact BE-TLIF but not MIS-TLIF outcomes, emphasizing the importance of adequate endoscopic training.

Keywords: Biportal endoscopic spine surgery, Minimally invasive spine surgery, Total blood loss, Hidden blood loss, Hematocrit

Free Paper: Lumbar (2)

S056

What Is the Optimal Cage Size in OLIF Surgery

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Purpose: 1. To identify an ROC-derived cage/MDH cut-off predicting subsidence (≥2 mm) after single-level OLIF in older adults and quantify the relative risk (RR) of subsidence associated with oversizing. 2. To compare postoperative clinical outcome and to examine fusion status across groups. 3. To develop and validate a practical method for preoperative estimation of optimal OLIF cage size.

Materials and Methods: ROC analysis identified the cage/MDH cut-off. Patients were categorized as oversize vs non-oversize using the cut-off. Unadjusted RR was computed from 2×2 tables. Adjusted RR used robust Poisson regression with a causal-graph informed adjustment set (age, sex, BMI,

BMD, diagnosis, severity, preoperative MDH, surgical level). Continuous secondary outcomes used robust linear regression (adjusted mean difference; AMD). Fusion status differences were assessed by group and further explored for association with clinical outcomes.

Results: ROC identified a cage/MDH cut-off of 1.793 (AUC 0.774; sensitivity 0.589; specificity 0.875). Subsidence occurred in 56/96 (58.3%). Oversize (≥1.793; n=38) showed higher subsidence incidence than non-oversize (n=58): 33/38 (86.8%) vs 23/58 (39.7%), unadjusted RR 2.19 (95% CI 1.56–3.08) and adjusted RR 2.04 (95% CI 1.47–2.82). Postoperative "good outcome" rates were not significantly different between oversize and non-oversize: postoperative ODI <20 was 12/38 (31.6%) vs 14/58 (24.1%) (adjusted RR 1.34; 95% CI 0.71–2.52). Fusion (union) rate tended to be lower in oversize vs non-oversize (84.2% vs 94.8%; adjusted RR 0.86; 95% CI 0.72–1.03), while subsidence was associated with lower fusion compared with non-subsidence (83.9% vs 100%; adjusted RR 0.83; 95% CI 0.72–0.95).

Conclusions: A cage/MDH ratio ≥1.793 predicted subsidence and was associated with approximately twofold higher subsidence risk after single-level OLIF in older adults. Oversizing was not associated with significantly different postoperative "good outcome" rates, but subsidence was associated with reduced fusion. Preoperative estimation of OLIF cage size by using cage not over 1.793 MDH would reduce incidence of cage subsidence in OLIF surgery.

Keywords: OLIF cage, Subsidence, Fusion, Preoperative OLIF cage estimation, ODI

S057

Long-Term Comparison of Proximal and Distal Adjacent Segment Degeneration After Short Fusion in the Lower Lumbar Spine: A Minimum 5-Year MRI-Based Study

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Purpose: Adjacent segment degeneration(ASD) after lumbar fusion remains a major clinical concern, yet its long-term course on MRI has not been well defined. In particular, differences in progression patterns and clinical relevance between proximal and distal ASD remain unclear. This study evaluated the incidence and characteristics of radiological(R-ASD), MRI-based(M-ASD), and clinical ASD(C-ASD) in proximal and distal adjacent segments after short fusion in the lower lumbar spine over a minimum 5-year follow-up.

Materials and Methods: Patients who underwent short fusion in the lower lumbar spine with at least 5 years of follow-up and available MRI were reviewed. Radiological and MRI parameters were assessed preoperatively and at final follow-up. R-ASD was defined by changes in disc height, segmental angle, angular motion, and vertebral slip. M-ASD was evaluated using grades of central canal and foraminal stenosis, facet degeneration, and disc degeneration. C-ASD was defined as symptomatic ASD requiring nerve block or revision surgery. Incidence and progression patterns were compared between proximal and distal segments, and correlations among ASD categories were analyzed.

Results: A total of 132 patients were included; 98 underwent single-level fusion at L4-5 and 34 underwent two-level fusion at L3-4-5. The mean age was 71.6 years, and the mean MRI follow-up was 100.2 months. Baseline demographics and preoperative MRI degeneration of adjacent segments did not differ between the groups. After single-level fusion, proximal R-ASD, M-ASD, and C-ASD occurred in 17.3%, 59.2%, and 41.8%, respectively, compared with 13.3%, 36.7%, and 19.4% at distal segments. After two-level fusion, proximal incidences were 35.2%, 76.5%, and 64.7%, whereas distal incidences were 14.7%, 41.2%, and 35.3%. In both fusion groups, M-ASD and C-ASD were significantly more frequent at proximal segments. Radiologically, proximal segments showed significant progression in all parameters except segmental angle, while distal segments showed no significant changes. On MRI, significant progression was observed in all parameters at proximal segments and in all except central stenosis at distal segments. M-ASD correlated with C-ASD at both proximal (κ=0.416, $p<0.001$) and distal (κ=0.322, $p<0.001$) segments.

Conclusions: After short fusion in the lower lumbar spine, M-ASD and C-ASD occurred more frequently at proximal than distal adjacent segments. Radiographic evaluation was less reliable for detecting distal ASD, and distal ASD

progression was not associated with central stenosis. The association between M-ASD and C-ASD highlights the role of MRI in assessing ASD progression.

Keywords: Adjacent segment degeneration, Lumbar fusion, Magnetic resonance imaging, Proximal and distal segments, Long-term follow-up

S058

Clinical and Radiologic Outcomes of the Use of Interlaminar Device (Coflex®) Among Patients with Low-Grade Lumbar Spondylolisthesis: A Single Center Study

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Purpose: Lumbar spinal fusion can relieve back pain and neurological issues but may accelerate degeneration in adjacent vertebrae. Motion-preserving alternatives, like the Coflex® interlaminar device, aim to maintain stability without this risk. This study evaluated the radiologic and clinical effectiveness of Coflex® after decompression for low-grade degenerative lumbar spondylolisthesis (DLS), with follow-ups at 1 to up to 6 years to assess outcomes and complications.

Materials and Methods: Forty-seven patients with low-grade DLS (Meyerding Gr I) and treated with lumbar decompression with consequent interlaminar device (Coflex®) application were analyzed retrospectively. Radiographic parameters – lumbar lordosis (LL), lower lumbar lordosis (LLL), intervertebral disc height (IDH), intervertebral foramen height (IFH), and vertebral translation (VT) – were obtained. Clinical outcomes were evaluated by visual analogue scale (VAS) and Oswestry Disability Index (ODI).

Results: A total of 47 patients (mean age 57, 30–92), comprising 50 implanted levels, were included in the study. Following surgical decompression and interlaminar device placement, LL showed a slight but non-significant decrease [42.89°±10.08 to 40.33°±8.30 (p=0.059)] and remained stable, while LLL remained unchanged. VT improved significantly from 3.82 mm±3.66 to 1.53 mm±1.84 (p<0.001) and remained stable until the final follow-up (p=0.922). IDH increased significantly from 10.23 mm±2.33 to 12.48 mm±3.11 (p<0.001), and IFH from 20.55 mm±3.40 to 24.05 mm±3.78 (p<0.001), both showing significant decreases at 12 months but stabilizing thereafter. Clinical outcomes, including VAS (p=0.006) and ODI (p=0.002), showed significant improvement compared to baseline, with continued improvement until the latest follow-up (p=0.001, p=0.031, respectively). One patient experienced infection, with no reports of adjacent segment disease or subsidence.

Conclusions: Patients with low-grade DLS treated with posterior decompressive laminotomy and Coflex® interlaminar device achieve and sustain significant improvements in key radiologic parameters, including LL, LLL, and VT, for up to six years post-surgery with minimal risks. Immediate postoperative improvements in IDH and IFH were observed, with only minor changes noted at long-term follow-up. Back pain and functional outcomes also improved, meeting minimal clinically important differences for VAS and ODI scores.

Keywords: Spondylolisthesis, Stenosis, Coflex, Inter-laminar Device, Motion-sparing Device

S059

Feasibility of the Sandwich Graft Technique in OLIF: A Retrospective Comparative Cohort Study

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Purpose: The sandwich grafting technique, which combines demineralized bone matrix (DBM) with bone morphogenetic protein (BMP), has been increasingly applied in oblique lumbar interbody fusion (OLIF). However, its clinical and radiological feasibility has not been clearly established. This study evaluated the feasibility of the sandwich technique across safety, perioperative parameters, clinical outcomes, and radiologic stability.

Materials and Methods: A cohort of patients who underwent OLIF at a single tertiary medical center in Korea from 2018

to 2023 was analyzed. Based on the type of graft material used in the OLIF cage, patients were classified into two groups: a DBM-only group, consisting of 45 patients (106 levels), and a sandwich technique group, consisting of 93 patients (191 levels). These two groups were compared on baseline characteristics, safety outcomes, perioperative parameters, ODI-based clinical outcomes, and radiologic measures (disc height restoration/retention, segmental lordosis, fusion, subsidence).

Results: Baseline characteristics were comparable between the groups. The sandwich group demonstrated significantly lower revision rates, lower complication rates, shorter operation time, and reduced estimated blood loss. Both groups showed significant ODI improvements. The 1-year ODI difference did not differ, demonstrating the clinical non-inferiority of the sandwich technique. Disc height restoration, segmental lordosis correction, and fusion rates were similar between the groups. The 1-year subsidence rate was significantly lower in the sandwich group. Bone strut formation occurred more frequently in the sandwich group.

Conclusions: The sandwich grafting technique in OLIF demonstrates favorable feasibility, with lower rates of revision, complications, shorter operative time, and less blood loss compared with DBM-only grafting. Clinical outcomes were non-inferior, and radiologic stability was preserved with reduced subsidence. These findings support the sandwich grafting technique as a viable and efficient grafting strategy in OLIF.

Keywords: OLIF, Sandwich grafting technique, BMP, Graft, Feasibility

S060

Validation of the VIEW Score: A Novel Intraoperative Grading Scale for Visualization in Endoscopic Spine Surgery

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Purpose: Clear intraoperative visualization is essential for safe and effective endoscopic spine surgery, yet existing assessments remain subjective and lack standardization. The Visualization in Endoscopic Workspace (VIEW) Score was developed to provide an objective, reproducible grading system for evaluating intraoperative visualization quality. This study aimed to validate the VIEW Score as a standardized and reliable tool for assessing visualization during endoscopic spine surgery.

Materials and Methods: The VIEW Score is a 4-point ordinal scale (0=Excellent to 3=Poor) developed through expert consensus to evaluate bleeding, clarity of anatomical structures, and impact on surgical progress. Five experienced endoscopic spine surgeons independently rated 40 de-identified, 5-second lumbar surgical video clips. After a 4-week washout period, the raters re-evaluated the same clips in a randomized order. Inter- and intra-rater reliability were analyzed using the Intraclass Correlation Coefficient (ICC) with a two-way random-effects model for absolute agreement.

Results: The VIEW Score demonstrated excellent inter-rater reliability for mean ratings (ICC(2,5)=0.963; 95% CI 0.940–0.979) and good single-rater reliability (ICC(2,1)=0.839; 95% CI 0.758–0.902). Intra-rater reliability was also high (mean ICC 0.889±0.04; range 0.840–0.943). Reliability remained consistently strong across approach (ICC(2,5)=0.965) and decompression phases (ICC(2,5)=0.945).

Conclusions: The VIEW Score is a reliable and objective grading system for assessing intraoperative visualization during endoscopic lumbar decompression. Its strong reproducibility supports its use for standardized communication, surgical training evaluation, quality assessment, and future research examining visualization, hemostasis, and surgical workflow.

Keywords: Endoscopic spine surgery, Intraoperative visualization, Reliability, Grading scale, Minimally invasive spine surgery

Best Paper Candidates Presentation I (Domestic)

S101

Infection-Related Outcomes After Transforaminal Lumbar Interbody Fusion Following Implementation of an Enhanced Skin-Preparation Protocol Including Hooded Surgeon Cap Use: A Single-Center Retrospective Cohort Study

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Purpose: Surgical site infection (SSI) following transforaminal lumbar interbody fusion (TLIF) remains a clinically meaningful complication that can necessitate reoperation and prolonged hospitalization. In arthroplasty, hooded helmet systems are used to mitigate microbial dispersion from operating-room personnel by reducing the shedding of hair- and skin-derived particles into the operative field. While multiple preventive measures are routinely implemented in spine surgery, evidence regarding the effectiveness of enhanced skin-preparation and draping protocols—incorporating hooded head covering and surgical hand scrubbing prior to draping—remains limited. We therefore investigated whether adoption of a hooded surgeon cap, together with a contemporaneous change in draping practice, was associated with reduced infection-related outcomes after TLIF.

Materials and Methods: We conducted a single-center retrospective cohort study of consecutive patients who underwent TLIF at our institution, comparing two calendar periods: January 1, 2015–December 31, 2019 and January 1, 2021–December 31, 2025. Patients were followed for up to 6 months postoperatively. The cohorts differed in infection-prevention practices during surgical draping. In 2015–2019, the operating surgeon and assisting staff wore standard surgical caps and performed sterile draping using aseptic gloves only. In 2021–2025, the operating surgeon additionally wore a hooded surgical cap over the standard cap, performed surgical hand scrubbing, and donned aseptic gloves prior to draping, as part of an enhanced infection-prevention protocol. The primary outcome was incision and debridement (I&D) performed for suspected postoperative wound infection. The key secondary outcome was a composite of I&D or infection-related readmission, with each component also reported separately. To mitigate temporal confounding, perioperative practices were reviewed. All TLIF procedures were performed by a single spine surgeon, and institutional routines for prophylactic antibiotics, drain management, and postoperative wound care were unchanged between periods. Covariates included patient demographics and comorbidities and operative factors (e.g., operative time, estimated blood loss, number of fused levels, and revision status). Associations were evaluated using univariable analyses with odds ratios (ORs) and 95% confidence intervals (CIs).

Results: Compared with the earlier period (2015–2019), the hooded-cap period (2021–2025) demonstrated a lower incidence of I&D for suspected postoperative wound infection (1.4% [6/444] vs. 4.0% [28/692]; unadjusted OR 0.32, 95% CI 0.13–0.79; p=0.011). The composite outcome of I&D or infection-related readmission was also lower in the hooded-cap period (2.7% [12/444] vs. 5.8% [40/692]; unadjusted OR 0.45, 95% CI 0.23–0.87; p=0.019). Component analyses showed a lower rate of I&D in the hooded-cap period (unadjusted OR 0.32; p=0.011), whereas infection-related readmission alone did not differ significantly between groups (1.4% [6/444] vs. 1.7% [12/692]; unadjusted OR 0.78, 95% CI 0.29–2.08; p=0.808).

Conclusions: In this single-center TLIF cohort, implementation

of an enhanced skin-preparation and draping protocol—including hooded head covering and surgical hand scrubbing prior to draping—was associated with statistically significant reductions in incision and debridement for suspected wound infection and in the composite endpoint of I&D or infection-related readmission within 6 months postoperatively. These findings suggest that enhanced head covering and related draping preparation measures may serve as a meaningful adjunct to established infection-prevention strategies in lumbar fusion surgery. Nonetheless, efforts to reduce postoperative infection should continue to emphasize well-established risk determinants, including operative duration, optimization of patient comorbidities, and meticulous intraoperative contamination control throughout exposure, instrumentation, and closure.

Keywords: Transforaminal lumbar interbody fusion, Hooded surgeon cap, Surgical site infection, Wound infection

S102

Effect of Smoking Cessation Duration on Fusion Quality After Single-Level Transforaminal or Posterior Lumbar Interbody Fusion

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Purpose: This study aimed to identify the minimum smoking cessation duration required to mitigate the risk of non-union and to determine the duration necessary to achieve high-quality interbody fusion comparable to non-smokers after single-level transforaminal or posterior lumbar interbody fusion (T/PLIF).

Materials and Methods: We retrospectively reviewed 2,303 adult patients (age >18) who underwent conventional 1-level T/PLIF for degenerative diseases between 2008 and 2024 at two tertiary centers. Patients were categorized into non-smokers (n=1,927), current smokers (n=165), and ex-smokers grouped by cessation duration: 0–6 months (n=41), 6–24 months (n=29), and >24 months (n=141). Fusion success (Bridwell grades 1–2) and quality (grades 1–4) were assessed via CT at 6–24 months postoperatively. Binary and ordinal logistic regression analyses were performed, adjusting for age, sex, uncontrolled diabetes, advanced chronic kidney disease, BMP usage, L1 Hounsfield unit, and surgeon-related factors.

Results: Binary logistic regression revealed that current smokers (OR 0.272, p<0.001) and ex-smokers with <6 months of cessation (OR 0.316, p=0.016) had significantly lower odds of achieving fusion success compared to non-smokers. Statistical equivalence in fusion rates (union vs. non-union) was achieved after 6 months of cessation. However, ordinal regression demonstrated that even with >24 months of cessation, fusion quality (grade distribution) remained significantly different from lifelong non-smokers (B=0.392, p=0.026), although the quality progressively improved as the cessation duration increased.

Conclusions: For patients undergoing 1-level T/PLIF, a minimum of 6 months of preoperative smoking cessation is required to reduce the risk of non-union to a level statistically comparable to non-smokers. Furthermore, if a superior grade of fusion quality is desired, a prolonged cessation period of more than 24 months should be recommended, as the qualitative impact of smoking on bone healing persists longer than its effect on simple union rates.

Keywords: Fusion quality, Lumbar interbody fusion, Non-union, Smoking cessation, Spinal fusion

S103

Effect of Sarcopenia and Malnutrition on Spine Surgery Outcomes

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Purpose: To evaluate the impact of preoperative sarcopenia and malnutrition on in-hospital complications and 1-year functional outcomes following lumbosacral spinal fusion surgery. While sarcopenia is a known risk factor in spinal surgery, the comparative impact of malnutrition versus sarcopenia on patient-reported outcomes (PROs) remains

understudied.

Materials and Methods: This study prospectively analyzed 90 patients who underwent lumbosacral spinal fusion for spinal stenosis or degenerative disc disease between May 2021 and August 2024. Sarcopenia was defined according to the Asian Working Group for Sarcopenia (AWGS) 2025 consensus, utilizing skeletal muscle index, handgrip strength, and gait speed. Nutritional status was assessed using the Prognostic Nutritional Index (PNI), Geriatric Nutritional Risk Index (GNRI), and Mini Nutritional Assessment–Short Form (MNA-SF). Outcome measures included in-hospital complications, length of stay, discharge disposition, and 1-year PROs including Visual Analog Scale (VAS), Oswestry Disability Index (ODI), and EuroQol-5 Dimension (EQ-5D). Multivariable logistic regression was performed to identify predictors for achieving the minimal clinically important difference (MCID).

Results: Of the 90 participants, 37 (41.1%) were classified as having sarcopenia. Sarcopenia was significantly associated with a higher rate of discharge to other facilities rather than home (48.65% vs. 28.30%, p=0.049). Malnutrition was significantly associated with increased ICU admission rates (16.00% vs. 0.00%, p=0.005). In terms of 1-year functional outcomes, nutritional indices were significant predictors of recovery. Higher MNA-SF scores were independent predictors for achieving MCID for VAS leg (OR 1.234, p=0.046) and ODI (OR 1.326, p=0.035). Furthermore, PNI (p=0.036) and GNRI (p=0.039) were significant predictors for achieving MCID in EQ-5D. Low muscle mass showed a trend toward predicting EQ-5D outcomes (OR 2.561, p=0.087) but did not reach statistical significance.

Conclusions: Sarcopenia and malnutrition exert distinct influences on recovery following lumbosacral fusion. Sarcopenia is primarily associated with discharge disposition, whereas malnutrition significantly increases the risk of ICU admission and impedes long-term functional improvement in ODI and quality of life. These findings highlight the importance of preoperative nutritional optimization, alongside sarcopenia assessment, to improve surgical prognosis.

Keywords: Sarcopenia, Malnutrition, Spine surgery

S104

Suboptimal Lordosis Distribution Index as a Risk Factor for Adjacent Segment Degeneration After Short-Level Fusion in Degenerative Spondylolisthesis

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Purpose: To determine whether a suboptimal lordosis distribution index (LDI) is a risk factor for adjacent segment degeneration (ASD) after short-level fusion in patients with degenerative spondylolisthesis (DS).

Materials and Methods: This study included 584 patients diagnosed with DS who underwent single-level posterior lumbar interbody fusion (PLIF) between 2012 and 2020 at a single institution. Adult spinal deformity patients with coronal imbalance (difference >3 cm between the C7 plumb line and the central sacral vertical line) or sagittal imbalance [sagittal vertical axis (SVA) ≥50 mm, pelvic tilt (PT) ≥20°, or pelvic incidence–lumbar lordosis (PI–LL mismatch) ≥11°], conditions previously identified as risk factors for ASD, and patients with a follow-up <5 years were excluded. To evaluate the influence of LDI on ASD, demographic data and sagittal spinopelvic radiographic parameters were collected and analyzed. Following the methodology of a previous study by Moreau et al., ASD was defined at the level immediately adjacent to the fusion by one or more of the following radiographic criteria on comparison of immediate postoperative and 3-year follow-up radiographs: new onset of ≥10° segmental kyphosis, and/or ≥50% loss of disc height, and/or ≥3 mm anteroposterior translation. Logistic regression analysis was performed to identify the risk factors for ASD.

Results: A total of 102 patients met the inclusion criteria, including 42 patients with ASD (Group I) compared to 60 patients without ASD (Group II). There were no significant differences between the two groups in demographic data, including age and index level of surgery. Postoperative segmental angle (SA; Group I: 2.5° vs. Group II: 7.0°, p=0.033) at the index level and L4–S1 lordosis (Group I: 25.1° vs. Group II: 31.1°, p=0.041) were significantly smaller in Group I than in Group II. Consistently, postoperative

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LDI (Group I: 46.1 vs. Group II: 57.3, p=0.029) was also significantly lower in Group I. There were no significant differences between the two groups in other parameters, including LL, SVA, or PI–LL mismatch. Logistic regression analysis identified suboptimal postoperative LDI (OR: 2.08, 95% CI: 1.87–3.41, p=0.021) as an independent risk factor for the development of ASD.

Conclusions: A suboptimal LDI may be a risk factor for the development of ASD after short-level fusion in patients with degenerative spondylolisthesis.

Keywords: Degenerative spondylolisthesis, Short-level fusion, Adjacent segment degeneration, Lordosis distribution index

S105

Validation of a Double-Injection Fluoroscopic Erector Spinae Plane Block (fESPB) Protocol in Lumbar Fusion: Time-Dependent Efficacy

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Purpose: Multiple studies have consistently demonstrated the effectiveness of fESPB for postoperative analgesia in lumbar spine surgery. However, the analgesic duration of a single-shot fESPB is limited by the pharmacokinetics of local anesthetics, which may result in suboptimal pain control during prolonged procedures. This study aimed to evaluate the efficacy of a 'Double-Injection Strategy' compared with the conventional single-shot technique and to establish an optimal re-injection threshold based on surgical duration.

Materials and Methods: This study was conducted in two sequential phases. In Phase 1, 68 patients who underwent lumbar fusion surgery were retrospectively reviewed to evaluate the analgesic efficacy of fluoroscopic-guided erector spinae plane block (fESPB). Patients were divided into a single-injection fESPB group (0.3% ropivacaine, 20 mL per side, administered bilaterally immediately before incision) and a volume-matched sham control group (normal saline 40 mL with contrast dye 10 mL). The primary outcome was postoperative Visual Analog Scale (VAS) scores measured immediately and at 12, 24, and 48 hours after surgery. Secondary outcomes included cumulative patient-controlled analgesia (PCA) usage, time to first rescue analgesic, total opioid consumption in morphine milligram equivalents (MME), Oswestry Disability Index (ODI), EQ-5D-5L, and PainDETECT scores. Length of hospital stay, time to ambulation, and postoperative complications were also recorded. 'Analgesic insufficiency' was defined as a mean postoperative VAS score exceeding 4, averaged across all four time points. Receiver operating characteristic (ROC) curve analysis with Youden’s index was performed to identify an optimal surgical duration cutoff predicting analgesic insufficiency, and multivariate logistic regression was used to identify its independent predictors. In Phase 2, based on the cutoff identified in Phase 1, an additional cohort of patients whose surgical duration exceeded this threshold was separately recruited. These patients received a double-injection protocol: the same preoperative fESPB plus a supplemental injection at the time of final intraoperative fluoroscopic confirmation. Their outcomes were retrospectively compared with Phase 1 patients who had received only a single injection and whose surgical duration also exceeded the cutoff (n = 10).

Results: In Phase 1, the single-injection fESPB group demonstrated significantly lower postoperative VAS scores compared with the sham control group. ROC curve analysis identified a surgical duration of 100 minutes as the optimal cutoff for predicting analgesic insufficiency (AUC 0.67, sensitivity 87.5%, specificity 50.0%). The moderate discriminative performance (AUC <0.70) and low specificity indicate that this threshold should be regarded as an approximate clinical reference. Multivariate logistic regression identified both surgical duration and surgical approach (open vs. biportal endoscopic) as independent predictors of analgesic insufficiency (p<0.05).

In Phase 2, among procedures exceeding 100 minutes, the double-injection group showed significantly lower VAS scores than the historical single-injection comparators from Phase 1 (p<0.05). However, the sample sizes in both groups were small (n=10 for the single-injection comparators), and these results should be interpreted with caution.

Conclusions: Conventional ultrasound-guided ESPB has demonstrated efficacy in postoperative pain control following spine surgery; however, it requires interdepartmental coordination with anesthesiology and additional procedural

time, limiting its practical applicability. Fluoroscopic-guided ESPB can be performed by the operating surgeon concurrently with the routine preoperative level check, offering a simplified and time-efficient alternative. This study confirmed that fESPB provides comparable analgesic efficacy in lumbar fusion surgery while identifying 100 minutes as an approximate surgical duration threshold beyond which its effect appears to diminish. Preliminary data from the subsequent double-injection cohort suggest that supplemental intraoperative fESPB may improve pain control in prolonged procedures. Given the moderate discriminative performance of the ROC analysis and the limited sample sizes in the comparative analysis, these findings require validation in larger prospective studies.

Keywords: Fluoroscopic erector spinae plane block, Open posterior lumbar interbody fusion, Biportal endoscopic lumbar interbody fusion, Preemptive analgesia, Time-based double-injection protocol

Best Paper: Candidates Presentation II (Domestic)

S106

Vertebral Rotation Discrepancy for Adding-on When Selecting the Touched Vertebra as the Lowest Instrumented Vertebra in Idiopathic Scoliosis

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Purpose: The concept of the touched vertebra (TV) has been widely applied in patients with thoracic curves of adolescent idiopathic scoliosis (AIS). However, the distal adding-on phenomenon is not uncommon in thoracic curves of AIS when selecting the TV as the lowest instrumented vertebra (LIV). Therefore, this study aims to evaluate the occurrence of the adding-on phenomenon when selecting the TV as the LIV.

Materials and Methods: A total of 96 thoracic AIS patients who underwent deformity correction with TV=LIV were retrospectively analyzed to evaluate the distal adding-on phenomenon: DA group (distal adding-on group) and non-DA group (non-distal adding-on group). Radiological variables included coronal (Cobb angle, coronal balance, sacral slanting angle, and L4 vertebral tilt), sagittal (sagittal vertical axis, thoracic kyphosis, and lumbar lordosis), and axial (vertebral rotation angle) parameters.

Results: When selecting the TV as the LIV, the rate of distal adding-on was 20.8% (20 of 96) with a mean 3-year follow-up. There was no statistical difference in L4 vertebral tilt (p=0.246) and the presence of sacral slanting (p=0.069) between the two groups. The mean number of remnant motion segments was significantly higher in the DA group (4.7) than in the non-DA group (3.8) (p<0.001). Furthermore, the difference in vertebral rotation angle between the lumbar apex and the TV level was significantly higher in the DA group (6.6) than in the non-DA group (1.3) (p<0.001).

Conclusions: Our study indicated that distal adding-on was influenced by the number of remnant motion segments and vertebral rotation discrepancy between the LIV and the lumbar apex when selecting the TV as the LIV. Therefore, to minimize the risk of postoperative adding-on, surgeons need to consider selecting the LIV caudal to the TV in cases where significant vertebral rotation discrepancy exists.

Keywords: Adolescent idiopathic scoliosis, Touched vertebra, Lowest instrumented vertebra, Motion segments, Vertebral rotation

S107

Over-Distraction of the Disc Space: Impact on Fusion and Rod Fracture After Lateral Lumbar Interbody Fusion with Posterior Column Osteotomy for Adult Spinal Deformity

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Purpose: Lateral lumbar interbody fusion (LLIF) with posterior column osteotomy (PCO) can achieve effective sagittal correction in adult spinal deformity (ASD) surgery.

In addition, the accessory rod (AR) technique has been applied to prevent postoperative mechanical complications, such as rod fracture (RF). However, excessive distraction of the disc space may occur during correction. Previous studies have suggested that aggressive disc space distraction can be associated with endplate injury and compromised fusion integrity. The purpose of this study was to evaluate the effect of over-distraction of the disc space on fusion outcomes and rod fractures after LLIF with PCO.

Materials and Methods: A total of 320 ASD patients who underwent long-segment fusion from T10 to S1 using LLIF with PCO, with (n=169) or without (n=89) AR, between August 2016 and December 2023 were retrospectively reviewed. Patients with a history of prior lumbar interbody fusion surgery (n=5) and those lost to follow-up (n=57) were excluded, resulting in a final study cohort of 258 patients with a mean age of 71.56±0.6 years. LLIF was performed on 744 segments, and intervertebral disc (IVD) angles (T12–S1) were measured using standing lateral lumbar spine radiographs. "Over-distraction of the disc space" was defined as an IVD angle greater than 30° on immediate postoperative radiographs. Fusion status was assessed using computed tomography (CT) at 2 years postoperatively, and RF was evaluated during a follow-up period of over 2 years.

Results: Over-distraction of the disc space was identified in 96 of 258 patients (37.2%; 39 without AR and 57 with AR). Among patients without AR, fusion at over-distraction levels was achieved in 35 of 39 patients (89.7%), indicating a high fusion rate despite the presence of over-distraction. Over-distraction of the disc space was not significantly associated with the occurrence of RF (odds ratio [OR]=1.00, p=1.00). In contrast, the AR technique was associated with a significantly lower incidence of rod fracture. RF occurred in 23 of 89 patients without AR compared with only 1 of 172 patients with AR (OR=0.03, p<0.001).

Conclusions: Over-distraction of the disc space was fused in 79.2%, indicating that over-distraction of the disc space did not negatively impact fusion outcomes or increase the risk of rod fracture. Rather, the use of the accessory rod (AR) technique demonstrated a significant protective effect against rod fracture following LLIF with PCO.

Keywords: Adult spinal deformity, Lateral lumbar interbody fusion, Posterior column osteotomy, Over-distraction of the disc space

S108

Comparison of Romosozumab and Teriparatide for Early Mechanical Stabilization in Acute Osteoporotic Vertebral Compression Fractures: A Randomized Prospective Study

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Purpose: Teriparatide is a well-established gold-standard anabolic agent known for promoting fracture union. However, while romosozumab is recognized for its potent ability to increase bone mineral density (BMD), its clinical efficacy in providing early mechanical stabilization for acute osteoporotic vertebral compression fractures (OVCFs) compared with teriparatide remains undefined.

We Asked: (1) Does romosozumab provide superior early mechanical stabilization of the fractured segment, measured by dynamic intravertebral instability (DII), compared with teriparatide at 3 months? (2) Does the romosozumab-to-denosumab sequence result in a greater increase in BMD at 12 months than the teriparatide-to-denosumab sequence?

Materials and Methods: Between August 2022 and January 2025, we conducted a randomized prospective study of 58 elderly patients with acute OVCFs. Patients were randomized to receive either romosozumab (n=30) or teriparatide (n=28) for 3 months, followed by denosumab. The primary radiologic outcome was dynamic intravertebral instability (DII), defined as the difference between supine and standing anterior vertebral body height. The stabilization rate was calculated as the percentage reduction in DII from baseline to 3 months. Secondary outcomes included 12-month BMD changes and bone turnover markers (P1NP, CTX).

Results: Baseline DII and BTM levels were comparable between the two groups. At 3 months, the romosozumab group achieved significantly lower residual instability (1.55±0.75 mm vs. 3.05±2.49 mm; p=0.005) and a higher stabilization rate (62.3±19.1% vs. 13.5±102.6%; p=0.019). At 12 months, DII was similar between groups (romosozumab: 1.2±0.9 mm vs. teriparatide: 1.3±1.0 mm; p=0.78), indicating that both regimens achieved meaningful stabilization over time. CTX decreased by 7.5% in the romosozumab group but

increased by 72.5% in the teriparatide group (p=0.004). The 12-month BMD change was higher in the romosozumab-to-denosumab group than in the teriparatide-to-denosumab group (median +3.92% vs. −0.90%; p=0.040, Mann–Whitney U test).

Conclusions: In elderly patients with acute OVCFs, sequential therapy starting with romosozumab provides superior early mechanical stabilization and greater long-term BMD gains than the teriparatide-based protocol. Romosozumab's unique dual-action mechanism, which suppresses bone resorption while stimulating formation, offers a more effective non-surgical strategy for stabilizing acute vertebral instability.

Keywords: Osteoporotic vertebral compression fracture, Romosozumab, Teriparatide, Intravertebral instability, Kummell disease

S109

Cost-Utility Analysis of Endoscopic Versus Microscopic Lumbar Discectomy: A Randomized Controlled Trial-Based Economic Evaluation

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Purpose: While endoscopic lumbar discectomy has demonstrated clinical benefits, comprehensive cost-utility analyses comparing it with conventional microscopic surgery remain limited. This study aimed to evaluate the cost-effectiveness of endoscopic lumbar discectomy compared with microscopic discectomy using quality-adjusted life years (QALYs) as the effectiveness measure from a healthcare provider perspective.

Materials and Methods: This economic evaluation was conducted alongside two randomized controlled trials comparing endoscopic (n = 110) and microscopic (n = 110) lumbar discectomy. Health-related quality of life was assessed using EQ-5D-5L at baseline, 2 weeks, and 3, 6, and 12 months postoperatively. One-year QALYs were calculated using the area-under-the-curve method with Korean value sets. Direct medical costs, including surgical costs, hospitalization, and complication-related expenses, were collected from institutional billing data. The primary outcome was the incremental cost-effectiveness ratio (ICER). Uncertainty was assessed using bootstrapping (5,000 iterations) and cost-effectiveness acceptability curves (CEACs). Covariate-adjusted analysis controlling for age, sex, comorbidity index, and baseline EQ-5D was performed.

Results: Complete data were available for 183 patients (95 endoscopic, 88 microscopic). Mean 1-year QALYs were 0.968 (SD 0.086) and 0.933 (SD 0.153) for the endoscopic and microscopic groups, respectively (ΔQALY=0.035, p=0.064). Mean total costs were essentially equivalent: 3,469,800 KRW versus 3,471,300 KRW (ΔCost=-1,500 KRW, p=0.984). Bootstrap analysis showed a 52.9% probability of dominance for endoscopic surgery. At the Korean willingness-to-pay threshold of 30,000,000 KRW/QALY, the probability of cost-effectiveness was 97.2%. Covariate-adjusted analysis revealed a statistically significant QALY advantage (ΔQALY=0.038, p=0.036). Subgroup analyses demonstrated heterogeneity by surgical level: L4–L5 and L5–S1 strongly favored endoscopic surgery (>93% cost-effective), while L3–L4 showed a lower probability (43.5%). Elderly patients (≥65 years) derived the greatest QALY benefit (ΔQALY=0.090).

Conclusions: Endoscopic lumbar discectomy demonstrates favorable cost-effectiveness with a statistically significant quality-of-life advantage after covariate adjustment. Cost-effectiveness varies by surgical level, with L4–L5 and L5–S1 strongly favoring endoscopic surgery. These findings support endoscopic discectomy as a cost-effective alternative for appropriately selected patients without additional burden on healthcare systems.

Keywords: Cost-utility analysis, Cost-effectiveness, QALY, ICER, Endoscopic spine surgery, Lumbar discectomy, Health economics, EQ-5D

S110

Feasibility of Intra-Cage vs. Extra-Cage Application of Recombinant Human Bone Morphogenetic Protein-2 in Posterior Lumbar Interbody Fusion

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Purpose: Although recombinant human bone morphogenetic protein-2 (rhBMP-2) is widely used to enhance fusion rates in posterior lumbar interbody fusion (PLIF), direct comparative studies of different rhBMP-2 application strategies remain limited. Therefore, this study aimed to compare the clinical efficacy of rhBMP-2 applied outside the cage and inside the cage in patients undergoing PLIF.

Materials and Methods: A retrospective comparative study was conducted on patients who underwent one- or two-level PLIF. Patients were divided into three groups according to graft material: a control group without rhBMP-2, a second group receiving rhBMP-2 applied outside the cage with allogeneic bone chips, and a third group receiving rhBMP-2 applied inside the cage using a collagen sponge. Radiographic fusion was evaluated at 1 year postoperatively using plain radiographs and computed tomography (CT) at both patient and segment levels. Clinical outcomes and postoperative complications were compared among groups.

Results: At 1 year postoperatively, CT-based fusion rates differed significantly among the three groups, with the highest rate observed in the extra-cage group (80.0%), followed by the intra-cage group (60.0%) and the control group (52.2%) (p=0.024). Plain radiographic fusion rates demonstrated a similar pattern. Multivariate analysis revealed that the extra-cage group was independently associated with higher odds of CT-based fusion compared with both the control group (odds ratio [OR], 4.16; p=0.008) and the intra-cage group (OR, 3.29; p=0.024). All groups exhibited significant improvement in clinical outcomes compared with preoperative status, with continued improvement over time; however, no significant differences were observed among the three groups at any postoperative time point. The incidence of rhBMP-2–related complications, including heterotopic ossification, reoperation rate, cage subsidence, and radiculitis, did not differ significantly among groups.

Conclusions: In patients undergoing one- or two-level PLIF, the application of rhBMP-2 in the extra-cage group resulted in higher CT-based fusion rates than the control group, while demonstrating a trend toward higher fusion rates compared with the intra-cage group at 1 year postoperatively. These findings suggest that strategic placement of rhBMP-2 outside the cage is an effective approach for maximizing fusion potential while maintaining a safety profile comparable to other methods.

Keywords: Posterior lumbar interbody fusion, Recombinant human bone morphogenetic protein-2, Fusion rates

Best Paper: Candidates Presentation III (Domestic)

S111

Early Dynamic Stability as a Surrogate Marker for Long-Term Success After Oblique Lumbar Interbody Fusion: A Minimum 5-Year Follow-Up Study

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Purpose: Previous studies have shown that radiographic interbody fusion after oblique lumbar interbody fusion (OLIF) is frequently incomplete at early follow-up, despite favorable clinical outcomes. These observations suggest that early radiographic fusion alone may not adequately reflect long-term surgical success. Given that fusion is a time-dependent biological process, the clinical relevance of incomplete radiographic fusion at 1 year remains unclear. This study aimed to evaluate the long-term clinical durability of OLIF and to investigate whether early postoperative dynamic stability (functional fusion) serves as a surrogate marker for long-term success.

Materials and Methods: This retrospective cohort study included 480 consecutive patients who underwent OLIF at a single institution between May 2015 and July 2019, with a minimum follow-up of 5 years (mean, 6.3 years). The mean patient age was 69.4±8.0 years. Radiographic evaluation at 1 year was performed using computed tomography (CT) and standing flexion–extension dynamic radiographs. Functional fusion was defined as the absence of segmental instability, indicated by angular motion ≤3° and translation ≤3 mm. Dynamic stabilization was assessed at both 1-year and 5-year follow-ups. The primary endpoint was revision surgery at the index OLIF level due to clinical failure.

Results: At 1 year postoperatively, the CT-based interbody fusion rate was 51.3% (246 of 480 patients). In contrast, dynamic stabilization was achieved in 95.1% of patients (458/480) at 1 year and further increased to 98.1% (471/480) at the 5-year follow-up. During the minimum 5-year follow-up period, revision surgery at the index level was required in only 3 patients (0.6%). Notably, all three patients were among the 22 cases (4.6%) who failed to achieve dynamic stabilization at 1 year, with revision performed for symptomatic nonunion. Conversely, no revision surgery was performed in patients who demonstrated segmental stability at 1 year, regardless of CT-based fusion status.

Conclusions: Despite a relatively low CT-based fusion rate at 1 year, OLIF demonstrated excellent long-term clinical durability with an extremely low revision rate. These findings indicate that the absence of early radiographic fusion does not necessarily predict unfavorable long-term outcomes. Early postoperative dynamic stability, or functional fusion, appears to be a more clinically meaningful surrogate marker for long-term success after OLIF. Assessment strategies emphasizing functional stabilization rather than early radiographic fusion alone may therefore better predict durable outcomes following OLIF.

Keywords: Oblique lumbar interbody fusion, Dynamic stability, Functional fusion, Surrogate marker, Long-term follow-up

S112

Radiographic Progression of Lumbar Degenerative Spondylolisthesis After Decompression Alone

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Purpose: To evaluate the radiographic progression rate of degenerative spondylolisthesis (DS) after decompression alone and its associated risk factors.

Materials and Methods: We enrolled patients with DS (at L3–4, L4–5, or L5–S1) who underwent decompression alone surgery with a minimum follow-up of greater than 1 year. We evaluated demographics, comorbidities, smoking history, follow-up duration, and the presence of revision surgery. Patients with a slip increase of at least 3 mm during postoperative follow-up compared with the preoperative status were classified as having DS progression. We also evaluated disc-related factors on plain radiographs and facet joint-related factors on MRI. The variables were compared between the two groups (progression vs. non-progression).

Results: We retrospectively analyzed 77 patients with DS (88 levels) with a mean age at diagnosis of 71.6 years. The mean follow-up period was 42.9 months. Initial slip distance averaged 4.4 mm, increasing to 5.4 mm at the final follow-up. DS progression occurred in 13.6% (12/88) during follow-up. When comparing the two groups, the progression group exhibited a higher rate of facet joint gap (63.6% vs. 29.3%, p=0.039) and a milder degree of initial slip (2.9 mm vs. 4.7 mm, p=0.024). There were no significant differences in facet joint osteoarthritis (p=0.628), facet joint angle (p=0.746), facet joint posterior cap (p=0.540), and disc-related factors (height and angle). Multiple logistic regression analysis identified preoperative slip distance (a cutoff of ≤5 mm indicating higher progression risk; odds ratio 9.7, p=0.038) and preoperative facet joint gap (odds ratio 4.7, p=0.029) as determinant factors. Two patients showed facet joint cysts on MRI with recurrence of leg pain. One patient required revision fusion, while the other improved with conservative treatment. Two patients (2.3%) required revision fusion at the

index level. There was no significant correlation between DS progression and revision surgery.

Conclusions: The overall rate of DS progression (≥3 mm increased slip distance compared with preoperative status) was 13.6% (12/88) in patients treated with decompression alone. DS progression predominantly occurred in patients with a mild preoperative degree (<5 mm of slip distance) and a preoperative facet joint gap. The rate of subsequent fusion at the index level was very low (2/88, 2.3%) and was not statistically associated with radiographic progression of DS.

Keywords: Spondylolisthesis, Decompression, Progression, Slippage, Degenerative lumbar

S113

Multiple Pathways to Stability: Comparative Analysis of Two Fundamentally Different Surgical Strategies in Posterior Atlantoaxial Fusion

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Purpose: Multiple surgical techniques exist for posterior atlantoaxial fusion, but whether different approaches achieve equivalent outcomes through distinct anatomical mechanisms remains unclear. This study compared two fundamentally different surgical strategies: facet-based fusion with biologics versus autograft-based posterior fusion, examining their fusion patterns, clinical outcomes, and predictors of stability.

Materials and Methods: We retrospectively analyzed 42 patients who underwent posterior C1–2 fusion using two distinct approaches: a facet-based technique with facet disarticulation and bone morphogenetic protein (BMP) augmentation (n=15), or an autograft-based posterior technique with facet preservation and iliac crest bone graft (n=27). Dynamic atlantoaxial instability was measured as the difference between flexion and extension anterior atlantodental interval (diff_AADI) at preoperative, 6-month, and 12-month time points. Linear mixed-effects models examined longitudinal stability changes, while Fisher's exact tests compared fusion patterns at facet and posterior sites. Multivariate linear regression identified independent predictors of final stability.

Results: The two approaches achieved identical overall fusion rates (73% vs. 74%, p=1.000) and final stability (2.15±0.99 mm vs. 2.14±1.15 mm, p=0.997) through mirror-image fusion patterns. The facet-based approach resulted in predominantly facet fusion (66.7% vs. 18.5%, p=0.003), while the autograft-based approach achieved predominantly posterior fusion (66.7% vs. 26.7%, p=0.023). Linear mixed-effects modeling demonstrated similar improvement trajectories between approaches (interaction p=0.737) with equivalent baseline instability (p=0.798). Multivariate analysis confirmed that surgical approach had no independent effect on outcome (p=0.806), with baseline dynamic instability being the only significant predictor of final stability (β=0.079, p=0.036). Within-group analysis demonstrated that BMP-treated patients with numerically greater baseline instability (9.77±2.92 mm vs. 6.29±4.59 mm, p=0.073) achieved final stability equivalent to non-BMP patients (1.92±1.22 mm vs. 1.94±1.00 mm, p=1.000).

Conclusions: Two fundamentally different surgical approaches achieved equivalent fusion rates and clinical stability through inverse fusion patterns, demonstrating that multiple anatomically sound pathways to mechanical stability exist in atlantoaxial fusion. Surgical technique showed no independent effect on outcome, while baseline severity was the only predictor. These findings support individualized technique selection based on surgeon expertise, patient anatomy, and resource availability, with the critical factor being the achievement of rigid instrumentation plus solid fusion at any anatomical site.

Keywords: Atlantoaxial fusion, Bone morphogenetic protein, Posterior fusion, Facet disarticulation, Dynamic instability

S114

Surgery-Free Survival and Risk Factors for Surgical Conversion After Diagnosis of Degenerative Cervical Myelopathy: A Nationwide Population-Based Cohort Study

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Purpose: Degenerative cervical myelopathy (DCM) is frequently managed with initial nonoperative treatment in patients with mild or equivocal symptoms; however, the likelihood and timing of subsequent surgical intervention in real-world practice remain incompletely defined. This study aimed to evaluate surgery-free survival after an initial diagnosis of DCM and to identify clinical and systemic factors associated with surgical conversion using a nationwide population-based cohort.
Materials and Methods: A retrospective cohort study was conducted using the National Health Insurance Service database. Adult patients (≥18 years) with cervical myelopathy recorded on at least two separate clinical encounters were identified. After applying predefined exclusion criteria, 109,700 patients were included. The primary outcome was time to first cervical spine surgery following the index diagnosis. Surgery-free survival was estimated using Kaplan–Meier analysis. Multivariable Cox proportional hazards regression was used to identify independent predictors of surgical conversion, including age, sex, body mass index category, comorbidities, and lifestyle-related variables.
Results: During the observation period, 2,543 patients (2.3%) underwent cervical spine surgery. Surgical conversion occurred predominantly in the early phase after diagnosis. Within 30 days, 1,917 surgeries were performed, corresponding to a cumulative incidence of 0.8%. The cumulative incidence increased to 2.1% at 1 year and reached 2.4% at 12 years, demonstrating a marked plateau after the first year. Among patients who underwent surgery, 93.4% did so within 1 year of diagnosis, whereas only 6.6% underwent delayed surgery beyond 1 year. Early surgical cases more frequently involved anterior fusion procedures, while delayed cases showed higher proportions of posterior decompression with or without fusion and laminoplasty. In multivariable analysis, older age (45–59 years and ≥60 years), obesity, diabetes mellitus, dyslipidemia, chronic renal disease, and current smoking status were independently associated with an increased risk of surgical conversion. Female sex was associated with a significantly lower likelihood of surgery.
Conclusions: In this nationwide cohort, conversion to surgery after an initial diagnosis of DCM was uncommon overall and occurred predominantly within the first year, followed by long-term stabilization in surgery-free survival. Systemic metabolic conditions, renal disease, smoking, and older age were significant predictors of surgical intervention. These findings support a risk-stratified surveillance approach after DCM diagnosis, emphasizing closer early monitoring and timely surgical evaluation in patients with adverse systemic risk profiles, while indicating that sustained nonoperative management is achievable in a substantial proportion of patients.
Keywords: Degenerative cervical myelopathy, Surgery-free survival, Risk factors, Population-based study, National Health Insurance database

S115

Posterior Cervical Foraminotomy Provides Comparable Motor Recovery to Anterior Cervical Discectomy and Fusion in Cervical Radiculopathy With Motor Weakness Despite Longer Recovery Time

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Purpose: (1) To compare motor recovery and outcomes between anterior cervical discectomy and fusion (ACDF) and posterior cervical foraminotomy (PCF) in patients with cervical radiculopathy presenting with motor weakness, and (2) to identify factors associated with incomplete motor recovery.
Materials and Methods: A retrospective cohort study was

conducted including patients with cervical radiculopathy and preoperative motor weakness who underwent either ACDF (158 patients) or PCF (134 patients). Patients who had surgery solely due to pain and without motor weakness were excluded. Baseline characteristics, surgical levels, and follow-up duration were analyzed. Motor function was evaluated using the weakest motor grade preoperatively and at final follow-up, recovery rate, and time required for complete recovery. Patient-reported outcome measures and radiographic parameters were assessed. Logistic regression analysis was performed to identify factors associated with incomplete motor recovery.

Results: A total of 58 patients in the ACDF group and 68 patients in the PCF group met the inclusion criteria. Baseline motor grades were comparable between groups (p=0.174). Final motor grade (p=0.204) and recovery rate (p=0.614) did not differ significantly between ACDF and PCF. Complete recovery was achieved in 79.3% of patients in the ACDF group and 73.5% in the PCF group, with no statistically significant difference (p=0.531). However, the time required for complete motor recovery was significantly longer in the PCF group compared with the ACDF group (p<0.001). Both surgical approaches resulted in substantial improvements in neck pain, arm pain, and disability scores, although ACDF demonstrated lower neck and arm pain scores at 1 year postoperatively. Logistic regression analysis revealed that a greater number of operated levels (odds ratio=2.417, p=0.007) and more severe preoperative motor weakness (odds ratio=0.355, p<0.001) were independently associated with a higher likelihood of incomplete motor recovery.

Conclusions: Despite the theoretical advantage of anterior decompression for motor recovery, PCF provides motor recovery outcomes comparable to ACDF in patients with cervical radiculopathy and motor weakness. While motor recovery following PCF may require a longer time, final motor outcomes are similar between the two approaches. Given its motion-preserving nature and minimal invasiveness, PCF represents a valid surgical option when anatomical considerations and surgeon preference favor a posterior approach. Surgeons should recognize the potential for delayed recovery with PCF and counsel patients accordingly, particularly in cases involving multiple affected levels or severe preoperative motor deficits.

Keywords: Cervical radiculopathy, Motor weakness, Anterior cervical discectomy and fusion, Posterior cervical foraminotomy, Recovery time

Best Paper Candidates: Presentation IV (International)

S116

Comparison Between Lowest Instrumented Vertebra (LIV) at L3 vs. L4 in Adolescent Idiopathic Scoliosis (AIS) Patients with Major Lumbar Curves with Lower End Vertebra (LEV) at L4

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Purpose: Evidence on the clinical and radiological outcomes of selecting L3 as the lowest instrumented vertebra (LIV) when the lower end vertebra (LEV) is L4 remains limited. This study aimed to compare the clinical and radiological outcomes between LIV at L3 vs. L4 in lumbar major AIS patients with LEV at L4.

Materials and Methods: AIS patients with Lenke type 5 and 6 curves with LEV L4 and LIV at either L3 or L4 were included, with a minimum follow-up of two years. Preoperative LIV tilt angle on right supine side-bending (RSB) radiographs corrected for pelvic obliquity was measured. L3 was selected as the LIV if L3 centralized (the concave pedicle is touched by the CSL on the RSB radiograph) and the vertical arm of the intraoperative crossbar assessment crossed the concave L3 pedicle when the patient was positioned prone under general anesthesia prior to skin incision. Propensity score matching was performed between the two groups based on age, height, weight, sex, Lenke classification, preoperative major Cobb angle, and operation duration. Immediate postoperative and final follow-up radiological outcomes (LIV tilt angle, correction rate, shoulder balance, coronal balance, adding-on phenomenon) and clinical outcomes (SRS-22 scores) were reviewed.

Results: Forty-six patients were matched into the L3 group

(LIV at LEV−1) and the L4 group (LIV at LEV). At the final follow-up, the L3 group demonstrated a significantly smaller residual lumbar Cobb angle of 19.4±7.6° compared with 26.7±11.7° in the L4 group (p=0.021). The correction rate of the lumbar curve was comparable between the groups (L3: 64.2±11.7% vs. L4: 61.8±11.2%; p=0.496). The L3 group demonstrated comparable mean coronal balance, clavicle angle, cervical axis, T1 tilt, and adding-on phenomenon compared with the L4 group at the final follow-up. The L3 group reported significantly better outcomes in pain, self-image, and total SRS-22 scores (4.6±0.4 vs. 4.3±0.6, p=0.029; 4.2±0.5 vs. 3.9±0.6, p=0.032; 4.3±0.3 vs. 4.1±0.3, p=0.029).

Conclusions: Fusion to LEV−1 (L3), when selected based on our criteria, yields comparable outcomes in correction rate, coronal balance, shoulder balance, and adding-on phenomenon, and demonstrates better clinical outcomes compared with fusion to LEV (L4). Postoperative LIV tilt angle on erect radiographs during the final follow-up can be predicted by the preoperative LIV tilt angle measured on right RSB radiographs.

Keywords: AIS, Major lumbar curve, LIV L3 vs. L4, LEV L4

S117

Postoperative Relocation of the Thoracic Kyphosis Apex as a Risk Factor for Proximal Junctional Kyphosis: A Potentially Preventable Condition

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Purpose: The purpose of this study was to evaluate the association between postoperative thoracic kyphosis apex location at the proximal junctional vertebra and the development of proximal junctional kyphosis (PJK) after long-level fusion surgery in adult spinal deformity (ASD) patients, and to identify preoperative factors predictive of postoperative thoracic kyphosis apex relocation to the proximal junctional vertebra (UIV or UIV+1).

Materials and Methods: A retrospective review of 107 patients who underwent long-level fusion surgery for ASD was performed. Patients were classified into PJK and non-PJK groups. Preoperative and postoperative thoracic kyphosis apex locations, along with preoperative and immediate postoperative spinopelvic parameters, were compared between groups. Multivariable logistic regression analyses were performed to identify independent predictors of PJK. Patients were further stratified into the proximal junctional (PJ) group, defined as having an apex at the upper instrumented vertebra (UIV) or UIV+1, and the non-PJ group, defined as having an apex distal to the proximal junction (>UIV+1). Additional multivariable logistic regression and receiver operating characteristic (ROC) analyses were conducted to identify preoperative predictors and radiographic cut-off values associated with postoperative junctional apex formation.

Results: The PJK group was older than the non-PJK group (p=0.003) and had greater immediate postoperative thoracic kyphosis (TK, p=0.026). Preoperative thoracic kyphosis apex distribution did not differ between groups; however, the PJK group had a significantly higher proportion of postoperative apex at the proximal junctional vertebra (UIV or UIV+1) than the non-PJK group (56.1% vs. 19.7%, p<0.001). In multivariable analysis, postoperative apex location at the proximal junctional vertebra independently predicted PJK (p=0.001), and immediate postoperative thoracic kyphosis was also significant (p=0.036). When stratified by postoperative apex location, the PJ group was older (p=0.005) and had greater preoperative thoracolumbar kyphosis (TLK), lumbar lordosis (LL), and PI–LL mismatch than the non-PJ group (all p<0.05). Preoperative lumbar lordosis was the only independent predictor of postoperative proximal junctional apex formation (p=0.025), with a cutoff value of 7.3° (AUC=0.682).

Conclusions: Postoperative thoracic kyphosis apex at the proximal junctional vertebra (UIV or UIV+1) is strongly associated with an increased risk of PJK. Preoperative LL may help predict proximal junctional apex formation and guide upper instrumented vertebra selection to reduce the risk of PJK.

Keywords: Adult spinal deformity, Proximal junctional kyphosis, Apex

S118

Minimally Invasive Decompression for Lumbar Degenerative Disease: A Systematic Review of Biportal Endoscopic vs. Open Surgery

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Purpose: Efforts to minimize soft tissue damage in surgery have driven the increasing use of minimally invasive techniques. In spine decompression surgery, this has translated into the use of endoscopic approaches. Unilateral biportal endoscopic (UBE) surgery is one of these techniques. Proponents of UBE report outcomes comparable to open surgery while minimizing soft tissue insult. This study aims to compare the clinical outcomes and safety of UBE versus open decompression surgery for lumbar degenerative disease.
Materials and Methods: A systematic literature search was conducted in accordance with the PRISMA 2020 guidelines in PubMed and DOAJ (inception to 2026), Europe PMC (2019 to 2026), and Google. Comparative studies evaluating UBE vs. open surgery (decompression without fusion) in cases of lumbar spinal stenosis and lumbar disc herniation were included. The primary aim was to compare the length of hospital stay, mid-term (±12 months) clinical improvement, operative time, and complications between groups. Study selection and data extraction were performed systematically, and risk of bias was assessed using appropriate tools based on study design.
Results: From 858 records identified, 13 eligible studies were included, comprising four randomized controlled trials (one being a prospective analysis of another study) and nine retrospective cohort studies. A total of 955 patients were analyzed, with five studies evaluating lumbar disc herniation and eight studies evaluating lumbar spinal stenosis. Across the included studies, UBE demonstrated clinical outcomes comparable to open surgery in terms of clinical improvement, operative time, and overall complication rates. UBE was consistently associated with shorter hospitalization compared with open surgery. Operative time varied among studies, with six studies reporting longer operative times for UBE and seven reporting longer operative times for open surgery. Overall complication rates tended to be higher in the open surgery group, with surgical site infection being the most notable difference, as no UBE-related infections were reported. Recurrence and reoperation rates were comparable between groups.
Conclusions: Unilateral biportal endoscopic surgery for lumbar decompression is a sound alternative for minimally invasive surgery in treating lumbar degenerative conditions. It has comparable outcomes and complication rates and is associated with shorter hospitalization. Operative time appears comparable between techniques and may improve with increased surgeon experience.
Keywords: Biportal endoscopic surgery, Lumbar decompression, Lumbar degenerative disease, Open surgery, Systematic review

S119

Rethinking Ligamentum Flavum Thickening: Histopathology Challenges the Hypertrophy-Only Paradigm in Lumbar Spinal Stenosis

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Purpose: Lumbar spinal canal stenosis (LSCS) is associated with thickening of the ligamentum flavum (LF). Increasing evidence suggests LF thickening may arise through two mechanisms: true fibrotic hypertrophy driven by fibroblast activation and extracellular matrix remodeling, or passive mechanical buckling secondary to intervertebral disc height loss. This study aimed to evaluate fibroblast density and collagen composition in LF tissue from LSCS patients and to analyze their relationship as histopathological indicators distinguishing active hypertrophy from mechanical buckling.
Materials and Methods: A cross-sectional analytic study was conducted on ligamentum flavum specimens from 43 LSCS patients who underwent decompressive surgery. Fibroblast density was quantified on hematoxylin–eosin–stained sections and expressed as cells per high-power field (HPF, 400×). Collagen proportion was assessed using Masson’s trichrome staining and expressed as a percentage of total tissue area. One-sample t-tests were used to compare fibroblast counts and collagen proportions with reference

normal values. Pearson's correlation test was used to analyze the relationship between fibroblast density and collagen proportion.

Results: The mean fibroblast count was 11.7 cells/HPF, significantly higher than the normal reference value of 10 cells/HPF (p=0.002). The mean collagen proportion was 57.3%, exceeding the normal range of 20–40% (p<0.001). Pearson correlation analysis demonstrated a strong negative correlation between fibroblast density and collagen proportion (r=−0.906, p<0.001). Although both parameters were increased, higher fibroblast counts were associated with relatively lower measurable collagen proportions, suggesting advanced fibrotic remodeling rather than linear collagen accumulation.

Conclusions: Ligamentum flavum tissue in LSCS exhibits histopathological features of abnormal fibrotic remodeling, characterized by increased fibroblast density and excessive collagen deposition. The strong negative correlation between fibroblast density and collagen proportion indicates a non-linear remodeling process consistent with advanced fibrosis. These findings support a dual-pathway concept of LF thickening in LSCS, involving active hypertrophic fibrosis and passive mechanical buckling. Histopathological assessment provides insight into the underlying mechanism of LF thickening and may help refine pathological classification and therapeutic strategies in LSCS.

Keywords: Lumbar spinal canal stenosis, Ligamentum flavum, Fibroblasts, Buckling, Histopathology

S120

VertebriX: An Interpretable AI Framework for Opportunistic Osteoporosis Grading from Routine Spine Imaging

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Purpose: Osteoporosis is a systemic disease, and osteoporotic vertebral fractures (OVFs) constitute a significant public health issue, characterized by chronic pain, spinal deformity, and diminished quality of life. Despite the diagnostic precision of dual-energy X-ray absorptiometry (DEXA), its limited accessibility, particularly in developing nations, constitutes a significant barrier to early diagnosis and prevention. Recent developments in artificial intelligence (AI) and machine learning (ML) indicate significant potential for enhancing radiological diagnosis through improved image interpretation, decreased interobserver variability, and the facilitation of large-scale screening in resource-constrained settings. This research assesses a new computer-aided system, VertebriX, aimed at detecting and grading osteoporosis from standard spinal images through a radiation-free and cost-effective method.

Materials and Methods: A retrospective analysis was conducted on a dataset comprising 304 spinal X-rays, including 110 normal, 98 osteopenic, and 96 osteoporotic cases, categorized according to their corresponding DEXA T-scores. An interpretable artificial intelligence framework, VertebriX, was developed for the automated segmentation and grading of osteoporosis using spinal images. Median filtering and contrast-limited adaptive histogram equalization (CLAHE) were employed for image preprocessing to improve the visibility of bone texture and to categorize patients into normal, osteopenic, or osteoporotic groups. An explainable AI approach using gradient-weighted class activation mapping was integrated into the VertebriX framework to make the system's predictions more transparent and clinically understandable. Visual saliency mapping was utilized to enhance the interpretability and clinical reliability of the system.

Results: A total of 304 spinal radiographs were analyzed. The baseline MobileNet model attained a mean accuracy of 78% and an F1-score of 0.84, indicating moderate performance prior to optimization. After the integration of double deep Q-network (DDQN)–based reinforcement learning, the optimized model achieved an accuracy of 93% along with macro and weighted-average F1-scores of 0.94, demonstrating strong classification stability and generalization. When compared with convolutional neural networks, InceptionNet, and EfficientNet, the optimized Modified MobileNet + DDQN model showed a clear improvement across all three metrics, achieving a precision of 0.97, recall of 0.92, and an F1-score of 0.94.

Conclusions: The study demonstrates that VertebriX enables the use of artificial intelligence in a comprehensible manner without exposing patients to radiation and offers a cost-

effective solution for grading osteoporosis using routine spine imaging scans. This approach supports early osteoporosis detection in healthcare environments with limited access to DEXA and may serve as a screening adjunct in spine practice.

Keywords: Osteoporosis, Artificial intelligence, Reinforcement learning, Explainable AI

Best Paper Candidates: Presentation V (International)

S121

Sagittal Balance and HRQOLs in Young Patients with High-grade Dysplastic Spondylolisthesis who Underwent Modified Harms' Technique Reduction: Long-term Follow-up, Single-center Study

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Purpose: To evaluate the global sagittal balance, regional spinopelvic alignment and Health-Related Quality of Life (HRQOL) 12-26 years after surgery for HGDS using modified Harms' all-posterior complete reduction technique.

Materials and Methods: Scoliosis Research Society (SRS)-22r questionnaire and standing whole spine radiographs were collected from 15 of 46 patients (11 grade 5, 3 grade 4, 1 grade 3) who underwent surgery for HGDS in our centre between 1998 and 2018. The mean age at surgery was 13.9 years (10–20 years) with a mean follow-up of 15 years (12–26 years). The modified Harms' reduction technique with a specific pedicle screw based distraction maneuver, wide decompression, gradual reduction and maintenance of reduction with interbody fusion was followed (12 patients had L5-S1 interbody fusion, 3 had posterolateral fusion with fixation to L4+Chopin plate system- before 2000). Parameters measured were segmental (slip percentage, Dubousset's lumbosacral angle), regional (pelvic tilt, sacral slope, L5 incidence, lumbar lordosis and thoracic kyphosis) and global alignment (T1 spinopelvic inclination).

Results: Mean slip percentage reduced from 89% (SD 11) to 23% (SD 5) with the Meyerding grade of all cases reduced to grade 1 or less. The correction was maintained at the last follow-up: slip angle from 53° preoperatively to −11°, Dubousset lumbosacral angle (LSA) 55° to 92° ($p<0.001$). Preoperatively 73% patients had unbalanced pelvis and 13% at final FU. All had adequate global sagittal balance (T1 spinopelvic inclination >0°). Only 1 patient had asymptomatic adjacent segment spondylolisthesis after 8 years FU post monosegmental L5-S1 TLIF. The median SRS-22r total score was 4.2 ($p<0.001$) including self-image unlike Anders Joelson et al. (2019) who concluded in situ fusion for high-grade isthmic spondylolisthesis had negative impact on self-image long into adult life (three-decade study). The SRS self-image and mental health scores showed statistically significant correlation with lumbo-sacral kyphosis correction- Dubousset lumbosacral angle >80° ($p<0.001$). No other radiological parameters or age had significant association with SRS scores. No long-term complications were noted (3 cases of partial foot drop (recovered by 12 weeks postoperatively) and 1 immediate screw revision for L5 screw pullout).

Conclusions: Our technique of significant reduction of HGDS, though surgically demanding, is safe and reproducible with maintenance of global sagittal balance (via correction of Lumbo-Sacral kyphosis), no adjacent segment complications and normal SRS-22r scores at long-term follow-up.

Keywords: High-grade spondylolisthesis, Children, Dysplastic, Reduction, Sagittal balance

S122

Percutaneous Endoscopic Discectomy Versus Open Discectomy: Long-Term Reduced Risk of Spinal Fusion and Insights Across Patient Subgroups from the Real-world Global Collaborative Network

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Purpose: The choice between Percutaneous Endoscopic Lumbar Discectomy (PELD) and Open Lumbar Discectomy (OLD) for managing lumbar disc herniation (LDH) remains debated. While both techniques achieve comparable short-term outcomes, their long-term effects, particularly regarding the progression to spinal fusion, are underexplored. This study evaluates the long-term risk of spinal fusion following PELD versus OLD, with a focus on subgroup-specific differences, including age, race, BMI, and comorbidities.

Materials and Methods: This is a retrospective cohort study utilizing the TriNetX Research Network. We analyzed 123,405 patients diagnosed with LDH between 2000 and 2023, including 93,853 PELD and 29,552 OLD cases. After propensity score matching, a 1:1 cohort was created to ensure baseline comparability. Patients were followed for up to 20 years to assess the risk of subsequent spinal fusion. Primary outcome was the incidence of subsequent spinal fusion surgery following PELD or OLD. Subgroup analysis included age groups, sex, race, lifestyle factors, and comorbidities.

Results: 1,223,803 patients diagnosed with LDH were identified using TriNetX. After excluding spinal fracture, malignancy, infection and applying 1:1 propensity score matching, 29,552 matched patients were included in each cohort. PELD significantly reduced the risk of spinal fusion compared to OLD over a 20-year follow-up (HR 0.706; 95% CI: 0.656–0.760). Subgroup analysis revealed consistent benefits across younger patients (20–45 years), high-BMI individuals, and White and African American populations. However, PELD demonstrated limited effectiveness in Asian patients and those with alcohol-related diseases.

Conclusions: PELD offers substantial long-term benefits in reducing the need for spinal fusion, particularly for younger, obese, and racially diverse patients. These findings support PELD as a personalized surgical approach that minimizes invasive burden while optimizing outcomes. Further research should investigate mechanisms underlying subgroup-specific differences and evaluate additional long-term endpoints, including functional recovery and quality of life.

Keywords: Lumbar disc herniation, Minimally invasive surgery, Endoscopic discectomy

May 22 (Fri) Crystal Ballroom (2F) Room A

S123

Does Segmental Kyphosis Matter in Cervical Disc Arthroplasty?

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Purpose: Cervical artificial disc replacement (ADR) is increasingly performed worldwide, with purported benefits of motion-preservation and minimization of adjacent segment degeneration. There has been some concern about performing ADR in kyphotic segments, for fear of worsening the kyphotic deformity. This study aims to compare the radiographic outcomes following ADR in patients with kyphotic, neutral and lordotic cervical spines.

Materials and Methods: The medical records and radiographs of 88 consecutive patients who underwent 1 to 4 levels of cervical disc arthroplasty for cervical myelopathy or cervical radiculopathy were retrospectively analysed. All patients were operated on by a single fellowship-trained spine surgeon based in an academic spine surgery tertiary referral center. The same implant was used for all patients. All patients had radiographs of their cervical spine taken in neutral, flexion and extension views, as well as full body slot scanning imaging pre-operatively, and at 3 months and 1 year post-operatively. Radiographic indices measured include cervical lordosis (CL), global cervical spine range of motion (ROM) as well as segmental lordosis and overall ROM at the operative levels. Regional and global sagittal balance parameters were also measured. Patients were divided into 3 cohorts – kyphotic, neutral and lordotic – according to their pre-operative CL on a neutral lateral radiograph. Level of significance was set to $p<0.05$.

Results: There were 35, 29 and 24 patients in the kyphotic, neutral and lordotic cohorts respectively. The mean global CL in the 3 cohorts was significantly different in neutral (13.5 vs 1.0 vs -13.9, $p<0.00001$), flexion and extension views on the pre-operative radiographs. The mean segmental lordosis at the operative levels in the 3 cohorts was also different (7.2 vs 1.2 vs -5.5, $p<0.00001$). The mean range of motion at baseline was similar across all cohorts, both overall ($p=0.161$) and segmentally ($p=0.582$) at the operative levels. There was a higher mean number of levels operated on in the kyphotic compared to the lordotic cohort (2.5 vs 1.7, $p=0.00084$). CL and segmental lordosis was maintained in the lordotic group and increased in the neutral (1 vs -4.2 degrees, $p=0.0272$) and kyphotic (13.5 vs 7.4 degrees, $p=0.011$) groups post-operatively. Global and segmental ROM was maintained in all 3 cohorts post-operatively. ROM per prosthesis however was lower in the kyphotic group (7.9 degrees) compared to the other 2 cohorts (lordotic 12.7 degrees, neutral 13.7 degrees, $p=0.0198$). C2-7 SVA, and global sagittal balance parameters were unchanged post-operatively in all 3 cohorts.

Conclusions: ADR can be performed safely in kyphotic cervical spine segments, and can be expected to produce a lordosing effect. Kyphotic cervical spines tended to be stiffer overall, with improvements in ROM seen following ADR albeit to a lesser extent per segment compared to lordotic and neutral spines.

Keywords: Cervical spine, Myelopathy, Radiculopathy, Kyphosis, Lordosis, Artificial disc replacement

S124

A Predictive Model for Optimal L4/5 Cage Height in Oblique Lumbar Interbody Fusion: A Quantitative MRI Analysis of 282 Adults

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Purpose: Selecting the optimal cage height is critical to the success of oblique lumbar interbody fusion (OLIF), influencing disc height restoration, foraminal decompression, and segmental alignment. However, surgeons often operate on severely collapsed L4/5 discs where the native disc height cannot be reliably measured, and MRI-based normative references or predictive models for cage selection are lacking. This study aimed to establish normative lumbar morphology, evaluate demographic and spinopelvic associations, and develop predictive models to estimate physiologic L4/5 disc height for OLIF planning.

Materials and Methods: A total of 282 healthy adults (18–40 years) with Pfirrmann grade ≤2 underwent standardized

lumbar MRI and standing radiographs. Disc height was measured using a validated 9-point midsagittal and parasagittal protocol. Foraminal height and segmental lordosis were quantified using established radiologic techniques. Pelvic incidence (PI) was categorized as low (<45°) or high (≥45°). Intersegmental relationships and predictors of L4/5 morphology were assessed using correlation analysis and linear/multivariable regression.

Results: Disc height, foraminal height, and segmental lordosis increased progressively from L1/2 to L4/5. No significant differences in disc or foraminal height were observed between PI groups (all $p>0.05$). L3/4 disc height strongly predicted L4/5 disc height ($R^2=0.743$; RMSE=0.59 mm), yielding the practical equation: L4/5 disc height=1.5232+0.9383×(L3/4 disc height). Foraminal height also showed strong adjacent-level continuity ($R^2>0.80$). Segmental lordosis was more variable, with L3/4 lordosis predicting only modest variance in L4/5 lordosis ($R^2=0.249$). PI was not associated with disc or foraminal morphology.

Conclusions: L3/4 disc height provides a precise, anatomy-based surrogate for physiologic L4/5 disc height and can be applied directly to cage height selection in OLIF. These normative data and predictive models offer an objective, clinically practical framework that may reduce cage sizing errors and improve alignment and decompression outcomes in lumbar fusion surgery.

Keywords: Lumbar disc height, Oblique lumbar interbody fusion, Foraminal height, Segmental lordosis, Magnetic resonance imaging

S125

Posterior-only Approach for Anterior Reconstruction in Dorsolumbar Spinal Tuberculosis

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Purpose: Spinal tuberculosis is the most common type of bone and joint tuberculosis; it may cause kyphotic deformity, neurologic deficit, and even death. The purpose of treatment of spinal tuberculosis is to correct neurological deficit, gain stability and cure tuberculosis. Anterior column reconstruction is important as the disease primarily affects the anterior column. This study aims to assess the efficacy and safety of the posterior-only approach for anterior reconstruction in dorsolumbar spinal tuberculosis.

Materials and Methods: A retrospective study was conducted among patients who underwent surgical treatment with anterior reconstruction through a posterior-only approach for spinal tuberculosis from January 2019 to December 2022. Operating time, blood loss and neurological function were assessed. Clinical outcomes were assessed using the Visual Analogue Scale (VAS) Score and the Oswestry Disability Index (ODI), and radiological outcomes were assessed using correction of the kyphotic angle and achievement of interbody fusion.

Results: A total of 28 cases were included with a mean age of 39.41±16.7 years. Mean duration of symptoms was 1.9±0.6 months. The mean operating time was 211.4±22.1 min, and blood loss was 510±62.2 ml. Mean VAS score improved from preoperative 7.2±1.3 to 0.42±0.13 and ODI Score from 57.1±11.2 to 6.23±2.53 at 1-year follow-up. All patients achieved bony fusion with kyphotic correction from 33.21±4.2 to 5.86±0.57. Complications were seen in 14.2 % of patients, which were managed conservatively.

Conclusions: Posterior-only approach for anterior reconstruction is a safe and effective method with good clinical and radiological outcomes in patients with dorsolumbar spinal tuberculosis.

Keywords: Anterior reconstruction, Spinal tuberculosis, VAS score, Kyphotic correction

Best Paper Candidates: Presentation VI (International)

S126

The iLLIF Score: A Predictive Success Scoring System for Indirect Decompression in Lateral Lumbar Interbody Fusion

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Purpose: Lateral lumbar interbody fusion (LLIF) is a minimally invasive technique for degenerative lumbar disease, but predicting surgical success remains challenging. This study developed and internally validated the iLLIF score to estimate the likelihood of favorable outcomes from indirect decompression.
Materials and Methods: A retrospective cohort study was conducted on 200 patients who underwent LLIF between 2014 and 2024. Patients were categorized based on clinical outcomes: successful (no intervention or reoperation at the index level within 12 months) versus unsuccessful. Independent predictors of success were identified using multivariate logistic regression. A five-point scoring system (iLLIF Score) was derived from significant predictors and validated using the area under the receiver operating characteristic curve (AUC).
Results: Among the 200 patients, 168 (84%) achieved successful outcomes. Multivariate analysis identified five independent predictors of success: (1) rest symptoms less than 50%, (2) reducible disc height greater than 13%, (3) radiographic instability, (4) absence of severe lateral recess stenosis, and (5) no history of previous surgery at an adjacent level. Each factor contributed one point to the iLLIF Score, with total scores ranging from 0 to 5. A threshold score of ≥3 predicted a high probability of success. The scoring model demonstrated high predictive performance, with the model showing an AUC of 0.973 (95% CI: 0.946–1.000).
Conclusions: The iLLIF Score is a practical tool for predicting successful outcomes following indirect decompression using LLIF. It offers a simple preoperative strategy for identifying suitable candidates, guiding surgical planning, and minimizing the need for additional decompression procedures.
Keywords: Indirect decompression, Lateral lumbar interbody fusion, Predictive score, Reoperation rate, Minimally invasive surgery

S127

Impact of Poor Preoperative Nutritional Status on Residual Neuropathic Pain after Cervical Laminoplasty in Geriatric Patients

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Purpose: Neuropathic pain (NeP) frequently persists after cervical spine surgery and adversely affects long-term recovery. While several clinical predictors have been reported, the influence of preoperative nutritional status on postoperative residual NeP remains poorly defined. This study aimed to evaluate the association between preoperative nutritional status and persistent NeP in geriatric patients undergoing cervical laminoplasty.
Materials and Methods: We retrospectively reviewed 119 patients aged ≥65 years who underwent cervical laminoplasty. NeP was assessed using the painDETECT questionnaire (PDQ), with NeP defined as a PDQ score ≥13. Residual NeP was defined as the persistence of NeP at 2 years postoperatively. Nutritional status was assessed using the Geriatric Nutritional Risk Index (GNRI), with malnutrition defined as GNRI ≤98 and further stratified by GNRI-based risk grades (normal, >98; mild, 92–98; moderate, 82–92). Pain-related outcomes, including PDQ scores and numerical rating scale (NRS), were compared across nutritional categories. Functional status was assessed using the Japanese Orthopaedic Association (JOA) score preoperatively and at 2

years, and functional recovery was evaluated using the JOA recovery rate (JOA-RR), with successful recovery defined as JOA-RR ≥42% (MCID). Multivariable logistic regression analysis was performed to identify independent predictors of postoperative residual NeP.

Results: Residual NeP at 2 years postoperatively was observed in 25% of patients. Patients with residual NeP demonstrated significantly impaired neurological recovery, with a lower JOA-RR and a reduced likelihood of achieving the MCID compared with those without residual NeP (JOA-RR, 28% vs. 48%; MCID achievement, 30% vs. 65%). The prevalence of residual NeP increased stepwise with worsening preoperative nutritional status, from 15% in patients with normal nutrition to 50% and 57% in those with mild and moderate nutritional risk, respectively ($p<0.001$). Consistent trends were observed in pain-related outcomes: mean PDQ scores at 2 years progressively increased (normal, 6.7; mild, 12.5; moderate, 12.9; $p<0.001$), whereas the proportion of pain-NRS 50% responders decreased (79%, 33%, and 36%; $p<0.001$) across nutritional risk grades. Multivariable analysis demonstrated that preoperative nutritional risk (GNRI grade) was independently associated with residual NeP (odds ratio [OR], 5.0; 95% confidence interval [CI], 1.6–15.5; $p=0.005$), along with higher preoperative PDQ scores (OR, 1.2; 95% CI, 1.1–1.4; $p<0.001$).

Conclusions: Poor preoperative nutritional status is strongly associated with persistent NeP after cervical laminoplasty. Increasing nutritional risk significantly elevates the likelihood of long-term postoperative pain, highlighting nutrition as a potentially modifiable factor in perioperative pain management for geriatric patients.

Keywords: Geriatric medicine, Cervical myelopathy, Elective cervical spine surgery, Neuropathic pain, Nutrition

S128

Beyond the Disc: Clinical and Radiological Mimics of Lumbar Disc Prolapse

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Purpose: This study aims to highlight different radiological mimics of lumbar disc prolapse, emphasizing the importance of preoperative diagnosis for choosing optimum management strategy. Patients presenting with lumbago sciatica or femorica are often initially suspected of having a lumbar disc herniation. However, numerous conditions can clinically and radiologically mimic lumbar disc herniation while requiring entirely different surgical approaches. These diagnostic challenges create significant difficulties and present a true clinical dilemma for spine surgeons.

Materials and Methods: This is a cross sectional study including 2500 patients, who became clinic-radiologically diagnosed as prolapsed lumbar intervertebral disc and underwent surgery in the two tertiary care hospital and our private set up of Bangladesh from 2015-2025. We analyzed patient's demographics, clinical presentation, radiological features, management strategies and outcome, including a pictorial literature review of the previously published relevant cases in the English literature.

Results: Out of the 2500 cases treated as lumbago sciatica or femorica, 194 patients' clinico-radiologically mimic lumbar disc prolapse. There was slight male predominance (55%) with an average age of 40.5 years. Intraoperatively, 70 patients (2.8%) diagnosed as epidural varicose vein, 40 patients (1.6%) as conjoined nerve root, 10 patients (0.4%) as intra-dural disc herniation, 15 patients (0.6%) as post-operative epidural scar, 10 patients (0.4%) as ossification of posterior longitudinal ligament with calcified disc, 5 patients (0.2%) as swollen nerve root, 1 patient (0.04%) as lumbar chondroma, 1 (0.04%) patient as acute subdural hematoma, 1 patient (0.04%) as discal cyst and 1 patient (0.04%) as vascular malformation. Besides this, 40 patients (1.6%) radiologically diagnosed as spinal tumor whereas intraoperatively diagnosed as sequestered disc. Considering the pathology, surgical modification done to achieve decompression of the

neural elements. At 3 months follow up, all of them achieved favorable neurological recovery, except 1 patient (0.04%) of venous malformation had moderate back pain.

Conclusions: A comprehensive understanding of these differential diagnoses of lumbar disc prolapse, emphasizing key distinguishing features enhances diagnostic precision and guide spine surgeons to avoid potential pitfalls in clinical practice.

Keywords: Conjoined nerve root, Epidural varicose vein, Prolapsed lumbar intervertebral disc

S129

Comparative Effectiveness of Anterior, Posterior, and Combined Surgical Approaches in Lumbar Tuberculosis: A Systematic Review and Meta-Analysis

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Purpose: This study examines the effectiveness of anterior, posterior, or combined surgical approaches in patients with lumbar tuberculosis by comparing clinical, radiological, and postoperative data.

Materials and Methods: A systematic review of the current literature was performed in Google Scholar, PubMed, Embase, and Medline from January 1, 2000, to November 30, 2025. Included studies compared at least two approaches: anterior, posterior, or combined. The main outcomes compared were improvement in neurological function, fusion rate, kyphosis correction, and postoperative complications. Other outcomes compared included postoperative pain, duration of surgery, and perioperative blood loss. Pooled analysis used a fixed-effects or random-effects model, depending on the heterogeneity of the data. Study quality was assessed using the Newcastle-Ottawa Scale.

Results: A total of 18 studies including 1,246 patients met the inclusion criteria. Of these patients, 412 were treated via an anterior approach, 498 via a posterior approach, and 336 via a combined approach. No significant difference was observed between the posterior and combined approaches in terms of neurological improvement. The anterior approach was associated with a significantly shorter operative time and less intraoperative blood loss, while the posterior and combined approaches resulted in significantly greater kyphosis correction than the anterior approach. Neurological function recovery and fusion rates were proportionate among the three approaches. However, the combined approach had a higher complication rate than the single anterior and posterior approaches.

Conclusions: Comparison of the anterior, posterior, and combined surgical approaches yielded satisfactory results in the surgical treatment of lumbar tuberculosis. The posterior approach allowed for optimal correction of the deformity and maximum perioperative safety, while the anterior approach may be preferable in patients with limited involvement. Surgical decisions should be individualized based on the extent of the disease, spinal stability, and patient characteristics.

Keywords: Lumbar spine tuberculosis, Anterior approach, Posterior approach, Combined approach, Surgical outcomes, Systematic review, Meta-analysis

S130

Sagittal Cervical Alignment and Clinical Outcomes Following Two-Level Anterior Cervical Decompression and Fusion with Plating

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Purpose: Anterior cervical decompression and fusion (ACDF) is an established surgical treatment for degenerative cervical disc disease with neurological deficit. While ACDF is considered the gold standard for single-level disease, the role of sagittal alignment restoration in two-level disease remains controversial. Previous studies have reported conflicting evidence regarding the association between postoperative cervical alignment and clinical outcomes. Restoration of sagittal alignment, however, has been proposed as a key surgical objective alongside decompression and fusion. The purpose of this study was to evaluate changes in cervical sagittal alignment following two-level ACDF with autologous iliac crest bone graft and plating, and to analyze

the association between alignment parameters and clinical outcomes.

Materials and Methods: This hospital-based prospective outcome study included 26 patients with two-level degenerative cervical disc disease treated with ACDF using autologous iliac crest bone graft and anterior cervical plating at Yangon Orthopedic Hospital, Myanmar, between September 2020 and August Clinical outcomes were assessed using the modified Japanese Orthopaedic Association (mJOA) score, Neck Disability Index (NDI), and Visual Analog Scale (VAS) for neck and radicular pain. Radiological sagittal alignment parameters including cervical lordosis (CL), segmental lordosis (SL), sagittal vertical axis (SVA), T1 slope (T1S), and T1S–CL mismatch were measured preoperatively and at final follow-up. Correlation analysis was performed to determine associations between changes in alignment and clinical outcomes.

Results: Significant improvement was observed in all clinical parameters postoperatively ($p<0.001$). Radiological analysis demonstrated statistically significant improvement in CL, SL, T1S, SVA, and T1S–CL mismatch at final follow-up. A significant negative correlation was identified between postoperative change in SVA and improvement in mJOA score ($r=0.540$, $p<0.05$), indicating better neurological recovery in patients with improved sagittal balance. Change in T1S–CL mismatch showed a stronger correlation with CL than with T1S, suggesting cervical lordosis as the dominant contributor to sagittal alignment restoration. Other sagittal parameters did not show statistically significant correlations with pain or disability scores.

Conclusions: Two-level ACDF with plating effectively restores cervical sagittal alignment and leads to significant neurological and functional improvement. Reduction in SVA appears to be moderately associated with improved myelopathy outcomes, highlighting sagittal alignment, particularly global balance, as an important surgical consideration. Achievement of optimal cervical alignment should be regarded as a key goal in the surgical management of two-level degenerative cervical disease.

Keywords: Cervical sagittal alignment, Two-level anterior cervical decompression and fusion, Sagittal vertical axis, Cervical lordosis, Degenerative cervical disc disease

Invited Lecture V

S131

Contemporary Perspectives on Proximal Junctional Failure

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Adult Spinal Deformity (ASD) is a highly prevalent condition, affecting 60% of the population over 60 years old. While surgical treatment offers substantial quality-of-life improvements, it carries significant risks, notably Proximal Junctional Kyphosis (PJK) and Proximal Junctional Failure (PJF). PJK is a common adjacent segment pathology occurring in 40% to 50% of patients following ASD surgery, with 66% of cases developing acutely within the first three months. This review evaluates the multifaceted risk factors and underlying mechanisms of PJK and PJF to establish comprehensive preventative strategies. Key patient-specific predictors of failure include poor bone quality—where preoperative Hounsfield Units under 120 predict bony PJK (Odds Ratio 5.7)—and severe frailty, which increases the risk of failure by 3.1 times. Additionally, higher fat infiltration in paraspinal muscles significantly correlates with increased junctional changes. Achieving precise, age-adjusted sagittal alignment is critical, as both over-correction and under-correction elevate PJK risk; furthermore, the normal segmental lordosis distribution must be carefully restored. Intraoperative flattening of thoracic kyphosis acts as a catalyst for over-correction and subsequent junctional failure. Surgical technique, particularly Upper Instrumented Vertebra (UIV) selection and orientation, fundamentally influences outcomes; cranially directed screws drastically increase PJK and PJF risk, whereas caudally directed screws reduce it. Prophylactic measures, such as posterior tethering, have demonstrated a 56% reduction in PJK and a 64% reduction in PJF. For managing recurrent PJK, revising surgeons should limit Proximal Junctional Angle (PJA) reduction to under 15° or extend the fusion proximally by more than 8 levels. Finally, recent analyses indicate that junctional failure modes are diverse, with approximately 25% of PJF cases presenting

as non-kyphotic disease, necessitating a broader definition of junctional pathology. Ultimately, mitigating PJK requires a holistic approach encompassing preoperative patient optimization, strict adherence to biomechanical alignment targets, and meticulous surgical execution.

Keywords: Spine, Kyphosis, Failure, Tomography, Fusion

Plenary Lecture II

S132

Serendipity and Spinal Deformity Surgery

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Serendipity, defined as the discovery of valuable or agreeable findings not actively sought, has played a critical role in the evolution of medicine and surgery. First coined in 1754 by Horace Walpole and derived from the tale of "The Three Princes of Serendip," the concept highlights the importance of observation, curiosity, and openness to unexpected findings.

Numerous scientific and medical breakthroughs, including penicillin, X-rays, and Teflon, were discovered serendipitously, emphasizing that innovation often arises outside structured pathways. In orthopaedics, historical examples such as John Charnley's early failures with Teflon arthroplasty, followed by the transition to high-density polyethylene, illustrate how unexpected outcomes can drive transformative advancements. Similarly, in spine surgery, techniques such as the Smith-Robinson anterior approach and Harrington instrumentation evolved through a combination of insight, adaptation, and serendipitous discovery.

The presentation further highlights how serendipity has influenced contemporary spinal deformity surgery, including the introduction of the Harrington instrumentation, the development of classification systems such as the Lenke classification and novel fixation strategies like the S2AI technique. These innovations often arose from iterative problem-solving and unanticipated intraoperative or clinical observations.

Personal experiences underscore the importance of mentorship, clinical judgment, and adaptability in recognizing and leveraging serendipitous opportunities. Case examples demonstrate that rigid adherence to dogma may not always be necessary, and that individualized, thoughtful approaches can lead to optimal outcomes. Additionally, surgical decision-making must account for unintended consequences.

In conclusion, serendipity remains a powerful force in surgical innovation and clinical practice. While structured knowledge and evidence-based decision-making are essential, the ability to recognize and adapt to unexpected findings is equally important. Embracing serendipity fosters creativity, drives progress, and ultimately enhances patient care in spinal deformity surgery.

Keywords: Serendipity, Spinal deformity, Surgical innovation, Spinal instrumentation

Symposium III. Lumbar: Current Surgical Strategies and Emerging Challenges in Revision Lumbar Surgery and Thoracolumbar Burst Fractures

Session 1: The Growing Burden of Revision Lumbar Spine Surgery: How Can We Do Better?

S133

Why Are Revision Lumbar Spine Surgeries Increasing?

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Purpose: Revision lumbar surgery is a growing clinical challenge in the aging population, but the reasons for its apparent increase remain incompletely understood. This

presentation aims to review recent epidemiologic trends, major causes, and modifiable risk factors for revision lumbar surgery, with particular attention to elderly patients.

Materials and Methods: A focused narrative review was performed using representative registry analyses, nationwide database studies, and recent meta-analyses summarized in this presentation. The review examined trends in primary lumbar surgery, revision burden, common indications for reoperation, and patient- and technique-related risk factors.

Results: Primary lumbar surgery has increased substantially over time in multiple national datasets, increasing the absolute burden of revision surgery. However, whether the revision rate itself is truly increasing remains uncertain across studies. Common causes of revision include recurrent stenosis, adjacent segment disease, pseudarthrosis, implant failure, and infection. Reoperation risk is associated with obesity, smoking, osteoporosis, diabetes, rheumatoid arthritis, multilevel fusion, and technical factors such as sagittal imbalance, superior facet violation, and decompression outside the fusion construct.

Conclusions: The burden of revision lumbar surgery is likely to remain high as the volume of primary surgery and the elderly population continue to increase. Careful patient selection, optimization of modifiable comorbidities, restoration of appropriate sagittal alignment, and meticulous surgical planning may help reduce avoidable reoperation. In elderly patients, prevention strategies may be as important as the revision procedure itself.

Keywords: Lumbar vertebrae, Spinal stenosis, Treatment failure, Spinal fusion, Reoperation

S134

Clinical Decision-Making and Strategic Planning in Revision Lumbar Spine Surgery

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Purpose: Revision lumbar spine surgery remains one of the most challenging fields in modern spine surgery because of distorted anatomy, epidural fibrosis, altered biomechanics, and reduced predictability of clinical outcomes compared with primary procedures. Therefore, effective decision-making requires comprehensive evaluation of underlying pathology, biomechanical instability, sagittal alignment, and patient-specific risk factors.

Materials and Methods: A systematic clinical evaluation is essential for appropriate surgical indication and strategic planning. Detailed review of prior operative history, symptom progression, neurologic status, walking tolerance, and previous nonoperative treatments should be performed. Attention should be directed toward identifying recurrent radiculopathy, neurogenic claudication, mechanical back pain, pseudarthrosis, adjacent segment disease, or postoperative deformity. Imaging evaluation should include standing whole-spine radiographs to assess global alignment and spinopelvic parameters, dynamic radiographs for instability, computed tomography for fusion assessment, and gadolinium-enhanced magnetic resonance imaging for neural compression, recurrent disc herniation, epidural fibrosis, and arachnoiditis.

Results: Successful revision surgery depends on an etiology-driven and alignment-focused strategy. In revision decompression procedures, epidural scarring and altered anatomy substantially increase the risk of unintended dural tears. Therefore, meticulous dissection through preserved anatomical planes and careful identification of bony landmarks are critical to minimizing neural injury. In pseudarthrosis, revision strategy should differ from the index operation according to the “golden rule” that a failed approach should not simply be repeated. Circumferential fusion with enhanced biomechanical stability and biologic augmentation, including the use of BMP-2, may improve fusion success. Adjacent segment disease requires differentiation between isolated stenosis and segmental instability, as decompression alone may be insufficient in the presence of sagittal imbalance or instability. Restoration of sagittal alignment is a key determinant of long-term clinical outcomes. Failure to restore spinopelvic harmony may predispose patients to recurrent mechanical complications, proximal junctional failure, and persistent disability. In rigid deformity or severe flatback syndrome, osteotomy techniques including Ponte osteotomy, pedicle subtraction osteotomy, or vertebral column resection may be required to achieve adequate correction.

Conclusions: Revision lumbar spine surgery requires a

multidimensional decision-making process integrating pathology-specific diagnosis, detailed radiographic analysis, and individualized patient risk assessment. Although technically demanding, appropriately selected patients with clearly identifiable mechanical pathology may achieve favorable clinical outcomes through carefully planned revision strategies emphasizing neural decompression, stable fusion, and restoration of sagittal alignment.

Keywords: Lumbar spine, Revision, Pseudarthrosis, Diagnostic imaging, Spinal fusion.

S135

Technical Strategies in Revision Surgery

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Introduction: Spinal revision surgery presents significant challenges due to anatomical changes, epidural fibrosis, impaired fixation function, and underlying biomechanical instability. The most common causes of revision surgery include nonunion, device failure, adjacent segment disease (ASD), deformity progression, infection, and persistent nerve compression. Successful reconstructive surgery requires a comprehensive understanding and the restoration of spinal stability and overall alignment.

Main: In surgical treatment, it is crucial to radiologically and clinically confirm the aforementioned causes prior to surgery, and attention must also be paid to sagittal changes. Surgical exposure should be performed through the previous surgical entry whenever possible; however, attempting a new approach is preferable to avoid nerve damage. If the same route is used, careful dissection is required to prevent nerve damage caused by epidural fibrosis. Decompression requires the utmost caution to minimize manipulation of the attached dura mater while addressing residual or recurrent nerve compression. In cases of nonunion, the previous device should be removed, and screws with a larger diameter or longer length than the previous pedicle screws may be used. In the presence of osteoporosis, cement reinforcement may be an option. For deformity correction, pelvic fixation using S2 screws or iliac screws, or double rods to enhance structural durability, may be utilized. Since revision surgery carries a higher risk of complications such as dural rupture, infection, neurological damage, and increased hemorrhage, it is considered necessary to perform a thorough assessment of these risks.

Conclusions: Spinal revision surgery requires consideration of an approach that can minimize complications if possible. It is considered necessary to take into account the various complications that may arise during surgery and to understand the various methods to resolve them.

Keywords: Revision surgery, Lumbar

S136

Tailored Surgical Strategies for Revision Lumbar Spine Surgeries Based on Patient-Specific Conditions

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With the increasing number of lumbar spine surgeries, the proportion of revision procedures has also steadily risen. An analysis of surgical data from our institution between 2022 and 2025 demonstrated that 342 of 1,532 cases were revision surgeries, yielding a mean revision rate of 22.3%. Notably, the annual revision rate showed a continuous upward trend, increasing from 19.6% to 27.7%. In 2025, revision procedures accounted for approximately one-third (27.7%) of all lumbar surgeries. These findings suggest that revision lumbar surgery is no longer an exceptional occurrence, but rather a routine clinical challenge that must be anticipated in the management of lumbar spinal disorders.

Revision lumbar surgery can be broadly classified into five categories: revision decompression, revision fusion, hardware removal or replacement, correction of spinal alignment, and infection management. Among these, this presentation focuses particularly on revision fusion surgery and correction of spinal alignment, proposing patient-specific surgical strategies based on individual pathological conditions.

The two principal issues addressed in revision fusion surgery are post-laminectomy instability and nonunion or pseudarthrosis. When instability develops following laminectomy, the choice of surgical technique depends on

the affected level and the condition of the anterior column support. Representative procedures include posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), lateral lumbar interbody fusion (LLIF), anterior column realignment (ACR), as well as minimally invasive approaches.

Nonunion and pseudarthrosis are among the most common indications for revision surgery. Failed fusion at the L5–S1 level is frequently associated with S1 screw loosening or breakage. Surgical strategy in such cases is based on three fundamental principles: reinforcement of mechanical fixation through hardware revision using larger or longer screws; restoration of anterior column support via interbody reconstruction; and optimization of the biological environment for fusion through adequate bone graft augmentation. In single-level nonunion, screw replacement and posterolateral fusion may be sufficient. However, in multilevel or recurrent failure cases, additional iliac fixation or supplemental cage insertion may be required. When implant failure is present, screw reinsertion combined with additional cage placement is essential to restore mechanical stability.

In cases where spinal malalignment accompanies fusion failure, a more complex reconstructive approach is necessary. Conditions such as iatrogenic flatback deformity may require a posterior-only approach, an anterior approach, or a combined posterior–anterior strategy. Posterior-only correction using pedicle subtraction osteotomy (PSO) with long-segment fixation can effectively restore sagittal alignment. An anterior approach may be indicated when cage subsidence or delayed union is the primary cause, allowing for cage revision and restoration of anterior support. A combined approach is typically reserved for patients with multilevel deformity and severe sagittal imbalance, integrating LLIF, PSO, and iliac fixation to achieve both structural stability and global alignment correction.

In conclusion, revision lumbar surgery is not merely a corrective procedure for prior surgical failure, but a highly demanding operation that requires precise identification of the underlying cause and a strategic, patient-specific approach. Even in same-level revision surgery, the operative technique must be tailored according to the specific pathology—whether instability, nonunion, implant failure, or spinal malalignment. Therefore, the key to successful revision lumbar surgery lies not in a uniform surgical method, but in a pathology-driven, individualized surgical strategy rather than a “one technique fits all” approach.

Session 2: Surgical Strategies for Acute Thoracolumbar Burst Fractures

S137

Is Spinal Fusion Always Necessary for Thoracolumbar Burst Fractures?

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Introduction: Thoracolumbar burst fractures represent one of the most common high-energy spinal injuries, frequently occurring at the thoracolumbar junction (T11–L2). These injuries are characterized by axial compression with failure of the anterior and middle columns, often accompanied by retropulsion of osseous fragments into the spinal canal. For decades, spinal fusion has been considered a standard adjunct to surgical stabilization, based on the assumption that permanent arthrodesis is required to prevent late kyphosis, implant failure, and chronic instability. However, with advances in pedicle screw fixation, minimally invasive techniques, and improved understanding of fracture healing biology, the necessity of routine fusion has been increasingly questioned.

Main Body: The traditional rationale for fusion in thoracolumbar burst fracture surgery was based on three principal concerns: 1) Anterior column insufficiency, leading to progressive kyphosis, 2) Posterior ligamentous complex (PLC) disruption, resulting in mechanical instability, 3) Risk of implant failure, particularly in short-segment constructs. Early-generation instrumentation lacked sufficient rigidity, and correction loss after implant removal was common. Consequently, posterior fusion with posterolateral bone grafting became routine practice to ensure long-term stability. However, modern pedicle screw systems provide segmental fixation with significantly greater biomechanical strength, challenging the assumption that fusion is mandatory in all

cases. The need for fusion depends largely on the interplay between: 1) Anterior column load-sharing capacity, 2) Integrity of the PLC, 3) Quality of reduction and restoration of vertebral height, 4) Bone mineral density. In fractures with preserved PLC integrity and moderate comminution, indirect reduction and stable posterior fixation may allow biological healing without formal arthrodesis. Several biomechanical studies have demonstrated that temporary posterior fixation can maintain alignment during fracture consolidation, particularly when the fractured vertebra is instrumented and kyphosis correction is adequately achieved. Conversely, in highly comminuted fractures, severe anterior column destruction may exceed the mechanical limits of posterior instrumentation alone, favoring fusion or anterior column reconstruction. Recent comparative studies and meta-analyses about Fusion vs. Non-Fusion in acute thoracolumbar burst fractures have reported: 1) No significant difference in long-term pain scores, 2) Comparable radiographic alignment maintenance, 3) Similar neurological outcomes, 4) Reduced operative time and blood loss in non-fusion cohorts, 5) Potential preservation of motion segments. Temporary posterior fixation without fusion, followed by implant removal after fracture healing, has been associated with restoration of segmental motion and decreased adjacent segment degeneration. However, some studies report higher rates of correction loss when: 1) Severe kyphosis is present preoperatively, 2) PLC disruption exists, 3) Osteoporosis compromises screw purchase. Thus, evidence suggests that fusion is not universally necessary but may be selectively indicated.

Conclusions: Spinal fusion is not universally necessary in the management of thoracolumbar burst fractures. Modern posterior instrumentation, improved imaging, and refined patient selection have enabled successful non-fusion strategies in appropriately selected cases. The critical determinant is not whether fusion is performed, but whether mechanical stability, sagittal alignment, and biological healing conditions are adequately restored. A selective, evidence-based approach—rather than routine fusion—appears most consistent with contemporary surgical principles.

Keywords: Thoracolumbar junction, Burst fracture, Posterior ligamentous complex, Spinal fusion, Non-fusion surgery

S138

Short-Segment Fixation vs. Long-Segment Fixation: Biomechanical and Clinical Considerations

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Purpose: To evaluate factors influencing posterior construct selection in acute thoracolumbar burst fractures and to assess the relative impact of construct length versus bone quality and fracture characteristics on mechanical outcomes.

Materials and Methods: A retrospective single-center cohort of 84 patients with acute thoracolumbar burst fractures was analyzed. Patients were categorized according to fixation strategy: long-segment fixation, 2-above/1-below constructs, and short-segment fixation. Multivariate logistic regression was performed to identify factors associated with the selection of long-segment fixation. Additionally, findings were interpreted in the context of current literature, including meta-analyses and biomechanical studies evaluating construct configuration and the role of intermediate screws.

Results: Long-segment fixation was performed in 69% of cases, 2-above/1-below constructs in 23%, and short-segment fixation in 8%. Osteoporosis was the only independent factor associated with selection of long fixation. Construct length itself was not independently associated with increased mechanical complications. Meta-analyses demonstrated that long constructs may better maintain final Cobb angle and reduce low back pain, whereas short constructs were associated with reduced blood loss and operative time; however, the overall quality of evidence was low. Construct-based analyses showed that inclusion of intermediate screws improved sagittal alignment maintenance and reduced implant failure rates. Biomechanical studies supported these findings, demonstrating reduced pedicle stress and improved load sharing with intermediate screw incorporation.

Conclusions: Posterior construct selection in thoracolumbar burst fractures should be guided primarily by bone quality rather than construct length alone. Short-segment fixation with intermediate screws appears sufficient in non-osteoporotic patients, whereas osteoporotic fractures require enhanced fixation strategies beyond simple extension of construct length.

Keywords: Thoracolumbar spine, Burst fracture, Osteoporosis, Posterior fixation, Pedicle screw instrumentation

S139

Percutaneous MIS Ligamentotaxis
- Thoracolumbar Osteoporotic Bursting Fracture -

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Background and Introduction: Osteoporotic compression fractures or bursting fractures in the thoracolumbar vertebrae often experience pain or lower extremity paralysis due to delayed progressive kyphosis that progresses even after vertebroplasty. However, according to the current government public health care criteria, there is a dispute over screw fixation in the case of osteoporotic bursting fractures.

Due to osteoporosis, ligamentotaxis after screw insertion should consider complications such as collapse of the vertebral body and failure of screw fixation after surgery. We would like to introduce the treatment experience of percutaneous minimally invasive ligamentotaxis using cement over the past 4 years in osteoporotic bursting fracture patients.

Main Body: Even in the presence of severe osteoporotic bursting fractures with more than 60% compression, indirect spinal compression can be successfully restored by percutaneous ligamentotaxis.

The surgery method is as follows:

1. Percutaneous mono screw fixation is performed on the vertebrae to be performed on one side.
2. Insert the ipsilateral percutaneous polyaxial screw into the lower vertebrae.
3. Inject a cement around the inserted screws, and then insert a rod, lock the lower pedicle screw first, and Lock the upper screw after distraction.
4. The other side has rod connections after percutaneous polyaxial screw fixation.
   Percutaneous surgery is possible up to short segment / long segment fusion level up to 5 vertebrae.

Conclusions: Even in severe osteoporotic bursting vertebral compression fractures, percutaneous MIS ligamentotaxis is useful, safe, and can be fixed percutaneously up to level 5, and cement reinforcement can prevent metal fixation failure.

Keywords: Osteoporotic bursting fracture, Percutaneous MIS, Ligamentotaxis

Invited Lecture VII

S140

Fluoroscope Guided Percutaneous Cement Augmentation for Proximal Junctional Failure After Long Spinal Fusion

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Introduction: For proximal junctional failure (PJF) with instrumented and junctional vertebral fractures, revision spinal surgery for level extension is usually the treatment. However, subsequently similar complications will happen again after such extensive procedures. This study aims to propose a minimally invasive procedure by percutaneous cement augmentation under fluoroscopy guidance as a salvage surgery for symptomatic PJF.

Methods: Thirty-two patients were reviewed. The procedures were performed under local anesthesia and basically similar to vertebroplasty except for the preexisting pedicle screws. The trocar was inserted under fluoroscopy guidance along the existing pedicle screw using the latero-pedicular technique. The clinical outcome and radiographic result were measured preoperatively and at the final follow-up.

Results: The mean length of the postoperative hospital stay was 1.2 days. The mean visual analog pain scale (VAS) improved from 7.5 to 2.3 postoperatively. Some cases had cement leakage outside the vertebral bodies, but not into posterior neuroforamen. There was no neurological complication in our series. Three patients needed extensive revision open surgery after cement augmentation.

Discussion: The strength of the current technique includes that it is a minimally invasive procedure and patients do not need general anesthesia and extensive surgery. The patients

will get significant pain relief and return to daily activity much earlier than the extensive fusion surgery.

Conclusions: Percutaneous cement augmentation is a safe, effective, and minimally invasive surgical technique for proximal junctional failure. However, further large-scale clinical analyses and long-term follow-up are needed.

Free Paper: Lumbar (3)

S141

Improved Keel Position Accuracy in Robot-Navigated Lumbar Disc Replacement

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Purpose: Modern keeled lumbar disc replacement (LDR) implants confer higher stability to prevent early migration and improve bony ongrowth. The placement and trajectory of keel cuts are hence vital for the implant's effectiveness and longevity. The use of robot assisted navigation enables potentially improved keel cut placement both coronally and rotationally. We aim to compare accuracy of keel position between free-hand (FH-LDR) and robot-navigated (RN-LDR) LDR placement.

Materials and Methods: Single-centre, single surgeon retrospective case-cohort analysis of LDR keel positions in post-operative computed tomography (CT) scans between elective FH-LDR (n=18) and RN-LDR (n=8) cases. Coronal deviation (mm) and rotational deviation (º) were measured on the axial view of each operated endplate.

Results: Post-operative axial CT results showed a lower mean coronal deviation (0.556±0.799 mm vs. 1.026±0.855 mm, p=0.2) while mean rotational deviation was significantly lower (2.24°±1.65° vs. 3.94°±2.41°, p=0.042) in the RN-LDR as compared with FH-LDR. Further subgroup analyses did not show any significant difference in coronal and rotational deviation between in those who underwent L4/5 and L5/S1 LDR.

Conclusions: This study suggests non-inferior rotational and coronal alignment in RN-LDR over conventional FH-LDR. RN-LDR can be considered in enabling acceptable stability and implant fixation and patient outcomes. However, further studies are required to quantify the level-specific thresholds for acceptable malalignment in LDR, and greater study numbers are required to justify the higher operating and maintenance costs associated with robot-navigation systems.

Keywords: Lumbar disc replacement, Lumbar disc arthroplasty, Robotic spine surgery, Robot-assisted navigation

S142

Predictors of Cage Subsidence After Oblique Lumbar Interbody Fusion

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Purpose: To evaluate preoperative and intraoperative predictors of cage subsidence and radio-graphic fusion after oblique lumbar interbody fusion (OLIF).

Materials and Methods: Seventy patients (119 levels) who underwent OLIF using a polyether–ether–ketone cage and posterior screw fixation between 2015 and 2023 were retrospectively reviewed. Pre-operative bone quality was assessed using the computed tomography–based Hounsfield unit (HU) and magnetic resonance imaging–based vertebral bone quality (VBQ) score on T1-weighted images. Radiographic parameters of anterior and posterior disc height (ADH, PDH), segmental and lumbar lordotic angle (SLA, LLA), foraminal height (FH), and cage position were measured preoperatively at one-year follow-up.

Results: Cage subsidence occurred in 21.0% of spinal levels (25/119 levels). Multivariate analysis identified these measures as independent predictors: HU (OR 1.017; p=0.012), VBQ score (OR 2.716; p=0.016), and PDH distraction (OR 1.418; p=0.019). ROC analysis identified cutoff values of HU <145.86, VBQ score >3.30, and PDH distraction >4.79 mm. None of the evaluated factors were significantly associated with one-year radiographic fusion.

Conclusions: Lower HU, higher VBQ score, and excessive PDH distraction are independent risk factors for cage subsidence after OLIF, although these factors do not appear

to affect short-term fusion outcomes.

Keywords: Spinal fusion, Cage subsidence, Osteoporosis, Hounsfield unit, Magnetic resonance imaging

distinct and different.

Keywords: Gut dysbiosis, Lumbar intervertebral disc degeneration, Pantoea dispersa, Gut microbiome

S143

Association of Gut Dysbiosis With Lumbar Intervertebral Disc Degeneration: A Cross Sectional Study

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Purpose: Back pain is the leading cause of disability worldwide and is associated with Obesity and chronic low-grade inflammation. Alterations in Intestinal Microbiota may contribute to the pathogenesis of intervertebral disc degeneration through metabolites affecting Immune and Inflammatory responses.

Materials and Methods: A cross-sectional analysis within the framework of a prospective study was performed. DNA was extracted from faecal and disc samples collected from adult symptomatic patients with lumbar degenerative disc disease. Alpha and beta diversity assessed differences in faecal microbial community between groups. Taxon-by-taxon analysis identified microbial features with differential relative abundance between groups. Clinical and radiological evaluation was performed using VAS score, ODI score, and Pfirrmann grading.

Results: The disc microbes were found to be distinct from the fecal microbes. Relative numbers of the species Pantoea dispersa were found specifically in disc samples and not in stool.

Conclusions: The study results noted a unique microbiota in the disc, Pantoea dispersa, which was entirely absent in fecal matter. A higher alpha diversity was found in lower Pfirrmann subgroup, suggesting a potential loss of microbiome from the disc as the degenerative process continues. The discs with lower ODI scores were found to harbour a higher load of microorganisms than those with higher ODI scores, underlying and establishing the fact that the disc loses its microbiological diversity as it undergoes degeneration. Gut and disc microbiota was thus found to be

S144

Intraoperative Venogram-Assisted Removal of Malpositioned Pedicle Screw Encroaching the Common Iliac Vein: Technical Note

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Purpose: Describe a safe and reproducible intraoperative technique using venography and balloon catheter assistance for the removal of a malpositioned pedicle screw encroaching the common iliac vein (CIV).

Materials and Methods: Retrospective case report : A patient with a right L4 pedicle screw breaching the anterior cortex and contacting the right CIV was identified on postoperative CT angiography following lumbar interbody fusion. Under general anesthesia, a balloon catheter was placed through the right internal jugular vein, and was advanced into the CIV. Direct screw contact into CIV was confirmed by intraoperative venography without extravasation. During gradual screw removal, sequential venograms were performed to monitor venous integrity. A new screw was subsequently inserted in the corrected trajectory, followed by repeat venography confirming preserved venous flow and no leakage.

Results: The intraoperative venogram demonstrated continuous venous patency and absence of bleeding throughout screw removal. The patient remained hemodynamically stable and had no postoperative vascular complications. Postoperative CT angiography confirmed intact CIV contour and optimal screw positioning.

Conclusions: Intraoperative venogram-assisted screw removal enables real-time vascular assessment and immediate endovascular readiness in cases where major vessel encroachment is suspected. This hybrid approach enhances surgical safety, minimizes bleeding risk, and provides a

reproducible protocol for the management of vascularly endangered pedicle screws.

Keywords: Pedicle screw malposition, Vascular injury, Common iliac vein, Intraoperative venography, Endovascular technique

S145

2D-Fluoroscopy Based Robotic Assisted Guidance System for Pedicle Screw Placement in Thoracolumbar Spine Surgery: Technical Note and Preliminary Case Report

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Purpose: The accuracy of pedicle screw placement is crucial to achieving optimal patient outcomes in spinal fusion surgery. While robotic guidance systems have been introduced to enhance this accuracy, conventional commercialized platforms mandate intraoperative three-dimensional (3D) imaging, such as from an O-arm or 3D C-arm, for the patient-to-robot registration process. This study aims to evaluate the initial clinical efficacy, accuracy, and safety of a robotic system that utilizes conventional 2D C-arm fluoroscopy for navigation and screw placement.

Materials and Methods: A prospective case series was conducted on the initial ten consecutive patients who underwent single-level thoracolumbar fusion using robotic guidance system between August and December 2025. All patients received robot-assisted pedicle screw fixation. We analyzed patient demographics, operative data (operative time, blood loss, length of stay), radiation exposure (time and dose), and screw placement accuracy using the Gertzbein-Robbins Scale (GRS). Safety outcomes, including the rates of intraoperative screw revision and facet joint violation, were also assessed.

Results: Fifteen patients (10 female, 5 male) with a mean age of 68.4 years were included. The mean operative time was 197.2 minutes, mean estimated blood loss was 180.0 mL, and the mean length of hospital stay was 8.6 days. The mean intraoperative fluoroscopy time was 69.2 seconds, with a mean radiation dose of 0.40 mGy. A total of 60 pedicle screws were placed. Postoperative analysis revealed that 100% of screws (60/60) were graded as clinically acceptable (GRS Grade A or B), with 95.0% being Grade A (˝excellent”) and 5.0% being Grade B (˝good”). No instances of cortical breach (Grade C or D) occurred. Intraoperative screw revision was performed in two patients (20.0%). There were no cases of facet joint violation.

Conclusions: This preliminary study demonstrates that the 2D fluoroscopy-based robotic guidance system provides excellent accuracy and safety for pedicle screw placement. The system achieves these results without the need for costly intraoperative 3D imaging systems, potentially increasing the accessibility of robotic technology in spine surgery. While these initial results are promising, larger-scale prospective studies are warranted to further validate its efficacy and compare it with existing technologies.

Keywords: Robotic-assisted pedicle screw fixation, 2D-fluoroscopy based robot surgery, Thoracolumbar spine surgery

Free Paper: Lumbar (4)

S146

Functional Outcome of Transforaminal Endoscopic Lumbar Discectomy: Experience of My Early 25 Cases in Nepal

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Purpose: To evaluate technical problems, complications and overall results of TELD.

Materials and Methods: First 25 cases aged 15 years to 65 years operated by transforaminal endoscopic discectomy between January 2023 and January 2024 are reported.

Inclusion Criteria: Patients having MRI proven lumbar disc prolapse with unilateral radiculopathy and clinical evaluation showing positive straight leg raising test with identification of a single nerve root lesion. Any patients with bilateral symptoms and cauda equina syndrome were excluded. All patients were operated in a single center by

single spine surgeon under local anesthesia and sedation whenever needed. All patients were evaluated for stretch pain and neurology soon after the surgery inside operation theatre. All patients were mobilized as soon as pain subsided and discharged on same day. Patients were evaluated for technical problems during surgery, complications and overall result by VAS (visual analogue scale) score for pain and ODI (Oswestry Disability Index) score for overall functional outcome. Patients were followed-up in 2 weeks, 6 weeks, 3 months and 6 months after surgery.

Results: The most affected disc level was L4-L5. All patients were treated for single-level disc prolapse. No dural puncture or root injury occurred. After 6 weeks postoperative follow-up, the mean VAS and ODI score decreased significantly. The average surgical time was 65.6 min ranging from 40 min to 90 min. Average blood loss was <20 ml. Technical difficulties were encountered in the initial 3 cases in insertion of needle to target the prolapsed disc, in 1 case camera became foggy and in 1 case complete disc was not removed due to bleeding issues. 2 patients got discitis and were treated with antibiotics. 90% of patients had significant improvement in VAS score and ODI score. No recurrence has been noted till now.

Conclusions: Transforaminal lumbar endoscopic discectomy is a safe and effective minimally invasive alternative to treat lumbar disc prolapse surgically. The procedure has numerous advantages like it is done under local anesthesia and sedation, shorter hospital stay, early return to work and daily activities and a low major complication rate.

Keywords: TELD, PIVD

S147

Does Endoscope Angle Influence Outcomes in ULBD: A Comparison of 0° and 30° Endoscopes for Lumbar Spinal Stenosis

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Purpose: Biportal endoscopic spine surgery (BESS) with unilateral laminectomy for bilateral decompression (ULBD) is widely used for treating lumbar spinal stenosis (LSS). Both 0-degree and 30-degree endoscopes are commonly employed, but their comparative benefits remain unclear. This study aimed to compare clinical and radiologic outcomes of ULBD performed with 0-degree versus 30-degree endoscopes.

Materials and Methods: This retrospective comparative study included 93 patients who underwent ULBD for LSS at a single tertiary center between May 2022 and December 2024. Patients were divided into two groups: 0-degree endoscope group (n=53) and 30-degree endoscope group (n=40). Clinical outcomes were assessed using Visual Analog Scale (VAS) for back and leg pain, Oswestry Disability Index (ODI), and EuroQol-5D (EQ-5D) at preoperative, 1-month, 3-month, 6-month, and 12-month postoperative time points. Radiologic analysis evaluated dural sac expansion and extent of bony resection using CT and MRI. Correlation analysis examined the relationship between resection extent and clinical outcomes.

Results: The 30-degree group reported significantly lower back pain VAS scores at 1 month postoperatively compared to the 0-degree group (2.35±1.56 vs. 3.42±1.88; $p<0.01$), although no significant differences were observed at subsequent follow-ups. Radiologically, the 30-degree group achieved comparable dural sac expansion with significantly less spinous process and lamina resection ($p<0.001$). All postoperative fractures, including spinous process and pars interarticularis fractures, occurred exclusively in the 0-degree group, although overall complication rates were similar between groups. Correlation analysis revealed that greater bony resection was associated with worse short-term back

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pain and ODI scores ($p<0.05$).

Conclusions: ULBD using a 30-degree endoscope provided superior short-term back pain relief and required less bony resection compared to the 0-degree endoscope, while maintaining comparable long-term clinical outcomes and adequate neural decompression. These findings suggest that the 30-degree endoscope may offer technical advantages in minimally invasive lumbar decompression surgery.

Keywords: Biportal endoscopic spine surgery, Lumbar spinal stenosis, Unilateral laminectomy for bilateral decompression, Endoscope angle

S148

Redefining Prognosis in Cauda Equina Syndrome: Why Aetiology and Level Matter More Than Timing

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Purpose: To challenge the traditional perception of Cauda Equina Syndrome (CES) as a monolithic surgical emergency defined primarily by surgical timing. This study investigates how Body Mass Index (BMI), aetiology (acute disc vs. stenosis), and the anatomical level of compression serve as more potent predictors of functional and autonomic recovery.

Materials and Methods

- A single-surgeon retrospective cohort analysis was conducted including 84 patients.
- The study analysed correlations between demographic profiles, aetiological factors, and compression levels with post-operative outcomes.
- Outcomes were measured using the Oswestry Disability Index (ODI) for disability, Visual Analogue Scale (VAS) for pain, and subjective bladder recovery rates.
- Etiological groups were categorized into acute Prolapsed Intervertebral Disc (PIVD) and Lumbar Canal Stenosis (LCS).

Results

- The mean cohort age was 42.7±12.6 years with a 70.2% male predominance.
- Bladder dysfunction was the ubiquitous hallmark, present in 89.3% of patients across all age groups ($p=0.86$).
- The average BMI of patients was 27.1±3.6 kg/m^2, with 63% of patients classified as overweight or obese.
- Increased BMI was associated with a shift toward L4–L5 involvement and multilevel disease.
- PIVD patients (mean age 37.4 years) showed an 89.5% bladder recovery rate, significantly higher than the 57.1% recovery in LCS patients (mean age 61.8 years, $p=0.01$).
- Multilevel disease demonstrated the poorest recovery rate at 18.2% and significantly higher residual disability (ODI, $p=0.02$).
- Post-operative pain relief (VAS) was effectively achieved across all groups, regardless of functional recovery status.

Conclusions

- CES outcomes are strongly influenced by the mechanism and extent of compression rather than timing alone.
- Single-level PIVD in younger patients carries a favourable prognosis.
- Multilevel involvement and LCS—characterized by chronic ischemic "pre-conditioning" and Schizas Grade D stenosis—face a significantly poorer functional trajectory.
- These findings necessitate stratified clinical counselling based on aetiological risk factors.

Keywords: Lumbar spine, Cauda equina syndrome, Schizas classification, Bladder dysfunction, Lumbar canal stenosis, Lumbar disc prolapse

S149

Sacroiliac Joint Vacuum Phenomenon as a Potential Predictor of Poor Outcomes After Short-Segment Lumbar Fusion

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Purpose: The clinical impact of sacroiliac joint (SIJ) vacuum phenomenon (VP) on outcomes after short-segment lumbar fusion remains unclear. This study evaluated the association between preoperative SIJ VP and postoperative clinical and radiological outcomes.

Materials and Methods: We retrospectively reviewed patients who underwent one- or two-level posterior or transforaminal

lumbar interbody fusion with at least one year of follow-up. Patients with adjacent segment degeneration, prior lumbar surgery, hip pathology, inflammatory disease, or postoperative complications were excluded. Preoperative SIJ VP was assessed on computed tomography, and patients were divided into a none/minimal VP group and a significant VP group (>50% of the SIJ). Clinical outcomes included the Oswestry Disability Index (ODI), EQ-5D, and visual analogue scale (VAS). Radiological outcomes included spinopelvic parameters measured on standing radiographs.

Results: Fifty-one patients were included (none/minimal VP, n=33; significant VP, n=18). Baseline characteristics were comparable between groups. Postoperatively, the VP group showed significantly less reduction in pelvic tilt and smaller increases in sacral slope, indicating reduced pelvic compensation after fusion. Patients with SIJ VP demonstrated significantly less improvement in ODI scores, while changes in other clinical measures were comparable. The Eno classification of SIJ degeneration was not associated with postoperative radiological or clinical outcomes.

Conclusions : Preoperative SIJ vacuum phenomenon was associated with reduced pelvic compensation and marginally poorer functional improvement following short-segment lumbar fusion, suggesting that SIJ VP may serve as a useful prognostic imaging marker.

Keywords: Sacroiliac joint, Vacuum phenomenon, Lumbar fusion, Spinopelvic alignment, Clinical outcomes

S150

The Correlation of Iliac Crest Morphology and Safe Working Zone for Lateral Lumbar Interbody Fusion

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Purpose: This study aims to evaluate iliac crest height and slope on plain radiographs and assess their correlation with the positions of the safe working zone (SWZ), lumbar plexus, and iliac great vessels on MRIs.

Materials and Methods: We reviewed lumbar plain films and MRIs of 98 patients. Iliac crest height was classified into high and low iliac crest height (HICH and LICH), and iliac crest slope was classified into high and low iliac crest slope (HICS and LICS). The SWZ, lumbar plexus position, and L4-5 oblique corridor were assessed from the MRIs.

Results: The LICH group had statistically significant wider SWZ on the left side compared with HICH (p=0.007). For the lumbar plexus, the HICH group had significantly more patients in Moro zone II (p=0.024) and significantly fewer patients in Moro zone IV (p=0.002). For the iliac slope, similar results were observed, there were statistically significant wider SWZ (p=0.003) and more posterior left-sided lumbar plexus position in the HICS group (p=0.002). The mean L4-5 oblique corridor showed no significant difference between the high and low iliac crest height or slope groups.

Conclusions: The LICH and HICS had a correlation with more widening SWZ and more posterior lumbar plexus position on axial MRI. These iliac crest types are suitable to perform LLIF of L4-5.

Keywords: XLIF, Lateral lumbar interbody fusion, MIS fusion, Anatomy, Lumbar plexus

Free Paper: Cervical (1)

S061

Biomechanical Consequences of Implant Footprint Mismatch and Positioning in Cervical Disc Replacement

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Purpose: A footprint mismatch between a cervical disc replacement (CDR) implant and the vertebral endplates is common; however, debate remains regarding the optimal implant position when use of an undersized-footprint device is unavoidable. This study aimed to evaluate the

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biomechanical impact of an undersized-footprint ball-and-socket CDR on spinal kinematics, facet joint stress, implant-endplate contact stress, and adjacent disc stress according to sagittal implant position.

Materials and Methods: A validated C4-C7 finite element model was developed from computed tomography data. A Prodisc® C Vivo prosthesis was implanted at C5-C6 in two configurations: (1) footprint-matched and (2) footprint-mismatched, using undersized implants positioned anteriorly (m-A), centrally (m-C), and posteriorly (m-P). Physiological follower loads (98 N) and pure moments (2 Nm) were applied to simulate flexion, extension, lateral bending, and axial rotation. Range of motion (ROM), implant-endplate contact stress, core stress, facet joint stress, and adjacent disc stress were compared.

Results: The m-A model reduced C5-C6 ROM by 22% in flexion but increased facet joint stress by 166% during extension and adjacent disc stress by up to 148% in flexion. Implant-endplate contact stress increased by up to 277% in the m-A model, suggesting a higher risk of subsidence. The m-C model showed lower increases in core stress, whereas the m-P model preserved comparable flexion and extension motion, indicating relatively more favorable biomechanical performance in both models.

Conclusions: Undersized cervical disc implants significantly alter segmental biomechanics, particularly when placed anteriorly, increasing the risks of subsidence, facet overload, and adjacent segment degeneration.

Keywords: Biomechanics, Cervical disc arthroplasty, Footprint mismatch, Finite element analysis, Implant positioning

S062

Biomechanical Effects of Plate Length and Screw Angulation in Anterior Cervical Discectomy and Fusion: A Finite Element Analysis

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Purpose: Plate length and screw angulation are important surgical variables in anterior cervical discectomy and fusion (ACDF); however, their biomechanical effects on stress distribution and implant-related behavior remain incompletely understood. This study aimed to evaluate the influence of plate length and screw angulation on stress distribution using finite element modeling (FEM).

Materials and Methods: A validated three-dimensional finite element model of the subaxial cervical spine was used to simulate single-level ACDF using a bioactive ceramic cervical cage (NOVOMAX®). Surgical models were constructed with varying plate lengths (short, intermediate, and long) and screw insertion angles, including hyper-angulated and neutral configurations. A physiological loading condition consisting of a 1-Nm pure moment combined with a 50-N follower load was applied during flexion, extension, axial rotation, and lateral bending. Peak von Mises stress (PVMS) was quantified at the cage-endplate interface, screw-bone interface, and implant components to estimate the biomechanical risks of subsidence, screw pull-out, and cage failure.

Results: Plate application consistently reduced PVMS at the cage-endplate interface, indicating lower biomechanical risks of subsidence and cage failure, whereas screw angulation and plate length had minimal influence on cage-related PVMS. In contrast, PVMS at the screw-bone interface was substantially affected by both screw angulation and plate length. Hyper-angulated screw configurations demonstrated lower PVMS than neutral screw insertion, particularly under flexion and extension loading. Longer plates further reduced screw-bone PVMS, suggesting improved resistance to screw pull-out. Changes in screw angulation and plate length did not result in meaningful differences in implant body stress.

Conclusions: Finite element analysis demonstrated that plate application plays a dominant role in reducing cage-related stress in ACDF, whereas screw angulation and plate length primarily influence screw-bone interface stress. Hyper-angulated screws combined with longer plates may provide biomechanical advantages by reducing screw pull-out risk without increasing implant stress. These findings provide biomechanical guidance for optimizing plate-and-screw configurations in ACDF.

Keywords: Anterior cervical discectomy and fusion, Finite element analysis, Plate length, Screw angulation, Cervical spine

S063

Early Experience with Cervical Disc Arthroplasty: Learning Curve, Technical Evolution, and Perioperative Outcomes

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Purpose: Anterior cervical discectomy and fusion (ACDF) remains a standard treatment for cervical degenerative disc disease (DDD). However, concerns regarding loss of motion and adjacent segment degeneration have driven increasing interest in cervical disc arthroplasty (CDA) as a motion-preserving alternative. Although clinical and radiographic outcomes of CDA are well documented, fewer studies have focused on the surgeon learning curve and technical evolution during early adoption. This study aims to characterize the learning curve of a single fellowship-trained spine surgeon performing CDA and to describe technical refinements developed over the first 100 cervical disc levels.

Materials and Methods: A retrospective cohort study was conducted at a single tertiary institution and deemed Institutional Review Board–exempt. The first 100 cervical disc levels treated with CDA by a single surgeon between January 2024 and January 2026 were reviewed. Single-level, multilevel (two- or three-level), and hybrid CDA–ACDF procedures were included. Patient demographics, surgical indications, intraoperative parameters, postoperative outcomes, and imaging findings were analyzed.

Results: Fifty-two patients encompassing 100 cervical disc levels were included. The mean age was 54.4 ± 13.3 years, and radiculopathy was the most common indication. The most frequently treated levels were C5–C6 (38%) and C4–C5 (36%), followed by C6–C7 (16%) and C3–C4 (10%). Procedures included 6 single-level CDAs, 22 two-level CDAs, 9 three-level CDAs, and 15 hybrid procedures. Operative duration increased with procedural complexity but demonstrated a consistent downward trend over successive cases, with operative time decreasing by 54% for two-level CDA and 41.7% for three-level CDA across the study period. Length of stay (LOS) increased with procedural complexity (p=0.011) and was significantly longer in patients with myelopathy compared with those without myelopathy (p=0.015).

Conclusions: Accumulated surgical experience facilitated identification of key technical principles essential for successful CDA, including neutral patient positioning, accurate and parallel Caspar pin placement, meticulous endplate preparation to reduce heterotopic ossification risk, precise midline implant positioning, and implant selection tailored to endplate morphology. Despite increasing procedural complexity, operative efficiency improved over time, demonstrating a measurable learning curve. CDA can be performed safely and with improving efficiency as surgeon experience increases. Adherence to fundamental technical principles and iterative refinement during early adoption may optimize perioperative outcomes. Further studies are warranted to correlate these technical strategies with long-term clinical and radiographic results.

Keywords: Cervical disc arthroplasty, Motion-preserving, Surgical learning curve, Technical evolution, Surgical outcomes

S064

Spontaneous Atlantoaxial Facet Joint Autofusion After Posterior C1–2 Fusion

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Purpose: To determine the incidence of spontaneous facet joint autofusion (SFA) after posterior C1–2 fusion using the Goel–Harms construct and to identify factors associated with SFA development, with particular emphasis on preoperative C1–2 facet osteoarthritis (OA).

Materials and Methods: This retrospective cohort study included 53 consecutive patients (median age, 56.0 years) who underwent posterior C1–2 fusion with the Goel–Harms technique at a single tertiary center and were followed for ≥24 months. All patients underwent computed tomography (CT) and flexion–extension radiographs at 12 months; patients without definite posterior graft union on 12-month CT were re-evaluated at 24 months. Posterior graft union

was defined as continuous trabecular bridging between the C1 posterior arch and C2 lamina on CT. SFA was defined as continuous osseous bridging across the C1–2 facet joint on CT. Stable fibrous union was defined as the absence of osseous union on CT with <2 mm motion on flexion–extension radiographs. Preoperative C1–2 facet OA was graded (1–4) on CT and dichotomized as low-grade (1–2) versus high-grade (3–4). Radiologic and clinical outcomes (NDI, JOA, EQ-5D, improvement rate, pain VAS) were compared between patients with and without SFA.

Results: At 12 months, posterior graft union was present in 35/53 patients (66.0%), whereas 18/53 (34.0%) lacked definite graft union; none demonstrated dynamic instability at 12 or 24 months. SFA was identified in 12/53 patients (22.6%) at 12 months. High-grade preoperative facet OA was strongly associated with SFA (p<0.001), while facet OA grade was not significantly correlated with posterior graft union at 12 or 24 months. Using a composite “fusion” outcome (posterior graft union and/or SFA), 40/53 patients (75.5%) had at least one osseous fusion pathway at 12 months, increasing to 44/53 (83.0%) at 24 months. Both groups demonstrated substantial improvements in NDI, JOA, EQ-5D, and pain VAS, with only small and inconsistent between-group differences.

Conclusions: SFA occurred in approximately one-quarterr of patients after posterior C1–2 fusion and was strongly associated with high-grade preoperative facet OA. SFA represents a clinically relevant “hidden fusion” mechanism that, together with posterior graft union, contributes to postoperative stability and favorable outcomes. CT assessment of the C1–2 facet joints should be incorporated into fusion evaluation after atlantoaxial instrumentation.

Keywords: Atlantoaxial instability, C1–2 fusion, Facet joint osteoarthritis, Spontaneous facet autofusion, CT

S065

Differentiation of Cervical Spondylotic Amyotrophy (CSA) and Amyotrophic Lateral Sclerosis (ALS) Using Electromyography

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Purpose: Cervical spondylotic amyotrophy (CSA) is characterized by muscle weakness and atrophy of the upper limbs without sensory deficits. Because of its clinical features, CSA should be differentiated from amyotrophic lateral sclerosis (ALS). The purpose of this study was to differentiate CSA from ALS using electromyography (EMG).

Materials and Methods: We compared 14 cases of CSA and 13 cases of ALS in which the differential diagnosis was established using EMG findings in patients presenting with symptoms in one upper limb. Although symptoms involved only one upper limb, parameters including bilaterality of abnormal EMG findings, the number of examined motor and sensory nerves, the number of abnormal nerves in motor and sensory conduction studies and needle EMG, paraspinal involvement, somatosensory evoked potentials (SSEP), and motor evoked potentials (MEP) were analyzed.

Results: Bilateral involvement, the number of abnormal nerves in motor and sensory conduction studies, and the proportion of abnormal nerves (%) showed statistically significant differences between CSA and ALS patients. In particular, the number of abnormal nerves in motor conduction studies was more discriminative than that in sensory studies. The optimal cut-off value for differentiation was 3.5 abnormal nerves in motor conduction studies, and the proportion of abnormal motor nerves was approximately 35.4%.

Conclusions: Electromyography is useful for differentiating CSA from ALS.

Keywords: Cervical spondylotic amyotrophy, Amyotrophic lateral sclerosis, Electromyography

Free Paper: Cervical (2)

S066

"Ligamentous Instability" in a Structurally Stable Cervical Spine: A Paradigm Shift in the Mechanism of Dynamic Compression in Degenerative Cervical Myelopathy

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Purpose: Degenerative cervical myelopathy (DCM) is classically conceptualized as a disease driven by static anterior and posterior compressive elements within a structurally "stable" cervical spine. Conventional assessment defines stability by vertebral alignment, absence of translation, and preserved segmental motion. Yet, clinical progression in many radiographically stable patients suggests an unrecognized biomechanical mechanism of neural compromise. This study introduces and characterizes a novel concept—ligamentous instability—wherein the ligamentum flavum (LF) dynamically buckles under physiological axial loading despite intact vertebral stability.

Materials and Methods: Fifty patients with clinically confirmed DCM and fifty age-matched controls with chronic axial neck pain underwent MRI in both supine and upright seated postures using an open MRI platform. Quantitative parameters included disc bulge (DB), ligamentum flavum thickness (LFT), sagittal spinal cord diameter (SSCD), cross-sectional spinal cord area (CCSA), cervical lordosis, and segmental angulation. Standard radiographic criteria confirmed the absence of vertebral or segmental instability in all subjects.

Results: Upright loading revealed marked dynamic posterior encroachment in DCM patients without evidence of vertebral instability. Compared to controls, DCM subjects exhibited greater upright posture–induced changes in DB (38.13% vs. 8.07%) and LFT (25.98% vs. 12.99%), accompanied by reductions in SSCD (14.05% vs. 3.08%) and CCSA (14.45% vs. 3.44%). The most pronounced dynamic stenosis occurred at C3–C4 during extension. Importantly, no pathological translation or angulation indicative of segmental vertebral instability was observed, confirming that LF buckling occurred in a structurally stable spine.

Conclusions: This study identifies ligamentous instability as a previously unrecognized mechanism of dynamic spinal cord compression in DCM. Unlike vertebral or segmental instability, ligamentous instability arises from load-dependent deformation of the LF and persists even when arthrodesis or motion-preserving procedures address anterior pathology. This paradigm challenges existing definitions of cervical stability and underscores the need for posture-sensitive imaging and revised treatment algorithms. Recognition of ligamentous instability may reshape surgical decision-making by highlighting dynamic posterior compression as a driver of disease progression in structurally stable cervical spines.

Keywords: Degenerative cervical myelopathy, Ligamentous instability, Upright MRI, Ligamentum flavum buckling, Dynamic spinal cord compression

S067

Long-Term Reoperation Risk After Cervical Artificial Disc Replacement (ADR) Versus ACDF: A Nationwide Cohort Study of Over 120,000 Patients from 2010 to 2023

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Purpose: Anterior cervical discectomy and fusion (ACDF) and cervical artificial disc replacement (ADR) are two commonly used anterior surgical techniques for treating degenerative cervical spine disease. ACDF has long been the standard surgical treatment; however, fusion-related complications—particularly adjacent segment disease—have prompted increasing use of ADR. Despite the theoretical motion-preserving advantages of ADR, long-term comparative data on reoperation risk remain inconsistent.

May 21 (Thu) Crystal Ballroom (2F) Room B

Materials and Methods: Using nationwide claims data from South Korea's Health Insurance Review and Assessment Service (HIRA), this retrospective cohort study identified all single- and multi-level ACDF and ADR procedures performed between 2010 and 2023. The primary endpoint was any cervical reoperation identified using additional procedural codes. Each patient was followed from the date of the index surgery until reoperation or the end of the study period (December 2023). Kaplan–Meier survival analyses and multivariable Cox proportional hazards models were used to compare reoperation risks, adjusting for age, sex, comorbidity burden, number of operated levels, hospital type, and history of psychiatric illness, diabetes, or osteoporosis. Subgroup analyses were performed based on age, sex, comorbidity burden, and number of operated levels.

Results: A total of 95,820 ACDF and 26,176 ADR patients were included. Over a median follow-up of 6.9 years (IQR, 3.2–10.5 years), 5,955 ACDF patients (6.21%) and 1,352 ADR patients (5.17%) underwent reoperation. Kaplan–Meier analysis demonstrated significantly lower cumulative reoperation incidence in the ADR group at 1-, 5-, and 10-year intervals (p<0.01). In multivariable Cox regression analysis, ADR was independently associated with a reduced risk of reoperation compared with ACDF (HR=0.905, 95% CI 0.850–0.963, p=0.0015). Subgroup analyses showed that the protective effect of ADR was most pronounced in patients younger than 50 years, those with a low comorbidity burden, and those undergoing multi-level procedures. Within the ACDF group, multi-level procedures were associated with a significantly higher reoperation risk compared with single-level procedures, whereas in the ADR group, reoperation risk did not differ between single- and multi-level cases. Male sex, multi-level surgery, higher comorbidity burden, psychiatric illness, diabetes, and osteoporosis were independently associated with increased reoperation risk.

Conclusions: ADR demonstrated a durable reduction in reoperation risk compared with ACDF, particularly among younger, healthier individuals and those undergoing multi-level procedures. These findings support ADR as a safe, motion-preserving alternative in appropriately selected patients.

Keywords: Artificial disc replacement, Anterior cervical discectomy and fusion, Long-term outcomes, Reoperation rate, Claims data

S068

Selecting the Distal Fusion Level in Multilevel Posterior Cervical Fusion: Impact of C7–T1 Junctional Mobility on Postoperative Malalignment

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Purpose: To identify preoperative risk factors affecting postoperative sagittal malalignment in patients undergoing multilevel posterior cervical fusion.

Materials and Methods: A total of 111 consecutive patients with cervical myelopathy who underwent multilevel posterior cervical fusion with a minimum follow-up of 2 years were included. Clinical outcomes were assessed using the subjective improvement rate, neck pain visual analog scale (VAS), arm pain VAS, Neck Disability Index (NDI), and Japanese Orthopaedic Association score. Radiological outcomes included C1–2 lordosis, C2–7 lordosis, C2–7 sagittal vertical axis (SVA), and T1 slope on lateral cervical spine radiographs. The difference in distance between the spinous processes of C7–T1 and the segmental angle at C7–T1 were measured on flexion and extension radiographs. Patients were grouped according to postoperative C2–7 SVA (≤40 mm vs >40 mm). Group comparisons were performed using t-tests (Welch's correction when appropriate). A prespecified multivariable logistic regression model was used to identify predictors of postoperative C2–7 SVA >40 mm. Model calibration (Hosmer–Lemeshow test) and discrimination (ROC-AUC) were assessed.

Results: Postoperative malalignment (C2–7 SVA >40 mm) occurred in 26 of 111 patients (23.4%). Preoperatively, C2–7 SVA was significantly higher in the >40 mm group (29.08±11.77 vs 18.56±12.37 mm; p<0.001). Flexion–extension difference (FE Diff) was also greater in the >40 mm group (6.25±3.22 vs 4.58±2.96 mm; p=0.015). At 2 years, NDI was lower in the ≤40 mm group (9.64±7.83 vs 13.73±9.78; p=0.030). In multivariable analysis, older age (OR 1.091 per year; 95% CI 1.024–1.163; p=0.007), larger preoperative C2–7 SVA (OR 1.067 per mm; 95% CI 1.021–1.116; p=0.003), and greater FE Diff (OR 1.217 per mm;

95% CI 1.036–1.429; p=0.018) were independent predictors of postoperative malalignment. Using a prespecified probability threshold of p ≥ 0.35, sensitivity was 69.2% and specificity was 87.1%.

Conclusions: A hypermobile C7–T1 segment is an important preoperative risk factor for postoperative sagittal malalignment following multilevel posterior cervical fusion.

Keywords: Cervical spine, Cervical myelopathy, Cervical sagittal alignment, Posterior cervical fusion, Sagittal vertical axis

S069

Does Laminoplasty Provide Better Outcomes Compared with Anterior Cervical Discectomy and Fusion for Patients with Spinal Canal–Cord Mismatch?

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Purpose: Spinal canal–cord mismatch (SCCM), characterized by a relatively large spinal cord within a narrow cervical spinal canal, is commonly observed in congenital cervical stenosis and has traditionally been considered an indication for posterior decompression such as laminoplasty. However, recent evidence suggests that anterior cervical discectomy and fusion (ACDF) may also provide sufficient decompression in selected patients. The purpose of this study was to compare clinical outcomes between ACDF and laminoplasty in patients with SCCM treated for cervical myelopathy.

Materials and Methods: We retrospectively reviewed 340 patients who underwent surgery for cervical myelopathy with a minimum follow-up of 2 years, including 188 treated with ACDF and 152 treated with laminoplasty. Among them, 61 patients with SCCM, defined as a spinal cord occupancy ratio (SCOR) ≥70%, were included (ACDF, n=39; laminoplasty, n=22). Baseline characteristics, operative details, and radiographic parameters, including C2–C7 sagittal vertical axis (SVA) and C2–C7 lordosis, were collected. Clinical outcomes were assessed using neck and arm pain visual analog scale (VAS) scores and the Japanese Orthopaedic Association (JOA) score. Intergroup comparisons were performed, and linear regression analysis was used to identify predictors of JOA recovery.

Results: The ACDF group underwent fewer operated levels than the laminoplasty group (1.8 vs. 3.8 levels, p<0.001). Preoperatively, C2–C7 lordosis was smaller in the ACDF group (10.8° vs. 16.6°, p=0.023), whereas SCOR and SVA were similar between groups. At the 2-year follow-up, both groups demonstrated significant clinical improvement. There were no significant differences between the ACDF and laminoplasty groups in postoperative neck pain VAS (1.7 vs. 2.2, p=0.467), arm pain VAS (2.7 vs. 3.5, p=0.263), or JOA score (15.0 vs. 14.7, p=0.542). The JOA recovery rates were also comparable (44.1% vs. 42.2%, p=0.901). Linear regression analysis showed that neither surgical approach nor SCOR was a significant predictor of JOA recovery.

Conclusions: In patients with SCCM, both ACDF and laminoplasty resulted in significant neurological and symptomatic improvement, with no significant difference in JOA recovery or patient-reported outcomes. These findings suggest that ACDF is a clinically viable alternative to laminoplasty in selected SCCM patients when the number of involved levels, sagittal alignment, and compression morphology are favorable. This challenges the traditional assumption that posterior decompression is inherently superior in SCCM and underscores the importance of individualized surgical decision-making.

Keywords: Congenital stenosis, Spinal canal–cord mismatch, Anterior cervical discectomy and fusion, Laminoplasty

S070

Radiological and Clinical Importance of Lamina Hinge Fractures After Open-Door Cervical Laminoplasty: A Propensity Score–Matched Study

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Purpose: Although several studies have investigated the clinical outcomes of laminoplasty hinge fractures, no well-

designed study involving a large, consecutively enrolled patient cohort has comprehensively evaluated both clinical and radiological outcomes. Therefore, this study aimed to evaluate the clinical and radiological significance of hinge fractures in a relatively large, consecutively enrolled cohort using a propensity score–matched retrospective design.

Materials and Methods: Patients who underwent laminoplasty and were followed for at least 2 years were included. Hinge fractures were assessed using immediate and 1-year postoperative computed tomography (CT). Patients with immediate postoperative hinge fractures were classified into the HF (+) group. The hinge without fracture [HF (−)] group was established using 1:2 propensity score matching. Radiological and clinical outcomes were compared between the groups preoperatively and at 6 months and 2 years postoperatively.

Results: Among 204 patients, 40 (19.6%) were included in the HF (+) group. Through 1:2 propensity score matching, 80 patients were assigned to the HF (−) group. Compared with the HF (−) group, the HF (+) group included a higher proportion of male patients and demonstrated larger preoperative C2 sagittal vertical axis (SVA). Additionally, the HF (+) group exhibited lower C2–C7 lordosis, larger C2 SVA, and greater C2–C7 flexion capacity at 2 years postoperatively. The neck pain visual analog scale score was higher in the HF (+) group at 6 months, but no difference was observed at 2 years postoperatively. Of 49 fractures in the HF (+) group, 40 (81.6%) achieved union, as assessed on 1-year postoperative CT.

Conclusions: Hinge fractures following laminoplasty occurred primarily in male patients and in those with larger preoperative C2 SVA. These patients exhibited relatively kyphotic changes postoperatively and experienced early postoperative neck pain. These findings suggest that particular attention should be paid to avoiding laminar hinge fractures during laminoplasty.

Keywords: Laminoplasty, Hinge fracture, Kyphosis, Neck pain, Union

Free Paper: Cervical (3)

S071

Outcomes of Selective Laminectomy for Cervical Myelopathy in Khanh Hoa General Hospital

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Purpose: To evaluate the effectiveness of selective laminectomy (SL) in treating cervical myelopathy (CM), focusing on spinal cord recovery (JOA recovery rate), axial neck pain (ANP) (VAS score), and cervical alignment (C2–C7 angle).

Materials and Methods: A total of 35 patients with CM underwent SL. Spinal cord recovery was evaluated using the Japanese Orthopaedic Association (JOA) score, while ANP and cervical alignment were measured preoperatively and at the final follow-up.

Results: The cohort included 24 males and 11 females, with a mean age of 57.0±11.9 years. The average number of levels treated was 3.0±0.6. The mean follow-up duration was 59 months (range, 2–158 months). Preoperatively, 10 patients (28.6%) experienced ANP with a mean VAS score of 1.5±2.8 cm. At the final follow-up, 5 patients (14.3%) still had ANP, with a mean VAS score of 0.3±0.7 cm. The reduction in pain was statistically significant ($p<0.01$), with no new or worsened ANP reported. Mean preoperative and postoperative JOA scores improved significantly from 10.0±2.8 to 14.1±1.8 ($p<0.01$), with a mean JOA recovery rate of 58.7±25.9%. Radiographic evaluation (14 patients) showed no evidence of new kyphosis.

Conclusions: SL, which preserves deep cervical extensor muscles and facet joints, is an effective surgical approach for CM, providing significant neurological improvement and reduced postoperative ANP, while potentially preventing kyphotic deformity.

Keywords: Cervical myelopathy, Selective laminectomy, JOA score, Axial neck pain, Kyphotic deformity

S072

Correlation Between Clinical Outcomes and Electromyography in Proximal-Type Cervical Spondylotic Amyotrophy Treated with ACDF with Total Uncinectomy

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Purpose: Cervical spondylotic amyotrophy (CSA) is characterized by upper limb muscle weakness and atrophy without sensory deficits. CSA is commonly classified into two subtypes according to the predominantly affected muscles: a proximal type, involving the scapular muscles, deltoid, and biceps, and a distal type, affecting the triceps, forearm muscles, and intrinsic hand muscles.

Materials and Methods: We compared electromyographic (EMG) findings and clinical outcomes in 14 cases of proximal-type CSA. Variables analyzed included symptom duration, preoperative manual muscle testing (MMT), number of stenotic levels, EMG amplitude and latency, follow-up duration, changes in MMT, and patient satisfaction.

Results: The mean follow-up duration was 36.3 months. Mean values were as follows: symptom duration, 14.89 weeks; preoperative MMT, 3.07; number of stenotic levels, 2; EMG amplitude decrease ratio, 43% for the axillary nerve and 44% for the musculocutaneous nerve; latency increase ratio, 28% for the axillary nerve and 25% for the musculocutaneous nerve. The mean follow-up MMT improved to 4.64. Surgical outcomes were excellent in 12 patients (85.7%), good in 1 (7.1%), and fair/poor in 1 (7.1%). Mean patient satisfaction was 8.71. Factors influencing MMT improvement included preoperative MMT and the presence of C5 involvement on EMG. In patients with C5 involvement (n=11), preoperative MMT and absence of central canal stenosis were significantly associated with MMT improvement.

Conclusions: In patients with CSA, surgical intervention may be considered even in cases with low preoperative MMT. In patients with C5 involvement on EMG, ACDF with total uncinectomy may be a reasonable surgical option.

Keywords: Cervical spondylotic amyotrophy, Electromyography, Clinical outcomes, ACDF, Uncinectomy

S073

Beyond the Cage: Autologous Sternal Bone Marrow Aspirate as a Biological Determinant of Success in Anterior Cervical Discectomy and Fusion: A Comparative Study with 2-year Follow-up

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Purpose: Pseudarthrosis remains a significant complication of anterior cervical discectomy and fusion (ACDF). Autologous bone marrow aspirate (BMA) is a rich source of osteoprogenitor cells that may enhance fusion; however, robust comparative data on its efficacy in modern ACDF constructs remain limited. This study aimed to determine whether augmenting a standard ACDF construct with BMA improves radiographic and clinical outcomes.

Materials and Methods: This single-center retrospective cohort study included 84 patients (186 levels) who underwent ACDF with a standalone cage and local autograft. Patients were divided into two cohorts: the BMA group (n=44), which received additional sternal BMA–infused gelatin sponge, and the non-BMA group (n=40). The primary outcome was radiographic fusion assessed by a blinded neuroradiologist. Secondary outcomes included patient-reported pain (VAS) and functional status (JOA score), collected preoperatively and at 6, 12, and 24 months postoperatively.

Results: The BMA group demonstrated significantly higher fusion rates at 6 months (80.6% vs. 66.3%, p=0.020), 12 months (88.3% vs. 78.3%, p=0.009), and 24 months (93.2% vs. 85.5%, p=0.006). Clinically, the BMA group reported significantly lower VAS neck and arm pain scores and higher JOA scores at the 12- and 24-month follow-ups (p<0.05 for all comparisons).

Conclusions: The addition of sternal BMA to a standard ACDF construct significantly improves both radiographic fusion rates and patient-reported clinical outcomes at 2-year follow-up. Given its low morbidity and significant benefits,

BMA should be considered a valuable biological adjunct in ACDF surgery.

Keywords: Orthobiologics, Bone marrow aspirate, Pseudarthrosis prevention, Stem cell therapy, Radiographic fusion

S074

Does Adding Uncovertebral Foraminotomy to Anterior Cervical Discectomy and Fusion Improve Patient Outcomes? A 5-Year Propensity Score–Matched Analysis of MCID and Mechanical Complications

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Purpose: This study aimed to evaluate whether adding uncovertebral foraminotomy (UVF) to anterior cervical discectomy and fusion (ACDF) affects long-term patient outcomes, specifically the achievement of the minimum clinically important difference (MCID) and the incidence of mechanical complications over a minimum 5-year follow-up.

Materials and Methods: From a cohort of 253 patients who underwent one- to three-level ACDF between 2006 and 2020, a propensity score–matched (PSM) analysis was performed. Patients were matched 1:1 into UVF (n=85) and non-UVF (n=85) groups based on age, sex, BMI, bone quality (CT Hounsfield units), and number of surgical levels. Outcome measures included the Neck Disability Index (NDI), visual analog scale (VAS) for neck and arm pain, and radiographic parameters including pseudarthrosis, cage subsidence, and loss of lordosis. Both absolute and relative MCID achievement rates were analyzed.

Results: In the matched cohort, NDI and neck pain VAS showed no significant differences between groups at any time point. The UVF group demonstrated higher arm pain VAS at 2 years compared with the non-UVF group (3.54±2.91 vs. 2.35±2.57; p=0.006), but this difference was not significant at the final follow-up. No significant differences were observed in MCID achievement rates across all clinical outcomes. Radiographically, C2–C7 lordosis and sagittal vertical axis (SVA) were comparable between groups. Although overall mechanical complication rates were similar, subgroup analysis revealed that bilateral UVF was associated with a higher incidence of pseudarthrosis compared with the non-UVF group (17.9% vs. 5.5%; p=0.017).

Conclusions: Adding UVF to ACDF does not confer additional long-term clinical benefits or improve MCID achievement. Furthermore, it may increase early postoperative arm pain and the risk of pseudarthrosis, particularly when performed bilaterally. Surgeons should carefully weigh the potential for increased mechanical complications against the lack of long-term clinical superiority when considering UVF.

Keywords: Anterior cervical discectomy and fusion, Uncinate process, Foraminotomy, Pseudarthrosis

S075

Hidden Cervical Myelopathy Presenting Predominantly with Gait Disturbance Despite Moderate Radiologic Compression: A Case Series

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Purpose: Degenerative cervical myelopathy is a common cause of progressive neurological impairment resulting from cervical spinal cord compression. Magnetic resonance imaging (MRI) plays a central role in treatment decision-making; however, the severity of radiologic compression does not always correlate with clinical presentation. In some patients, significant functional impairment may be present despite relatively subtle or moderate imaging findings, creating diagnostic uncertainty and potentially delaying appropriate intervention.

Materials and Methods: We retrospectively reviewed a consecutive case series of three patients who underwent anterior cervical discectomy and fusion (ACDF) for

clinically significant cervical myelopathy. All patients demonstrated meaningful preoperative gait disturbance, whereas typical upper extremity myelopathic symptoms such as hand clumsiness or fine motor dysfunction were absent or minimal. In all cases, alternative causes of dizziness and gait disturbance were systematically evaluated and excluded. All patients demonstrated concomitant grade 1 retrolisthesis at the affected cervical level. In two cases, flexion and extension MRI was performed to assess dynamic instability; however, no significant dynamic aggravation of spinal cord compression was identified. On static MRI, all three cases demonstrated moderate cervical spinal cord compression. Comprehensive preoperative assessment supported cervical myelopathy as the primary etiology in all patients.

Results: ACDF was successfully performed in all cases, achieving adequate decompression of the cervical spinal cord, restoration of cervical lordosis, and stable fixation confirmed on postoperative imaging. No intraoperative or postoperative complications occurred. All patients demonstrated marked postoperative improvement in gait function, and follow-up imaging confirmed effective spinal cord decompression.

Conclusions: This case series highlights the concept of hidden cervical myelopathy, in which gait disturbance may represent the predominant or initial clinical manifestation despite the absence of prominent upper extremity symptoms. Even in the setting of moderate static cord compression and without clear dynamic worsening on flexion–extension imaging, clinically meaningful myelopathy may be present. Reliance on imaging severity alone may underestimate disease significance, and careful clinical assessment with exclusion of non-cervical causes can guide timely surgical intervention and lead to favorable functional outcomes.

Keywords: Hidden cervical myelopathy, Degenerative cervical myelopathy, Gait disturbance, Anterior cervical discectomy and fusion

Invited Lecture II

S076

Dropped Head Syndrome: Current Advances in Diagnosis and Treatment

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Dropped head syndrome (DHS) is considered to arise from a variety of etiologies, including neurogenic, myogenic, inflammatory, metabolic, and iatrogenic causes, and isolated neck extensor myopathy (INEM). However, there have been few comprehensive reports, and many aspects of its pathophysiology and treatment strategies remain unclear. We have experienced more than 700 cases of DHS to date.

In treatment, priority should first be given to managing the underlying causative disease, and conservative treatment consisting mainly of orthotic therapy, pharmacological treatment, and physical therapy is generally considered the first-line approach. Based on various analyses, we developed a rehabilitation program specifically effective for DHS, namely the short and intensive rehabilitation (SHAiR) program, and have incorporated it into clinical practice with favorable outcomes.

On the other hand, for patients who are resistant to at least three months of conservative treatment, those with progressive myelopathy, or those with severe dropped head resulting in difficulty with oral intake, we actively perform surgical treatment with thorough informed consent.

In this lecture, we will present our various research findings and treatment strategies for DHS based on our clinical experience.

Keywords: Dropped head syndrome (DHS), Clinical manifestation, SHAiR program, Conservative treatment, Surgical procedures

Asian Spine Society Session II

S077

Spine Tuberculosis Surgery: Not Just an Easy Case (Combine Meta-Analysis)

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Purpose: An appropriate surgical approach for spinal tuberculosis is essential to achieve favorable outcomes. However, the optimal surgical strategy—whether anterior-only or posterior-only—remains controversial. This study aimed to compare clinical outcomes between anterior and posterior surgical approaches through a combined analysis of institutional experience and a meta-analysis.

Materials and Methods: This study combined retrospective clinical experience with a systematic review and meta-analysis. Institutional data included patients who underwent spinal tuberculosis surgery with postoperative follow-up ranging from 1 to 5 years, with evaluation of pain (VAS) and clinical outcomes. The meta-analysis protocol was registered in PROSPERO (CRD42023458454). Comprehensive electronic database searches were conducted in PubMed, ScienceDirect, and Scopus. Study quality was assessed using the ROBINS-I tool and the Newcastle–Ottawa Scale (NOS). Meta-analysis was performed to compare Visual Analog Scale (VAS), Oswestry Disability Index (ODI), intraoperative blood loss, and length of hospital stay. Subgroup analyses were conducted for pediatric and adult populations, as well as for comparative studies and randomized controlled trials (RCTs). This systematic review followed PRISMA guidelines.

Results: The initial search identified 779 articles (768 from databases and 11 from other sources), of which 11 studies were included in the meta-analysis. Meta-analysis results demonstrated significant improvements in both approaches. For VAS, anterior approach pre- versus postoperative change was −4.15 (95% CI, −5.13 to −3.17), and posterior approach change was −4.49 (95% CI, −5.77 to −3.21). For ODI, anterior approach change was −23.16 (95% CI, −28.24 to −18.08), and posterior approach change was −25.38 (95% CI, −30.61 to −20.14). Length of hospital stay showed no significant difference between approaches, whereas blood loss was higher in the posterior approach (mean difference, 83.54; 95% CI, 9.75–157.33). Kyphotic correction (Cobb angle) was greater in the posterior approach. In addition, systematic review findings indicated differences in postoperative complication profiles between the two approaches. Institutional clinical data demonstrated similar trends.

Conclusions: The posterior approach appears to provide superior radiological correction and comparable or better clinical outcomes compared with the anterior approach in spinal tuberculosis surgery. However, surgical decision-making should be individualized based on patient characteristics and disease severity.

Keywords: Spinal tuberculosis, Anterior approach, Posterior approach, Spine surgery

S078

High-Grade Spondylolisthesis: What Are the Options Available?

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High-grade spondylolisthesis (Meyerding grades III, IV, and spondyloptosis) typically requires surgical intervention due to the risk of slip progression and symptoms such as increasing pain or neurological deficits.

The surgical techniques and approaches vary depending on age, sagittal balance, and the surgeon's expertise. Reduction in high-grade spondylolisthesis improves sagittal alignment, fusion rates by increasing contact area, and overall patient satisfaction; however, it also carries higher risks of neurological complications (e.g., L5 nerve deficit), increased blood loss, longer operative time, and implant failure. Instrumented in situ fusion has been described as an effective alternative method with comparable results.

The current presentation describes the pros and cons of posterior techniques, including reduction and in situ fusion, for high-grade spondylolisthesis.

S079

Safe Surgery in Spinal Deformity

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Surgical correction of spinal deformity is a complex procedure associated with significant risks, including neurological injury, excessive blood loss, and implant-related complications. Ensuring patient safety requires meticulous preoperative planning, careful intraoperative techniques, and comprehensive postoperative care. Preoperative evaluation should include detailed clinical assessment, radiological analysis, and optimization of comorbid conditions to minimize perioperative risks. The use of advanced imaging, three-dimensional planning, and assessment of sagittal and coronal balance helps in accurate surgical strategy formulation.

Intraoperatively, neuromonitoring techniques such as somatosensory and motor-evoked potentials play a critical role in early detection of neurological compromise. Modern surgical technologies, including navigation systems, improved instrumentation, and blood conservation strategies, further enhance safety and accuracy. Staged procedures, when appropriate, can reduce operative time and physiological stress in complex deformity corrections. Additionally, adherence to standardized surgical protocols and a multidisciplinary team approach contributes to better outcomes.

Postoperative management focuses on early mobilization, effective pain control, and close monitoring for complications such as infection, implant failure, and neurological deficits. With advances in surgical techniques and perioperative care, spinal deformity surgery can be performed safely with improved functional outcomes and quality of life. Continuous evaluation of surgical protocols and incorporation of evidence-based practices remain essential to further enhance safety in spinal deformity surgery.

S080

Outcome Study of Anterior Debridement and Instrumentation in Subaxial Cervical Spinal Tuberculosis

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Background: In Myanmar, TB is one of the major public health problems and is ranked second among priority diseases in the National Health Plan. In high prevalence countries, where the load of tuberculosis cases is significant, Myanmar is one of the 22 high-burden countries that account for 80% of the world's new tuberculosis cases. Although tuberculosis of the cervical spine is rare, the quality of life is very disastrous for the patient and the family because of quadriplegia. Therefore, treatment is very important for the patient to restore normal life. Surgery should be reserved for those patients who have advanced tuberculosis with unacceptable complications such as paraplegia or deformity. We would like to share our experience of eighteen patients with tuberculosis of the cervical spine who were treated with anterior debridement, bone graft and instrumentation.

Materials and Methods: In this study, a total of 18 patients with subaxial cervical tuberculosis involving fewer than three consecutive disc levels were treated with anterior debridement, bone graft and instrumentation, and the procedure was performed by a single surgeon. A review of the demographic data, medical records, and X-rays before and after surgery and at subsequent follow-ups was performed prospectively.

Results: Neurological improvement assessed with mJOA score at 1-year follow-up was seen in all 18 patients (17 patients were severe mJOA score marks and 1 was moderate mJOA score at preoperative time). The kyphotic degree at presentation ranged from −10 to 5 degrees with an average

kyphosis of −3.3. The average kyphotic correction at 1-year final follow-up was found to be −2 to 20 degrees (i.e., a mean correction of 11 degrees). All operated segments with bone graft and instrumentation were fused, with bridging trabecular bone seen on computed tomography of the cervical spine.

Conclusions: Advantages of this surgical treatment are early healing by extirpation of the infected focus, histological confirmation of disease activity, shortening of chemotherapy, reduction of late recurrence rates, correction and/or prevention of deformity and early effective neurological recovery in this study.

Level of Evidence: 4

Keywords: Tuberculosis, Subaxial cervical spine, Anterior cervical debridement and instrumentation

Symposium II. Cervical: Comprehensive Management of Multilevel Cervical Foraminal Stenosis

S081

The Diagnostic Challenge: Identifying Symptomatic Levels in Multilevel Cervical Foraminal Stenosis

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Purpose: To review and synthesize the current evidence on identifying the symptomatic level in patients with multilevel cervical foraminal stenosis, and to propose a layered diagnostic strategy that integrates clinical examination, imaging, electrodiagnostic studies, and selective nerve root block (SNRB) for accurate level localization prior to surgical decision-making.

Materials and Methods: A focused literature review was conducted on the diagnostic performance of (1) symptom distribution and pain drawings, (2) the bedside neurological examination, (3) magnetic resonance imaging including oblique sagittal grading systems, (4) electrodiagnostic studies, and (5) SNRB in patients with cervical radiculopathy and multilevel degenerative disease. Studies correlating each diagnostic modality with surgically or block-confirmed symptomatic levels and with postoperative outcomes were prioritized.

Results: Each modality used in isolation has substantial limitations. Up to 87% of asymptomatic individuals show degenerative cervical MRI findings, and the maximal grade of foraminal stenosis does not correlate with symptom severity or laterality in multilevel disease. Pain drawings agree with MRI in only 31%, and the bedside neurological examination shows specificity of 98–99% but sensitivity of 7–14%. Sensory territories of C6 and C7 overlap nearly completely. Region-specific scapular pain (suprascapular for C5/C6, interscapular for C7/C8, scapular for C8) provides a useful clinical clue. SNRB corresponded to the most severely stenotic MRI level in only 60% of two-level disease and to the dermatomal pattern in only 28%; when surgery was guided by SNRB findings, 82–100% of patients achieved good or excellent outcomes, including those operated at a level discordant with imaging.

Conclusions: In multilevel cervical foraminal stenosis, no single diagnostic modality reliably identifies the symptomatic level. A layered strategy combining careful history with attention to scapular pain distribution, focused neurological examination, oblique sagittal MRI grading, selective electrodiagnostic studies, and SNRB in equivocal cases offers the most accurate level localization and reduces the risk of unnecessary multilevel surgery.

Keywords: Cervical radiculopathy, Selective nerve root block, Foraminal stenosis, Electrodiagnostic study, Pain drawing

S082

Posterior Cervical Foraminotomy: How to Get Enough Decompression and Reduce Complications

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Purpose: Posterior cervical foraminotomy (PCF) is a motion-preserving alternative to anterior cervical discectomy and fusion for unilateral cervical radiculopathy. Three

contemporary approaches—open microscopic, uniportal endoscopic, and biportal endoscopic PCF—are now widely employed. This lecture reviews how to achieve sufficient decompression while minimizing complications such as foraminal restenosis, kyphotic deformity, and loss of motion.

Materials and Methods: A focused literature review was performed comparing the three contemporary PCF techniques with respect to surgical trajectory, extent of facetectomy, decompression adequacy, sagittal alignment, range of motion (ROM), and foraminal restenosis. Recent comparative studies, including the presenter's own series, were synthesized to derive practical principles.

Results: All three approaches yield comparable clinical improvement, but the surgical trajectory differs meaningfully. Endoscopic approaches—both uniportal and biportal—permit an inclinatory route to the foramen, allowing greater facet preservation than the more vertical microscopic trajectory (Kim JY et al., Neurospine 2022; Jung JW et al., Eur Spine J 2025). However, the approach alone does not guarantee success: decompression must extend across the full anatomic extent of the foraminal pathology to prevent incomplete relief. Conversely, overly aggressive bone removal carries its own risk—Lee DH et al. (Global Spine J 2023) demonstrated that greater intraoperative foramen widening is associated with more postoperative bony bridging and foraminal restenosis. Choi JU et al. (Spine J 2026) re-examined the classical 50% facetectomy threshold and reaffirmed that excessive resection compromises segmental stability. Lee S et al. (J Neurosurg Spine 2026) further showed that patients with narrow preoperative foraminal height (<6 mm) had higher revision rates and inferior NDI improvement, suggesting alternative strategies in this subset. From the presenter's work, when the functional Spurling phenomenon is adequately resolved by sufficient decompression, functional kyphosis is corrected and cervical lordosis is well maintained postoperatively (Lee HR et al., J Neurosurg Spine 2023). Postoperative segmental ROM reduction, when it occurs, correlates with high preoperative flexion ROM, advanced disc degeneration, and bony bridge formation (Lee DH, Lee HR et al., Medicina 2024).

Conclusions: Successful PCF requires (1) selecting an approach matched to the lesion location, favoring an inclinatory endoscopic trajectory whenever feasible; (2) ensuring that decompression spans the entire foraminal pathology rather than relying on approach alone; (3) limiting facetectomy to preserve segmental stability; and (4) recognizing patient-specific risk factors such as narrow foraminal height and advanced disc degeneration. Adherence to these principles maximizes decompression while minimizing restenosis, kyphosis, and motion loss.

Keywords: Cervical spine, Cervical radiculopathy, Posterior cervical foraminotomy, Endoscopy, Decompression

S083

When Decompression Alone Is Not Enough: Practical Indications for Fusion

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Background: Multilevel cervical foraminal stenosis spans a wide pathological spectrum, ranging from posterolateral soft-disc herniation to bony uncovertebral hypertrophy with vertical foraminal collapse. Motion-preserving decompression — posterior cervical foraminotomy (PCF) or total disc replacement (TDR) — has gained popularity, yet a meaningful subset of patients fares significantly better with anterior cervical discectomy and fusion (ACDF). Recognizing these patients preoperatively is essential to avoid inadequate decompression, residual motor deficit, and unplanned reoperation.

Discussion: Six clinical scenarios consistently favor fusion over decompression alone.

1. Vertically narrow foramina (foraminal height 〈6 mm)

This morphology reflects predominantly bony stenosis from uncovertebral spurs and disc collapse. PCF cannot widen the foramen vertically, whereas ACDF restores foraminal height through disc-space distraction. A 2026 Spine Journal study showed that in this subset, PCF was associated with significantly worse two-year arm and neck pain (p=0.036; p=0.004), and 100% of PCF revisions occurred at the index level due to recurrent radiculopathy.

2. Severe preoperative motor weakness (≤III/V)

Posterior decompression alone yields incomplete recovery in this group, with only 63% achieving normalization of strength at 24 months in published series. More

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complete anterior decompression with structural support is mechanistically and clinically superior.

3. Anticipated extensive facetectomy (≥50%)

When wide facet resection is anatomically required for adequate root decompression, 67% of patients develop spontaneous bone-bridge formation, silently undermining the motion-preservation rationale. Controlled instrumented fusion is more honest in this setting.

4. Regional kyphosis (〉13°) or segmental instability

These conditions mandate fusion to prevent failure of posterior decompression, restore sagittal alignment, and arrest progressive deformity.

5. Post-PCF restenosis or recurrent radiculopathy

Foraminal narrowing of ≥20% develops in approximately 30% of patients after PCF, often with index-level symptom recurrence; conversion to or primary ACDF is appropriate in such patients.

6. Hybrid surgery (CDA+ACDF) within mixed multilevel pathology

When fusion is necessary at one level only, contemporary practice places arthroplasty cranially and ACDF caudally in 96% of constructs. This configuration reduces superior adjacent-segment burden, leverages the natural rigidity of C7–T1, and matches the anatomical reality that bony foraminal stenosis predominates at C5–6 and C6–7.

Take-Home Message

Surgical strategy in multilevel cervical foraminal stenosis should be pathology-driven, not approach-driven. Fusion, when correctly indicated by foraminal morphology, neurological severity, alignment, stability, and the anticipated extent of decompression, is not the failure of motion preservation — it is the right operation for the right patient.

Keywords: Cervical radiculopathy, Foraminal stenosis, Fusion, Multilevel pathologies

S084

Can Total Disc Replacement Still Serve as a Therapeutic Alternative for Multi-Level Cervical Foraminal Stenosis?

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Purpose: Cervical disc arthroplasty (CDA) has accumulated robust Level I evidence supporting its non-inferiority and increasing superiority over anterior cervical discectomy and fusion (ACDF) for one- and two-level degenerative disc disease, with 10-year follow-up data confirming durable clinical benefit, preserved segmental motion, and lower rates of secondary surgery at index and adjacent levels. The role of CDA in multi-level cervical foraminal stenosis, however, remains less clearly defined. Foraminal stenosis frequently involves uncovertebral hypertrophy, posterolateral osteophytes, and facet arthrosis—pathologies that challenge the premise of motion preservation and demand thorough decompression that may extend beyond the standard arthroplasty corridor. In this setting, posterior cervical foraminotomy (PCF) offers direct decompression while preserving motion, and represents the principal motion-preserving alternative to CDA. This lecture critically appraises whether CDA can still be regarded as a legitimate therapeutic alternative in this specific setting.

Materials and Methods: A focused review of pivotal randomized controlled trials, long-term prospective cohort studies, and meta-analyses pertaining to two-level and selected multi-level CDA was conducted, with emphasis on patient cohorts in which radiculopathy from foraminal pathology was the dominant indication. Outcome measures of interest included Neck Disability Index, visual analog scale scores, segmental range of motion, heterotopic ossification, and reoperation rates at index and adjacent levels.

Results: Two-level CDA demonstrates statistically superior overall success and lower secondary surgery rates compared with two-level ACDF through 10-year follow-up, with maintained segmental motion and acceptable rates of clinically significant heterotopic ossification. Reported

outcomes for selected three-level constructs remain favorable but are derived from smaller, lower-level evidence. Successful application in foraminal stenosis appears contingent on preserved segmental mobility, absence of significant facet arthropathy or bridging osteophytes, adequate disc height, and the technical feasibility of complete uncovertebral resection without compromising prosthesis stability. In contrast, advanced facet arthrosis, segmental immobility, or extensive uncovertebral bridging osteophytes consistently emerge as predictors of suboptimal outcome and should be regarded as relative contraindications. Comparative cohort studies of CDA and PCF report broadly similar short- to mid-term clinical outcomes for unilateral radiculopathy, with no high-level evidence establishing superiority of either procedure in multi-level foraminal pathology.

Conclusions: CDA retains a defensible, evidence-based role in multi-level cervical foraminal stenosis, but only within strict patient selection criteria. In suboptimal candidates, fusion-based or posterior decompressive strategies remain the safer default. Surgical judgment in patient selection ultimately determines whether motion preservation translates into clinical benefit.

Keywords: Cervical vertebrae, Spinal stenosis; Radiculopathy, Total disc replacement, Foraminotomy

Invited Lecture IV

S085

Medially Directed Lateral Mass Screw for Cervical Spine Fixation: Feasibility Study Using CT Scan and Preliminary Clinical Results

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Purpose: Cervical lateral mass screws (LMS) remain a mainstay for instrumentation in posterior spinal fusion. Traditional trajectories emphasize a laterally divergent screw to avoid the vertebral artery and nerve root, allowing insertion under fluoroscopy or freehand. However, there are a number of pitfalls, including restricted lateral angulation from the spinous process, difficulty aligning with C2, C7, or upper thoracic pedicle screws for rod placement, and interference with subsequent laminectomy through the lamina–lateral mass gutter. Although cervical pedicle screws offer greater length and purchase, they are technically demanding and carry higher risks of spinal cord or vertebral artery injury. A medially directed LMS towards the pedicle inlet, without traversing the pedicle, may offer a better alternative. This study aimed to define CT-based morphometric parameters for safe screw length and axial convergence angle for this medially directed trajectory in the subaxial spine of C3–C7.

Materials and Methods: Preoperative cervical CT scans from 41 Chinese patients older than 50 years were retrospectively analyzed. Patients with congenital anomalies, fracture, tumor, infection, destructive pathology, or prior posterior cervical surgery were excluded. Three-dimensional CT reconstructions were used to determine the standardized entry point as per Abumi technique, axial convergence angle relative to the sagittal plane, and maximum screw length from C3 to C7 bilaterally. Measurements were compared by side, sex, and vertebral level using independent-samples t-tests and two-way ANOVA. $p<0.05$ was regarded as statistically significant.

Results: The overall mean maximum screw length was 12.3 mm, and the overall mean axial convergence angle was 39.3°. Mean screw lengths and convergence angles were similar between left and right sides and showed no significant sex-based differences. No significant differences were identified across C3–C7 levels. Based on these findings, a practical screw length of 12 mm appears reasonable, with 11 mm for smaller corridors and 13 mm for larger ones. A convergence angle of approximately 38–41°, with 40° as a practical starting point, appears anatomically feasible.

Conclusions: In this cohort, a medially directed subaxial cervical LMS trajectory towards the pedicle inlet was anatomically feasible from C3 to C7. These data provide a standardized CT-based planning method, but biomechanical validation, reliability testing, and clinical outcome studies are required before broad clinical adoption.

Keywords: Cervical vertebrae, Pedicle screws, Cone-beam computed tomography, Feasibility studies

Free Paper: Cervical (4)

S086

Automated Measurement of Cervical Sagittal Parameters Using a Hierarchical Deep Learning Pipeline: A Robust Approach to C7 Obscuration on Radiographs

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Purpose: To develop and externally validate a hierarchical deep learning pipeline for automated cervical sagittal measurements, specifically addressing the persistent clinical challenge of C7 obscuration on lateral radiographs.

Materials and Methods: A multi-stage hierarchical pipeline was developed, integrating a global Keypoint R-CNN (ResNet-50-FPN backbone) with an MLP-based localizer and dedicated specialist models for C2 and C7 refinement on high-resolution patches. The model was trained on 5,604 images from multinational institutions in China and Korea. Performance was evaluated on an internal test set and a challenging independent external validation set (n=100) enriched for C7 obscuration (82.0%). Reliability and accuracy were assessed using the intraclass correlation coefficient (ICC), Pearson correlation (r), and mean absolute error (MAE) compared to dual-read consensus expert annotations.

Results: In the external validation set, the hierarchical pipeline achieved excellent reliability for C2–C7 lordosis (ICC=0.97, MAE=2.57°), C2 slope (ICC > 0.99, MAE=0.83°), and C7 slope (ICC=0.93, MAE=2.31°). Subgroup analysis demonstrated the model's robustness in "complete obscuration" cases, where the C2–C7 lordosis MAE improved from 4.52° to 3.59° compared to a single-stage baseline. The AI model showed perfect repeatability (ICC >0.99) and achieved higher agreement with human specialists for C7 slope (ICC 0.81–0.84) than the inter-expert reliability between specialists themselves (ICC 0.67).

Conclusions: The hierarchical deep learning model provides a robust, accurate, and clinically generalizable tool for automated cervical alignment assessment under real-world conditions. By utilizing specialist models to refine keypoint detection, this multi-stage approach effectively overcomes the limitations of C7 obscuration and establishes a new benchmark for standardized measurement in complex clinical scenarios.

Keywords: Cervical spine, Sagittal alignment, Hierarchical deep learning, C7 obscuration, Keypoint detection

S087

Biomechanical Analysis Comparison of Different Cervical Posterior Screw Fixation Techniques: A Finite Element Study

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Purpose: To biomechanically compare the stress distribution of established posterior cervical fixation techniques—conventional pedicle screw (PS), Abumi's technique, unicortical lateral mass screw (LMS), and bicortical LMS—with a novel pedicle screw method, the Lee's point technique, using finite element modeling (FEM).

Materials and Methods: A patient-specific FEM of C5–C6 was developed using high-resolution CT data of a degenerative cervical spine. Five fixation models were constructed: Lee's point, Abumi's, conventional PS, unicortical LMS, and bicortical LMS. Screw dimensions were ø3.5×28 mm for PS and ø3.5×14/18 mm for LMS. A pure moment of 1.0 Nm was applied in flexion, extension, axial rotation, and lateral bending, and the peak von Mises stress (PVMS) of both the vertebrae and implants was recorded for each loading condition.

Results: Abumi's technique showed the highest PVMS at C5–C6 (23.09–43.22 MPa and 24.96–39.91 MPa), with stress concentrated at the pedicle entry and medial wall. Lee's point and conventional PS demonstrated more evenly distributed stress across the pedicle and near cortex of the lateral mass.

Unicortical and bicortical LMS showed stress mainly at the entry point, with overall lower and more uniform magnitudes. Implant stress was greatest in Abumi's construct (up to 295 MPa), moderate in Lee's and conventional PS, and lowest in LMS models.
Conclusions: Abumi's technique showed higher localized stress concentrations that may warrant careful patient selection, particularly in those with compromised bone quality. Lee's point technique achieved a balanced stress profile comparable to conventional PS, suggesting a favorable biomechanical profile for posterior cervical fixation.
Keywords: Cervical spine, Pedicle screw, Lateral mass screw, Finite element analysis

S088

Vertebral Body Sliding Osteotomy as a Less Invasive Alternative to 540° Surgery for Cervical Myelopathy with Rigid Kyphosis

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Purpose: Cervical myelopathy with rigid kyphosis often requires multilevel decompression and realignment. Although 540° surgery—posterior decompression with screw fixation, anterior decompression and fusion, and posterior rod connection—can achieve adequate neural decompression and sagittal correction, it involves a substantial surgical burden. This study compared vertebral body sliding osteotomy (VBSO), an anterior-based technique, with 540° surgery for multilevel cervical myelopathy with rigid kyphosis.
Materials and Methods: A retrospective cohort of 57 patients treated between 2015 and 2022 was analyzed, including 38 who underwent VBSO and 19 who underwent 540° surgery. All patients required fusion across three or more levels and had a minimum of two years of follow-up. Selective ACDF was added to VBSO when pathology extended across disc spaces. Clinical outcomes included the Japanese Orthopaedic Association (JOA) score, Neck Disability Index (NDI), and visual analog scale (VAS) for neck pain. Radiological parameters included C2–7 lordosis, segmental lordosis, and canal occupying ratio. Operative time, estimated blood loss (EBL), and complications were also evaluated.
Results: Improvements in JOA, NDI, and neck pain VAS were comparable between groups (all p>0.05). Postoperative C2–7 lordosis was similarly restored, and complication rates showed no significant differences. VBSO demonstrated a markedly shorter operative time (262.1 vs. 440.4 minutes, p<0.001) and lower EBL (100.4 vs. 272.2 mL, p<0.001).
Conclusions: VBSO achieved clinical and radiological improvement with a reduced surgical burden relative to 540° surgery. These findings suggest that VBSO may be considered a reasonable and efficient alternative for treating cervical myelopathy with rigid kyphosis.
Keywords: Cervical vertebrae, Osteotomy, Cervical myelopathy, Rigid kyphosis, Ossification of posterior longitudinal ligament

S089

Management of Primary Cervical Spine Infections: Outcomes of 59 Patients over Three Decades

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Purpose: Primary cervical spine infection is a rare but rapidly progressive disease that can cause early neurological damage, leading to increased morbidity and mortality. Despite its rising incidence, optimal treatment remains controversial. This study compared clinical, hematological, microbiological, and radiological outcomes among such patients treated with different methods.
Materials and Methods: This retrospective comparative study is a secondary analysis of a previously reported cohort of 59 patients with primary cervical spine infection between 1992 and 2018 at a single institution. Patients were stratified into conservative (Group C, n=14), surgery with instrumentation (Group S+I, n=32), and surgery without instrumentation (Group S, n=13) groups. Outcome measures included neurological status, antibiotic duration, hematological markers, and radiological parameters (segmental angle, C2–C7 angle, segmental height, fusion rate), as well as complications.

Results: The mean age and follow-up period were 61.4 years and 19.4 months, respectively. Group S+I demonstrated significantly better neurological outcomes at the last follow-up (p=0.047) and shorter antibiotic treatment duration (p<0.001). Radiological outcomes were superior in Group S+I, with greater improvements in segmental angle (p<0.001), C2–C7 angle (p<0.001), mean segmental height (p<0.001), and fusion rate (84.4% vs. 14.3% and 46.2% in Group C and Group S, respectively; p<0.001). Group S had significantly higher complication (46.2%, p=0.011) and mortality (30.8%, p=0.001) rates. Hematological and microbiological results were not significantly different among groups.

Conclusions: Surgical debridement with anterior instrumentation provided superior outcomes compared with conservative treatment or surgery without instrumentation. Early surgery with appropriate stabilization should be considered to optimize prognosis and minimize complications.

Keywords: Primary cervical infection, Instrumentation, Surgical debridement, Antibiotics, Spondylodiscitis

S090

Impact of Postoperative Mean Arterial Pressure Maintenance Duration on Clinical Outcomes and Complications in Cervical Spinal Cord Injury Patients

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Purpose: Maintaining adequate mean arterial pressure (MAP) after acute spinal cord injury (SCI) is crucial to prevent secondary ischemic injury. While guidelines recommend maintaining MAP >85 mmHg, the clinical impact of the specific duration of maintaining this target remains unclear. We evaluated how the duration of MAP maintenance above 85 mmHg during the first 5 postoperative days affects clinical outcomes, focusing on the cumulative burden of hypotension.

Materials and Methods: We retrospectively reviewed 74 patients who underwent surgical treatment for cervical SCI at a single trauma center. Postoperative MAP was continuously monitored for 5 days to calculate the percentage of time MAP was maintained > 85 mmHg. Clinical outcomes included ICU length of stay, systemic complications (defined as cardiovascular events and acute kidney injury [AKI]), respiratory complications, and neurological recovery (ASIA impairment scale improvement). Statistical significance was set at p<0.05.

Results: MAP maintenance duration showed a significant negative correlation with ICU length of stay (r=-0.237, p=0.048). A distinct threshold effect was identified regarding systemic complications: patients who failed to maintain the target MAP for at least 80% of the time (effectively experiencing a hypotensive burden for >20% of the period) had a significantly higher incidence of systemic complications compared to the compliant group (24.0% vs. 4.8%, p<0.05). Notably, AKI was the most prevalent complication within the systemic group, accounting for the majority of cases in the low-adherence group. No significant association was found between MAP maintenance and neurological recovery (p=0.33) or pleural effusion (p=0.285).

Conclusions: The cumulative burden of hypotension is a critical determinant of systemic outcomes in cervical SCI patients. Exposing patients to suboptimal perfusion (MAP <85 mmHg) for more than 20% of the first 5 postoperative days significantly increases the risk of systemic complications, predominantly AKI, and prolongs ICU stay. Hemodynamic management should strictly minimize the duration of drops below the target threshold to preserve renal and systemic perfusion, although this protocol alone may not independently dictate neurological recovery.

Keywords: Spinal cord injury, Mean arterial pressure, Acute kidney injury, Hypotension, Postoperative complications

Free Paper: Deformity (1)

S091

Impact of Enhanced Recovery After Surgery (ERAS) Protocol on Postoperative Pain and Clinical Recovery in Adult Spinal Deformity Surgery

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Purpose: While Enhanced Recovery After Surgery (ERAS) protocols have demonstrated benefits in accelerating recovery and ensuring patient safety for adult spinal deformity (ASD) correction, their impact on postoperative analgesic efficacy and comprehensive clinical outcomes remains underexplored. This study aimed to evaluate the effects of an ERAS protocol on perioperative outcomes and postoperative analgesic efficacy in patients undergoing ASD correction surgery.

Materials and Methods: Seventy-seven ASD patients who underwent posterior-only correction surgery at a single institution were included. Demographic characteristics, radiographic parameters, and surgical data were recorded. Patients receiving the ERAS protocol were prospectively enrolled in the ERAS group (n=40), while those without ERAS were retrospectively identified from institutional databases as controls (non-ERAS group, n=37). Primary outcomes included surgical time, estimated blood loss (EBL), postoperative nausea and vomiting (PONV) incidence, total morphine sulfate equivalent (MSE) consumption, and visual analog scale (VAS) pain scores. Secondary outcomes encompassed perioperative recovery milestones: time to ambulation, oral intake initiation, Foley catheter removal, drainage tube removal, and length of stay (LOS).

Results: The ERAS group demonstrated significantly shorter operative times (359±80 vs. 433±143 minutes, p=0.008) and reduced MSE consumption (18.8±20.4 vs. 77.7±51.0 mg, p<0.001) compared to controls. Fewer ERAS patients required patient-controlled analgesia (45% vs. 70.3%). The protocol group achieved an average of 1 day earlier functional recovery, with reduced time to ambulation, oral intake initiation, and catheter removal. Mean VAS scores were consistently lower in the ERAS group at postoperative day 1 (1.9±1.1 vs. 4.0±1.2, p<0.001), day 2 (2.0±1.1 vs. 3.4±0.8, p<0.001), and day 3 (2.1±1.2 vs. 3.2±0.8, p<0.001). Hospital stays were also significantly shorter in the ERAS group (9.4 vs. 10.9 days, p=0.005).

Conclusions: Implementation of an ERAS protocol for ASD correction surgery significantly improves perioperative recovery trajectories, enhances postoperative pain control, and optimizes overall recovery quality. These findings support the standardized adoption of ERAS principles in adult spinal deformity surgery.

Keywords: Enhanced recovery after surgery, Adult spinal deformity, Perioperative outcomes, Postoperative analgesia, Length of stay

S092

Risk Factors for Revision Surgery After Acute Proximal Junctional Fracture Following Adult Spinal Deformity

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Purpose: Acute proximal junctional fracture (APJFx) is a severe form of proximal junctional kyphosis after adult spinal deformity surgery and is often associated with revision surgery. However, the clinical course of APJFx is heterogeneous, and not all patients require revision. This study aimed to identify independent risk factors for revision surgery after APJFx to guide the timing and necessity of revision surgery.

Materials and Methods: This retrospective cohort study included patients who developed APJFx within 6 months after undergoing multi-level (≥5 levels) fusion surgery. Demographic, surgical, and radiographic variables were analyzed. Initial postoperative alignment was evaluated using the sagittal age-adjusted score (SAAS) and the Global Alignment Proportion score. Radiographic parameters at

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the time of APJFx detection were also assessed. Revision-free survival was analyzed using Kaplan–Meier analysis. Independent predictors of revision surgery were identified through multivariate logistic regression, and optimal cutoff values were determined using receiver operating characteristic analysis. Patients were stratified into four subgroups based on identified risk factors.

Results: Eighty patients met the inclusion criteria, and 35 patients (43.8%) underwent revision surgery during a mean follow-up of 24.6 months. Most revision surgeries (82.9%) were performed within 24 months after APJFx detection. Multivariate analysis identified two independent predictors of revision surgery: a higher SAAS pelvic incidence minus lumbar lordosis (PI–LL) modifier score (odds ratio [OR]=1.76; cutoff=0.5 point, indicating PI–LL overcorrection) and a greater proximal junctional angle (PJA) at APJFx detection (OR=1.10, cutoff=22.5°). Patients with both risk factors exhibited the highest revision rate (71.4%), whereas those with neither risk factor had the lowest rate (17.6%).

Conclusions: Revision surgery after APJFx is common, particularly in patients with PI–LL overcorrection and increased PJA at fracture detection. Risk-based stratification using these parameters may aid in guiding early surgical decision-making and surveillance strategies.

Keywords: Adult spinal deformity, Acute proximal junctional fracture, Revision surgery, Risk factors

S093

Rotated Prone Lateral Anterior Column Realignment Versus Pedicle Subtraction Osteotomy for Adult Spinal Deformity: A Matched Cohort Analysis of Radiographic and Clinical Outcomes

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Purpose: Rotated prone lateral surgery allows for simultaneous access to both anterior and posterior columns via a radiolucent Jackson table rotation technique, distinct from the conventional prone transpsoas approach. This study aims to compare the clinical and radiographic outcomes of rotated prone lateral anterior column realignment (ACR) versus conventional pedicle subtraction osteotomy (PSO) for adult spinal deformity (ASD) correction in a matched cohort.

Materials and Methods: We retrospectively reviewed a consecutive series of patients who underwent rotated prone lateral ACR for ASD correction from 2019 to 2024. To compare outcomes with conventional techniques, a control group of patients who underwent PSO between 2016 and 2024 was identified. The PSO patients were strictly matched to the ACR cohort in a 1:1 ratio based on primary surgical indication, age, body mass index (BMI), and Charlson Comorbidity Index (CCI). Demographics, surgical details, radiographic sagittal parameters, and complications were analyzed.

Results: A total of 60 patients were included, with 30 patients in the rotated prone lateral ACR group and 30 matched patients in the PSO group. Demographics were comparable between groups (age: 59.3 vs. 64.1 years, p=0.257; BMI: 25.0 vs. 25.7 kg/m^2, p=0.667). Surgically, the rotated prone lateral ACR group demonstrated significantly shorter instrumentation levels (4.8±2.0 vs. 6.9±1.4, p=0.001) and less blood loss (1,412±1,023 vs. 2,073±1,227 mL, p=0.045) compared to the PSO group. Surgical duration was comparable (6.0 vs. 5.5 hours, p=0.848). Radiographically, both groups achieved substantial correction. There were no significant differences in the change in local Cobb angle (43.3° vs. 40.1°, p=0.462) or postoperative PI–LL mismatch (5.5° vs. 5.3°, p=0.908), indicating comparable correction power. The ACR group achieved significantly better postoperative pelvic tilt (9.3° vs. 14.4°, p=0.012). The ACR group also showed a trend toward lower complication rates, particularly in screw loosening and rod fractures.

Conclusions: Rotated prone lateral ACR provides comparable sagittal alignment restoration to conventional PSO. However, it offers distinct advantages, including significantly reduced blood loss and shorter fusion constructs. These findings suggest that rotated prone lateral ACR is a safe and effective alternative to PSO, potentially reducing surgical morbidity.

Keywords: Adult spinal deformity, Rotated prone lateral surgery, Anterior column realignment, Pedicle subtraction

osteotomy, Sagittal alignment

S094

Analysis of Gait in Patients with Adult Spinal Deformity Using Inverse Dynamics by Any Body Modeling System

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Purpose: Pelvic retroversion is a key compensatory mechanism for maintaining sagittal balance in ASD. However, some patients fail to achieve adequate pelvic compensation despite marked sagittal malalignment, and the biomechanical basis of this failure remains unclear. This study investigates the biomechanical characteristics of ASD patients with sagittal imbalance who fail to achieve pelvic compensation, using gait analysis and musculoskeletal simulation with the AnyBody Modeling System.

Materials and Methods: From August 2020 to January 2023, 154 patients who underwent ASD corrective surgery by a single surgeon were retrospectively reviewed. Preoperative gait analysis data were available for all patients. Among them, 52 patients were identified as having sagittal imbalance (SVA >147.5 mm) and pelvic compensation failure (PT/PI <0.68) based on standing whole-spine X-rays. Using stratified random sampling, 8 patients were selected as the study group. Their gait data were analyzed using the AnyBody Modeling System to extract joint moments and muscle activity during walking. For comparison, 21 patients with similar sagittal imbalance but preserved pelvic compensation (PT/PI ≥0.68) were identified, and 8 matched controls were selected via propensity score matching. The maximum joint moments and muscle activity during gait were compared between the two groups.

Results: In the musculoskeletal simulation, the study group demonstrated significantly lower hip anteroposterior force and hip proximodistal force compared with the control group: hip anteroposterior force, 4.23±2.25 Nm/Bwt vs. 8.96±4.39 Nm/Bwt (p=0.017); hip proximodistal force, 41.01±15.01 Nm/Bwt vs. 60.64±16.75 Nm/Bwt (p=0.014). Muscle activity of the psoas major and erector spinae was also significantly reduced in the study group: psoas major, 1.09±1.25 vs. 2.71±1.68 (p=0.046); erector spinae, 0.96±0.63 vs. 2.29±1.14 (p=0.012).

Conclusions: Among ASD patients with sagittal imbalance, those without pelvic compensation exhibited reduced hip extension moments compared with patients with preserved compensation, indicating a diminished ability to achieve pelvic retroversion. In addition, they demonstrated lower activity of the psoas major and erector spinae muscles, suggesting that stable contraction of these muscles is important for maintaining pelvic retroversion.

Keywords: Pelvic compensation, Adult spine deformity, Gait analysis, AnyBody, Musculoskeletal simulation

S095

Correction Degree and Spinopelvic Parameters Associated with Proximal Junctional Complications: A Systematic Review and Meta-Analysis

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Purpose: The purpose of this study was to investigate the association between spinopelvic parameters and proximal junctional complications (PJK/PJF), including analysis based on age-adjusted PI–LL mismatch categories.

Materials and Methods: This systematic review and meta-analysis was conducted in accordance with the PRISMA 2020 guidelines. A comprehensive literature search of PubMed, EMBASE, and the Cochrane Library was performed to identify studies published through March 2025 that evaluated proximal junctional kyphosis (PJK) and/or proximal junctional failure (PJF) following adult spinal deformity surgery or long-segment (≥4 levels) fusion in adult patients. Two independent reviewers screened studies and extracted data on preoperative and postoperative spinopelvic parameters, including pelvic incidence, lumbar lordosis, pelvic incidence–lumbar lordosis mismatch (PI–LL), pelvic

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tilt, sacral slope, thoracic and thoracolumbar kyphosis, T1 pelvic angle, sagittal vertical axis, and lower lumbar lordosis. In addition, studies stratifying patients by correction degree according to age-adjusted PI–LL targets were included. Age-adjusted alignment was defined using both a formula-based approach [(Age–55)/2+3] and age-specific reference thresholds. Random-effects meta-analyses were performed to calculate mean differences or standardized mean differences for continuous variables and odds ratios for proximal junctional complication rates. Study quality was assessed using the Newcastle–Ottawa Scale, and heterogeneity was evaluated using the I^2 statistic.

Results: A total of 47 studies were included in the meta-analysis. Patients who developed PJK had lower preoperative lumbar lordosis and sacral slope, but higher pelvic tilt, T1 pelvic angle, and sagittal vertical axis compared with non-PJK patients. Postoperatively, the PJK group showed significantly lower PI–LL values and sacral slope, and increased pelvic tilt, thoracic kyphosis, thoracolumbar kyphosis, and T1 pelvic angle. When stratified by the age-adjusted PI–LL formula, overcorrection was associated with a significantly higher risk of PJK [OR=2.67, 95% CI=1.61–4.42], whereas no significant difference was observed for PJF. Using age-specific thresholds, overcorrection was significantly associated with a higher risk of PJF [OR=1.67, 95% CI=1.10–2.52].

Conclusions: Preoperative sagittal imbalance and postoperative overcorrection were associated with an increased risk of proximal junctional complications, while only limited associations were observed for PJF. Importantly, overcorrection beyond age-adjusted PI–LL thresholds was significantly linked to both PJK and PJF, underscoring the need for alignment targets tailored to patient age.

Keywords: Proximal junctional kyphosis, Proximal junctional failure, Adult spine deformity, Spinopelvic parameters, Correction degree

Free Paper: Deformity (2)

S096

Utilizing Stable Vertebra on Push-Prone Traction Radiographs for the Determination of the Lowest Instrumented Vertebra: A Novel Approach for AIS Patients with Lenke Type 3C and 6C

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Purpose: To assess whether using the stable vertebra on push-prone traction radiographs for selecting the lowest instrumented vertebra (LIV) in adolescent idiopathic scoliosis (AIS) patients with Lenke type 3C and 6C undergoing posterior spinal surgery can preserve more lumbar motion segments while still achieving a satisfactory surgical outcome.

Materials and Methods: AIS patients with Lenke type 3C and 6C who underwent posterior spinal surgery between 2021 and 2024 were enrolled in the study. Preoperative 36-inch whole-spine radiographs, including the push-prone traction view, were obtained for curve flexibility assessment. The lowest instrumented vertebra (LIV) was determined by identifying a stable vertebra (SV) on push-prone traction radiographs. Demographic data, including sex, age, BMI, Lenke curve type, and pre- and postoperative major coronal Cobb angle, thoracic kyphosis, lumbar lordosis, and C7 to central sacral vertical line (C7–CSVL), were collected. Statistical analysis was conducted to assess the differences in curve magnitudes between pre- and postoperative measurements.

Results: Thirty-six AIS patients (33 females and 3 males) with a mean age of 13.9±2.2 years were included in this study, with a mean follow-up period of 28.4 months. Preoperatively, the cohort presented with Lenke type 3C (24 of 36) and type 6C (12 of 36). The preoperative thoracic curve was corrected to an average of 5.7°, demonstrating an average correction rate of 89%. Similarly, the preoperative lumbar curve was corrected to an average of 5°, with a correction rate of 90%.

Conclusions: Push-prone traction radiographs may serve as

an alternative method for determining the optimal LIV level in patients with Lenke type 3C and 6C. Identifying the stable vertebra on push-prone traction radiographs as the LIV can potentially preserve more lumbar motion segments while achieving favorable surgical outcomes.

Keywords: Adolescent idiopathic scoliosis, Lenke, Lowest instrumented vertebra, Push-prone, Traction

S097

Sagittal Profiles and Their Reciprocal Changes Manifesting in Proximal Junctional Kyphosis Following Deformity Correction in Adolescent Idiopathic Scoliosis

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Purpose: To investigate sagittal profiles—including sagittal shape and alignment—in relation to proximal junctional kyphosis (PJK) following deformity correction in patients with adolescent idiopathic scoliosis (AIS).

Materials and Methods: A total of 282 AIS patients who underwent deformity correction were retrospectively reviewed. Patients were categorized into two groups according to the presence of PJK at the 2-year follow-up: the PJK group (n=48) and the non-PJK group (n=234). Sagittal shape was classified as normal thoracic kyphosis (TK), hypo-TK with/without thoracolumbar kyphosis (TLK), and cervicothoracic kyphosis. Coronal, sagittal, and spinopelvic radiographic parameters were measured. Changes in Roussouly classification and correction relative to the functional T10 pelvic angle target were assessed to evaluate sagittal restoration and its association with PJK.

Results: At the 2-year follow-up, the incidence of PJK was 17.0% (48 of 282). The upper instrumented vertebra (UIV) level differed significantly between the two groups (p=0.002). The mean absolute Δ sagittal vertical axis (SVA) between the postoperative and the 2-year follow-up was also greater in the PJK group (28.9 mm vs. 17.3 mm, p=0.008). Regarding sagittal shape, the PJK group was most prevalent in normal TK (43.8%) and cervicothoracic kyphosis (31.3%), whereas the non-PJK group was most prevalent in hypo-TK without TLK (40.2%), followed by normal TK (35.0%) (p<0.001). Multivariate logistic regression showed that lower UIV level, cervicothoracic kyphosis, and greater ΔSVA were significantly associated with PJK.

Conclusions: Our findings indicated that the UIV level, cervicothoracic kyphotic profile, and greater changes in the SVA were contributing factors to the development of radiographic PJK. In contrast to adult spinal deformity, PJK in AIS rarely causes serious clinical sequelae but instead represents reciprocal changes driven by the original sagittal shape and subsequent alterations in sagittal alignment.

Keywords: Adolescent idiopathic scoliosis, Proximal junctional kyphosis, Reciprocal change, Kyphotic shape, Sagittal balance

S098

An Innovative 3D-360° Scanning Camera Radiation-Free Device for Assessing the Trend of Adolescent Idiopathic Scoliosis Curve

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Background: Adolescent idiopathic scoliosis (AIS) requires regular whole-spine X-ray follow-up before reaching the indication for surgical intervention. However, prolonged monitoring with spinal X-rays results in cumulative radiation exposure, which may increase the risk of cancer in adolescents. Therefore, tracking the progression of scoliosis while reducing radiation exposure has always been a challenging task.

Purpose: To introduce a new radiation-free device for evaluating curve trends and to compare it with traditional X-rays in AIS patients.

Methods: From August 2023 to September 2024, we collected data from a total of 55 patients diagnosed with adolescent idiopathic scoliosis, ranging in age from 14 to 30 years. All

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patients underwent whole-spine X-ray anteroposterior and sagittal view imaging and scanning with the new device. The results were analyzed using deep learning, comparing point cloud data generated by the device with the corresponding conventional X-ray findings.

Results: The Jaccard Index and Mean Square Error (MSE) were used as metrics to analyze the differences between the two groups. The average Jaccard Index across the 55 patients was 0.91. The MSE had an average value of 1.96×10^{-5}. The results showed a high degree of similarity in the trends of spinal curvature between the two methods.

Conclusions: This new device can be considered as an alternative to traditional X-rays for adolescent idiopathic scoliosis patients who have not reached the surgical indication.

Keywords: Adolescent idiopathic scoliosis, Radiation exposure

S099

Surgical Treatment of Scoliosis in NF-1: Outcomes and Complications

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Purpose: Neurofibromatosis type 1 (NF1)–associated scoliosis presents early in life and is characterized by severe dystrophic changes and rapid curve progression. Surgical treatment is technically demanding due to poor fixation quality and high complication rates. However, large surgical series on outcomes and complications are limited, and consensus on surgical strategies remains lacking.

Materials and Methods: We retrospectively reviewed 49 patients with dystrophic NF1 scoliosis (spinal fusion, n=39; growing rod, n=10) treated surgically between 2007 and 2023. All patients met NIH diagnostic criteria and had a minimum follow-up of 2 years (mean, 6.3 years). Radiological outcomes and complications (including correction loss/curve progression and adding-on) were evaluated. Linear regression, Fisher's exact test, and independent-sample t-tests were used for statistical analysis.

Results: The mean preoperative coronal Cobb angle in the entire cohort was 71°, and the mean kyphosis angle was 56° in patients with hyperkyphosis (n=15). The mean coronal curve and kyphosis correction rates were 56% and 54%, respectively. The overall complication rate was 33% (28% in the spinal fusion group and 50% in the growing rod group). Among patients who underwent posterior fusion (n=36), higher implant density was associated with improved curve correction but not with final coronal balance or reduced correction loss. Greater apical vertebral rotation (AVR) and rib penciling/transverse process spindling were associated with inferior correction rates. Correction loss greater than 5° occurred in 6 patients (17%), and distal adding-on occurred in 7 patients (19%). Lumbar or thoracolumbar curve type and rib penciling/transverse process spindling were associated with correction loss, whereas a larger preoperative curve angle and higher AVR were associated with adding-on ($p<0.05$).

Conclusions: In dystrophic NF1 scoliosis, correction remains limited and complication rates are high. Although higher implant density improves curve correction, it may not reliably prevent coronal imbalance, correction loss, or adding-on. Preoperative curve characteristics—particularly apical vertebral rotation and rib penciling—were significant predictors of postoperative outcomes, suggesting that surgical intervention should be considered before advanced dystrophic progression occurs.

Keywords: Neurofibromatosis type 1, Dystrophic scoliosis, Surgical outcome, Complications, Implant density

S100

Where Is the Spinal Cord Located Along the Spine in Adolescent Idiopathic Scoliosis (AIS) Patients: A Magnetic Resonance Imaging (MRI) Study

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Purpose: Medial perforation and screw-related neurological complications have been reported with posterior spinal instrumentation and fusion (PSIF) in AIS patients. The potential risk of spinal cord injury due to pedicle breach

during screw insertion is influenced by the cord location within the spinal canal; hence, we aim to document the spinal cord position at different levels of the spine in patients with AIS to better understand its anatomical location, with the aim of reducing the risk of neurological complications.

Materials and Methods: Preoperative whole-spine MRI images of 81 AIS patients who underwent PSIF over a period of ten years were extracted and used to measure the position of the spinal cord within the spinal canal according to quadrants, the closest distance of the spinal cord from the medial pedicle wall, as well as the left and right lateral canal spaces (LCS) at each level from T1 to L1 vertebrae. All Lenke 1 to Lenke 6 curves were included. Non-idiopathic or congenital scoliosis patients, as well as poor-quality MRI images, were excluded.

Results: The spinal cord mainly moved in a counterclockwise direction as it progressed caudally from T1 to L1 vertebrae. The cord was touching the medial pedicle wall at eight out of 13 vertebral levels measured, five of which were statistically significant (p<0.05). At the common apical vertebral levels T8, T9, and T10, there was a significant negative correlation between the left LCS and Cobb angle (R=-0.220, -0.286, and -0.289), as well as a significant positive correlation between the right LCS and Cobb angle (R=0.398, 0.383, and 0.406). The narrowest left LCS (1.1±1.3 mm and 1.2±1.3 mm) and widest right LCS (8.3±2.1 mm and 7.9±2.4 mm) were both at T8 and T9 vertebral levels.

Conclusions: With better insight into the spinal cord location within the spinal canal, extra precautions can be taken when inserting pedicle screws at levels where the spinal cord is in proximity.

Keywords: Adolescent idiopathic scoliosis, Magnetic resonance imaging, Spinal cord position, Cord distance from canal wall, Lateral canal space

Free Paper: Deformity (3)

S151

Pedicle Subtraction Osteotomy for Adult Spinal Deformity: A Comparative Analysis of Perioperative Safety and Radiographic Efficacy in Primary vs. Revision Settings

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Purpose: Pedicle subtraction osteotomy (PSO) is a cornerstone technique for sagittal plane correction in adult spinal deformity (ASD). While its effectiveness in primary deformity correction is well-reported, it is presumed to carry greater risk in revision settings. This study evaluates radiographic and safety outcomes of PSO performed for primary and revision ASD.

Materials and Methods: We performed a retrospective cohort analysis of consecutive adult patients undergoing single-level lumbar PSO, stratified into primary (n=12) and revision (n=17) surgical groups. Baseline demographics, operative metrics, sagittal alignment parameters, and perioperative complications were evaluated. Radiographic outcomes included sagittal vertical axis (SVA), pelvic incidence–lumbar lordosis (PI–LL) mismatch, and thoracolumbar alignment at preoperative, early postoperative, and 1-year follow-up intervals. Statistical significance was set at p<0.05.

Results: Cohorts were well-matched for age (61.0 vs. 60.4 years, p=0.75) and BMI (28.5 vs. 29.5, p=0.62). Revision surgery was associated with significantly greater estimated blood loss (EBL) (3671 mL vs. 2575 mL, p<0.001) and trended toward longer operative time (464 vs. 446 min, p=0.27). There was no statistically significant difference in the rate of any major perioperative complication, including motor deficit (23.5% vs. 8.3%, p=0.361), bleeding >4L (23.5% vs. 16.7%, p=0.696), or deep infection (5.9% vs. 8.3%, p=1.00). Both groups achieved profound and significant (p<0.001) improvement in all key sagittal parameters from baseline to one year. Revision PSO produced a significantly greater improvement in sagittal

vertical axis (SVA) (-103mm vs. -90mm, p=0.028), while Primary PSO resulted in a superior final pelvic incidence-lumbar lordosis (PI-LL) match (3° vs. 7°, p=0.043). The magnitude of PSO resection was larger in the Primary group (27.3° vs. 24.8°, p=0.002). Correction was maintained from 6 weeks to 1 year in both groups with minimal loss.

Conclusions: Despite greater intraoperative blood loss, PSO in the revision setting does not confer a significantly higher risk of major perioperative complications compared to primary PSO. Both strategies are highly effective for sagittal realignment, with the revision cohort achieving greater global alignment (SVA) correction and the primary cohort achieving a more harmonious lumbopelvic relationship (PI-LL). These data support the safety and efficacy of PSO regardless of prior surgical history.

Keywords: Adult spinal deformity, PSO, Revision surgery, Complications, Sagittal alignment

S152

Incidence and Risk Factors of Revision Surgery with Acute Proximal Junctional Failure After Anterior Column Realignment for Adult Spinal Deformity

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Purpose: The association between anterior column realignment (ACR) technique and acute proximal junctional failure (APJF) in adult spinal deformity (ASD) has not been thoroughly evaluated, and risk factors for revision surgery following APJF remain unclear. Therefore, this study aimed to identify incidence and risk factors of revision surgery with APJF following ACR for ASD.

Materials and Methods: We included patients with severe degenerative sagittal imbalance who underwent deformity correction using ACR at one or more levels between 2020 and 2023. APJF was defined as proximal junctional failure occurring within 6 months postoperatively. Cases requiring revision surgery were classified as bony or soft tissue failures. Patient characteristics, surgical, and radiographic factors were compared to identify risk factors for revision surgery. Univariate and multivariate logistic regression analyses were used to determine independent risk factors.

Results: The study included 114 patients (mean age 70.7±5.3 years) with an average fusion length of 7.2±1.9 levels. APJF occurred in 36 patients (31.6%), with 24 cases of bony failure and 12 of soft tissue failure. Revision surgery was performed in 14 patients (38.9% of APJF cases, 12.3% of the cohort) at an average of 156.6±76.2 days postoperatively. Of these, 12 cases were due to bony failure and 2 to soft tissue failure. Univariate analysis identified cranial screw angle at the upper-instrumented vertebra (UIV), preoperative thoracic kyphosis (TK), postoperative TK, and proximal junctional angle (PJA) as significant risk factors. Multivariate analysis revealed independent risk factors for revision surgery: cranial screw angle at UIV (HR 21.578, p<0.001), preoperative TK (HR 1.049, p=0.034), and postoperative PJA (HR 1.125, p=0.046).

Conclusions: The incidence of revision surgery due to APJF following ACR for ASD was 12.3%. Key risk factors included cranial UIV screw angle, greater preoperative TK, and increased postoperative PJA.

Keywords: Adult spinal deformity, Anterior column realignment, Acute proximal junctional kyphosis, Revision surgery, Risk factor

S153

Postoperative Thoracic Muscle Atrophy is Associated with Delayed Proximal Junctional Kyphosis Following Adult Spinal Deformity Surgery: A Level-Specific Analysis

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Purpose: Proximal junctional kyphosis (PJK) is a common complication following long spinal fusion for adult spinal deformity. While early PJK (within one year) has been extensively studied, delayed PJK occurring beyond one year postoperatively remains poorly understood. This study examined the association between postoperative thoracic

muscle atrophy and delayed PJK, with specific attention to regional differences across thoracic spinal levels.

Materials and Methods: A retrospective cohort study was conducted on 122 patients who underwent posterior spinal fusion for adult spinal deformity. Delayed PJK was defined as PJK occurring more than one year postoperatively, and 10 delayed PJK cases were identified. Using preoperative and one-year postoperative CT imaging, thoracic paraspinal muscle cross-sectional area (CSA) was measured at seven levels (T5-6, T6, T6-7, T7, T7-8, T8, T8-9). Muscle atrophy was calculated as the percentage change from preoperative to postoperative CSA. Level-by-level comparisons were performed using independent t-tests. Age-controlled analysis using ANCOVA was performed to adjust for potential confounding effects.

Results: Ten delayed PJK patients (mean age 66.4±8.8 years, 80% female) and 112 controls (mean age 72.5±7.0 years) were analyzed. The age difference was not statistically significant (p=0.197). Overall thoracic muscle atrophy was significantly greater in the delayed PJK group (-7.24±6.07%), compared to controls (0.70±15.24%, p=0.039). Level-specific analysis revealed marked regional variation. The T8-9 level showed the most significant difference, with delayed PJK patients demonstrating -16.29±7.42% muscle loss versus -3.48±18.55% in controls (difference -12.81%, p=0.012). Interestingly, the T5-6 level showed paradoxical muscle hypertrophy in delayed PJK patients (19.35±13.59% vs 5.85±20.37%, difference 13.50%, p=0.090). After controlling for age using ANCOVA, the overall muscle atrophy effect remained substantial at -6.07% but lost statistical significance (p=0.386, 95% CI: -19.72% to 7.58%).

Conclusions: This study demonstrates that postoperative thoracic muscle atrophy is significantly associated with delayed PJK, with the lower thoracic levels (T7-T9) showing the most pronounced muscle deterioration. The T8-9 level emerges as the most critical region, showing highly significant muscle loss (p=0.012) independent of other factors. The pattern of muscle changes suggests a regional vulnerability, with lower thoracic paraspinal muscles experiencing greater atrophy in patients destined to develop delayed junctional failure.

Keywords: Delayed PJK, Thoracic muscle atrophy, Adult spinal deformity, Thoracic paraspinal muscles, Paraspinal muscle cross-sectional area

S154

Comparative Analysis of Three Lordosis Correction Parameters for Predicting Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery

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Purpose: Although the extent of lordosis correction, as measured by pelvic incidence minus lumbar lordosis (PI-LL), age-adjusted PI-LL, and L1PA, has been identified as a risk factor for PJK, direct comparison of their predictive ability has not been fully explored. This retrospective study aims to compare the predictive performance of three lordosis correction parameters for proximal junctional kyphosis (PJK) in adult spinal deformity (ASD) surgery.

Materials and Methods: A total of 323 patients who underwent lower thoracic spine to pelvis fusion with a 2-year follow-up were included. Three lordosis correction parameters were measured postoperatively: PI-LL, age-adjusted PI-LL offset, and L1PA offset. PJK was defined both radiographically and clinically. Logistic regression models with restricted cubic splines were used to assess the relationship between each parameter and the occurrence of PJK. Discriminative performance was evaluated using the area under the receiver operating characteristic curve (AUC), and calibration performance was assessed using Brier scores (lower scores indicate better performance). Odds ratios were calculated at multiple offset levels to evaluate effect sizes.

Results: All three parameters demonstrated similar discriminative abilities (AUCs: 0.638 for PI-LL, 0.648 for age-adjusted PI-LL offset, and 0.704 for L1PA offset; p>0.05). However, the L1PA offset model showed significantly superior calibration performance (Brier score=0.196) compared to PI-LL (0.211) and age-adjusted PI-LL offset (0.210). Effect size analysis revealed that while overcorrection (negative offset values) increased PJK risk across all models, only the L1PA offset demonstrated a clear

dose-response relationship. Correlation analysis showed that L1PA had only a moderate correlation with PI-based parameters, suggesting it captures distinct alignment features.
Conclusions: All three lordosis correction parameters were predictive of PJK, but the L1PA offset showed improved calibration and more consistent risk stratification. L1PA may serve as a more robust and individualized metric for guiding alignment in ASD surgery.
Keywords: Adult spinal deformity, Proximal junctional kyphosis, PI-LL, age-adjusted PI-LL, L1PA

S155

Sequential Rod Insertion Strategy After Anterior and Posterior Surgery to Minimize Coronal Imbalance in Degenerative Lumbar Kyphoscoliosis

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Purpose: Degenerative lumbar kyphoscoliosis (DLK) is characterized by combined sagittal and coronal malalignment. Although sagittal balance has traditionally been emphasized because of its association with functional outcomes, growing evidence underscores the clinical significance of coronal malalignment (CM). Accordingly, there is increasing demand for surgical strategies that minimize CM while achieving adequate sagittal correction in patients with DLK. This study aimed to evaluate the effectiveness of a sequential rod insertion strategy in reducing CM and to identify risk factors associated with residual CM.
Materials and Methods: This retrospective observational study included 97 patients with DLK and significant CM(coronal balance distance [CBD]>3 cm) who underwent corrective anterior–posterior surgery with a sequential rod insertion strategy between March 2020 and March 2024. Sagittal and coronal parameters were assessed preoperatively and postoperatively. Surgical treatment consisted of anterior oblique lumbar interbody fusion at L1–L5 and/or anterior lumbar interbody fusion at L5–S1, followed by posterior instrumentation. During the posterior stage, a sequential rod insertion technique was applied based on the Qiu CM classification: in type B curves, the convex side was addressed first using a rod derotation technique, whereas in type C curves, the concave side was corrected first using a pulling maneuver. This approach allowed for controlled correction of both coronal and sagittal alignment. Patients were categorized into a coronal balance (CB; CBD<3 cm) group and a coronal imbalance (CI; CBD≥3 cm) group. Univariate and multivariate logistic regression analyses were performed to identify risk factors for residual CM.
Results: Both sagittal and coronal alignments improved significantly following AP surgery combined with the sequential rod insertion strategy. The PI–LL mismatch decreased from 50.7° to 8.8°, and the CBD improved from 4.3cm to 1.6cm. Overall, 80 patients (82.5%) achieved coronal balance (CB group), while 17 patients (17.5%) remained in the CI group. Multivariate analysis identified fewer anterior fusion levels (odds ratio [OR], 0.35; p=0.039), preoperative type C curves (OR, 15.43; p=0.005), and greater preoperative CBD (OR, 3.50; p=0.016) as independent risk factors for residual CM.
Conclusions: The sequential rod insertion strategy combined with AP surgery effectively restored coronal alignment in patients with DLK while achieving satisfactory sagittal correction. Preoperative type C curves, fewer anterior fusion levels, and greater preoperative CBD were strong predictors of residual CM. These factors should be carefully considered during preoperative planning to optimize coronal correction outcomes.
Keywords: Degenerative lumbar kyphoscoliosis, Coronal malalignment, Sequential rod insertion, Risk factors, Type C curve

Free Paper: Deformity (4)

S156

Managing Scoliosis in Immunocompromised Patients with Hyper IgE Syndrome: Evidence Review and Suggested Protocol

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Purpose: Primary immunodeficiency disorders, particularly Hyper-IgE syndrome, present significant challenges in spine surgery due to heightened infection risks. Scoliosis corrective surgery in these patients requires meticulous perioperative management to prevent potentially life-threatening complications. This case report describes the successful surgical management of severe scoliosis in a patient with primary immunodeficiency disease, highlighting a comprehensive infection prevention protocol that has not been previously documented in the literature.
Materials and Methods: A 20-year-old female with diagnosed Hyper-IgE syndrome and severe scoliosis requiring corrective surgery was managed with a specialized perioperative protocol. The patient was maintained on lifelong oral antibiotics and monthly intravenous immunoglobulin (IVIG) therapy. Preoperative preparation included thorough screening to ensure absence of active skin infections. Prophylactic intravenous cefazolin 2 g three times daily was administered for one week prior to surgery. Immediately preoperatively, the patient received IVIG 50 g (1 g/kg body weight) to optimize immune function. Intraoperatively, strict infection control measures were implemented, including minimizing operating room personnel to essential staff only. Postoperatively, intravenous antibiotics were continued for 10 days, followed by an additional week of oral antibiotics. A second IVIG dose (50 g) was administered on postoperative day 5. Surgical wound assessment was performed on postoperative days 3 and 14 to monitor for signs of infection.
Results: The patient underwent successful scoliosis corrective surgery without any infectious complications. Wound examination at day 3 and day 14 revealed no signs of infection, with appropriate healing progression. The patient tolerated the procedure well, and the extended antibiotic prophylaxis protocol proved effective in preventing postoperative infections. No adverse events related to the immunodeficiency disorder or the intensive perioperative management were observed. The patient achieved satisfactory spinal correction and maintained infection-free status throughout the postoperative period.
Conclusions: This case illustrates that scoliosis corrective surgery can be safely performed in patients with primary immunodeficiency disorders when comprehensive infection prevention strategies are employed. The multimodal approach—comprising preoperative IVIG administration, prolonged antibiotic prophylaxis, stringent intraoperative infection control, and vigilant postoperative monitoring—proved effective in mitigating infection risk. To our knowledge, this represents the first reported case of successful scoliosis surgery in a Hyper-IgE syndrome patient with detailed perioperative management protocol. These findings provide valuable guidance for spine surgeons managing similar high-risk patients, emphasizing that with appropriate precautions, complex spinal surgery can be undertaken safely in this challenging population.
Keywords: Primary immunodeficiency disorder, Scoliosis, Surgery

S157

Impact of Declining Birth Rates on the Temporal Trend in the Prevalence of Idiopathic Scoliosis in South Korea: An Analysis of School-Based Screening Data, 2008–2023

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Purpose: The evidence for school-based scoliosis screening programs is currently indeterminate, given the conflicting

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opinions among healthcare professionals. This population-based study aims to estimate the screening and confirmed diagnosis rate of adolescent idiopathic scoliosis (AIS) from the school-based scoliosis screening programs in South Korea.

Materials and Methods: This population-based retrospective study was conducted based on prospectively collected data of school-based scoliosis screening program for schoolchildren aged 10 to 14 years, 2008-2023. The primary outcomes were the temporal trend of annual screening and confirmed diagnosis rate of AIS between 2008 and 2023 and the correlation trends between the diagnosis of AIS and the collected population census data, such as total fertility rate, and crude birth rate.

Results: The prevalence of AIS showed a gradually decreasing trend over the 15-year follow-up, ranging from 6.63% (95% CI: 6.48-6.78) in 2012 to 2.87% (95% CI: 2.72-3.02) in 2023. The confirmed diagnosis of AIS was significantly correlated with the total fertility rate (r=0.686, p<0.001) and crude birth rate (r=0.735, p<0.001). For girls with AIS, there was a significant correlation between menarche age and Cobb's angle over a 15-year follow-up (r=-0.414, p=0.008).

Conclusions: The diagnosis rate of AIS from school-based scoliosis screening showed a decreasing trend between 2008–2023, which may be correlated with the birth-related indicators. In addition, the increasing tendency in curve magnitude observed among female students appears to be influenced by the progressively earlier onset of menarche.

Keywords: Scoliosis, School-based scoliosis screening program, Prevalence, Total fertility rate, Menarche age

S158

The Changes of Muscle Character During Treatment of Adolescent Idiopathic Scoliosis

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Purpose: The treatment of adolescent idiopathic scoliosis (AIS) is exercise, brace, and operation depends on age and Cobb's angle . During the treatment, the muscle character can change like more soft or spastic. The purpose of this study was to evaluate the changes in the muscle elasticity during AIS treatment.

Materials and Methods: This study was a prospective study. Seventy-six patients with AIS were recruited and thirty-four patients were dropped. Finally, fifteen patients in operation and brace groups and fourteen patients in exercise group were included. The elasticity was measured at thoracolumbar junction at initial, 6 months and 12 months on both convex and concave side by one radiologist.

Results: There was no difference in the elasticity between groups and each side, except the concave side at 6 months. The elasticity was lower in the operation group (13.1±6.8, p=0.014) compared with the brace (21.5±10.1) and exercise (29.0±12.9) groups. In the linear mixed model, only the convex side in the operation group at 6 months showed a significant change in the elasticity compared with the initial value (p=0.046) during 1 year.

Conclusions: After deformity correction and fusion for AIS, the muscle elasticity is recovered after postoperative 6 months. However, the brace or exercise did not affect the muscle elasticity.

Keywords: Muscle, Adolescent, Scoliosis, Brace, Operation

S159

A Novel and Simple Technique to Correct Shoulder Balance in Patients Undergoing Surgery for Adolescent Idiopathic Scoliosis

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Purpose: The study was performed to analyze common radiographic parameters in the AIS patients undergoing PSI and determine their role in post-operative shoulder imbalance.

Materials and Methods: A descriptive case series; all patientsthat underwent surgical correction of AIS during the year of 2020 were retrospectively studied, over a period of one month (i.e. 20th June to 20th July 2024).

Results: A total of 62 patients were assessed. The pre-op, 6-week post-op and final follow-up RSH, clavicle angle, T1 tilt angle and 1st rib angles were compared. RSH value changed significantly (p=0.001) from 7.18±9.65 to -0.03±12.23. Clavicle angle also showed statistically significant (<0.001) change from 0.29±2.19 to -1.85±1.70. Similarly medial parameters of shoulder balance i.e. T1 tilt angle and 1st rib angle showed statistically significant (<0.001) change from -0.34±9.53 to 4.97±5.77 and -1.65±6.53 to 3.76±4.33, respectively. Pearson's correlation with RSH of each of the shoulder balance parameters i-e clavicle angle, T1 tilt angle and 1st rib angle were done for each temporal reading i-e pre-op, 6-week post-op and final follow-up. As is obvious from the aforementioned table only pre-op clavicle angle had statistically significant correlation with the pre-op RSH at r=0.526, p<0.001.

Conclusions: Clavicle angle has positive correlation with the RSH thus can be used for assessment of shoulder balance to improve patients' appearance and subsequent satisfaction rate. However, the medial radiologic parameters; namely, T1 tilt and 1st rib angle don't demonstrate significant correlation with shoulder balance thus shouldn't be used as predictors of shoulder balance.

Keywords: Adolescent idiopathic scoliosis, Posterior spinal fusion, Shoulder imbalance, Radiographic shoulder height, First rib angle

S160

The Price of Straightening Spines: Comparative Financial Burden of Adolescent Idiopathic Scoliosis and Congenital Scoliosis Surgery in a Tertiary Care Centre in a Third World Country

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Purpose: Understanding the costs of surgical correction of pediatric deformity aids patients, physicians, and hospitals in making informed decisions about cost-effective management strategies. Therefore, we conducted a study to assess and compare the hospital costs associated with the surgical management of adolescent idiopathic scoliosis and congenital scoliosis.

Materials and Methods: This was a retrospective observational single-center study performed at a large tertiary-level public sector hospital in India. We retrospectively reviewed 100 consecutive pediatric deformities undergoing posterior spinal fusion from 2019 to 2021 at a tertiary public sector hospital in Northern India. We assessed hospital costs from a payor's perspective under the following heads: surgical costs, hospitalization costs, and supportive costs. Regression analysis was used to assess the factors associated with higher costs.

Results: The mean total cost of surgery was Rs. 6,79,062±1,53,468. The mean surgical costs, hospitalization costs, and supportive costs were Rs. 4,82,070±1,08,476, Rs. 1,55,008±95,842, and Rs. 41,983±16,551 respectively. Implant costs contributed 62% of the total cost while hospital stay contributed 17% of the costs. Congenital scoliosis (p=0.040) had a lower cost while private ward admission (p<0.001), longer hospital-stay (p<0.001), increasing ICU duration (p<0.001), and higher number of screws (p<0.001) were independently associated with increased cost.

Conclusions: The hospital cost for scoliosis surgery was found to be Rs. 6.7 lakhs (7416 USD) which was lower compared to Western countries. Congenital scoliosis did not increase hospital costs despite having higher operative time and longer hospital stay. As implant costs contribute to roughly two-thirds of the total cost of surgery, strategies aimed at improving cost-effectiveness of scoliosis surgery should focus on reducing the cost of implants.

Keywords: Scoliosis, Adolescent idiopathic scoliosis, Congenital scoliosis, Deformity correction, Hospital costs

Free Paper: Basic Research (1)

S161

Finite Element Analysis of Stress Variation in Adjacent Vertebrae and Intervertebral Discs After Vertebroplasty for Osteoporotic Vertebral Compression Fractures

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Purpose: Osteoporotic vertebral compression fractures (VCFs) commonly affect the thoracolumbar junction and are associated with substantial pain, immobility, and morbidity. Vertebroplasty offers rapid pain relief and mechanical stabilization but may alter local biomechanics and risk of adjacent level stress. The current study aims to evaluate stress redistribution in adjacent vertebrae and intervertebral discs following vertebroplasty using finite element analysis (FEA) models.

Materials and Methods: A patient-specific finite element model of the T11-L3 spine was used to simulate L1 compression fractures and subsequent vertebroplasty with polymethylmethacrylate (PMMA) or hydroxyapatite (HA) bone cement across three osteoporotic spine models. Stress intensity patterns were evaluated under physiological loading for T12, L1, L2 vertebrae and T12-L1 and L1-L2 intervertebral discs. Stress analyses were performed across baseline, post-fracture, and post-vertebroplasty states.

Results: Fracture induction elevated stress across all examined vertebrae and adjacent discs, with the greatest increases observed at L2 and in both T12-L1 and L1-L2 discs. Vertebroplasty substantially reduced the fracture-induced spike in stress intensity at all levels. However, even after vertebroplasty, stress levels at T12, as well as T12-L1 and L1-L2 discs remained notably higher than baseline. This pattern was consistent for both PMMA and HA cements, with no significant difference between materials. Notably, the L2 vertebra experienced an approximate five-fold reduction in stress post-vertebroplasty, suggesting effective unloading of the inferior adjacent segment.

Conclusions: Vertebroplasty effectively mitigates fracture-induced stress redistribution but does not fully restore pre-fracture biomechanics, particularly at T12 and adjacent intervertebral discs.

Keywords: Osteoporosis, Vertebral compression fracture, Vertebroplasty, Finite element analysis, Intervertebral disc

S162

Automated Measurement of Cervical Sagittal and Local Parameters Using a Generalizable Deep Learning Model: A Multi-national Development and Validation Study

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Purpose: Manual measurement of cervical sagittal parameters is time-consuming and exhibits significant interobserver variability. Existing artificial intelligence models fail when C7 is obscured by shoulder anatomy. Therefore, we aimed to develop and externally validate a deep learning model for automated cervical alignment measurements under clinical conditions, including C7-obscured cases.

Materials and Methods: In this retrospective observational study, 5,604 lateral cervical radiographs were obtained from multinational institutions (China and Korea). A multi-stage hierarchical pipeline was developed, integrating a global Keypoint R-CNN (ResNet-50-FPN backbone) with an MLP-based localizer and dedicated specialist models for C2 and C7 refinement on high-resolution patches. Model outputs were compared to dual-read consensus expert annotations using intraclass correlation coefficient (ICC), Pearson correlation (r), mean absolute error (MAE), and Bland-Altman analysis. An independent dataset (n=100) enriched for C7 obscuration (82.0%) was utilized for external validation to ensure clinical generalizability.

Results: In the external validation set, 62 patients (62.0%) had a partially obscured C7 and 20 patients (20.0%) had a fully obscured C7. The hierarchical pipeline demonstrated excellent reliability for C2–C7 lordosis (ICC=0.97,

MAE=2.57°), C2 slope (ICC>0.99, MAE=0.83°), and C7 slope (ICC=0.93, MAE=2.31°). Mean errors for these parameters were clinically negligible at –0.44°, 0.06°, and –0.38°, respectively. Reliability for all disc height measurements was excellent in the internal test set (ICC=0.97–0.99). Subgroup analysis demonstrated the model's robustness in complete obscuration cases, where C2–C7 lordosis MAE improved from 4.52° to 3.59° compared to a single-stage baseline. The AI model showed perfect repeatability (ICC>0.99) and achieved higher agreement with human specialists for C7 slope (ICC 0.81–0.84) than the inter-expert reliability between the specialists themselves (ICC 0.67).

Conclusions: The hierarchical deep learning pipeline enables rapid, accurate, and clinically generalizable automated cervical alignment measurements. By utilizing specialist models to refine keypoint detection, this multi-stage approach effectively overcomes the limitations of C7 obscuration and establishes a new benchmark for standardized measurement in complex clinical scenarios.

Keywords: Cervical spine, Sagittal alignment, Artificial intelligence, Keypoint detection, Automated measurement

S163

Brain-Derived Neurotrophic Factor (BDNF) Enhances Osteogenesis of Bone Marrow-Derived Stromal Cells Through P38 MAPK Signaling Pathway

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Purpose: Brain-derived neurotrophic factor (BDNF) has gained attention as a therapeutic agent due to its potential biological activities, including osteogenesis. However, the molecular mechanisms involved in the osteogenic activity of BDNF have not been fully understood. This study aimed to investigate the action of BDNF on the osteoblast differentiation in bone marrow stromal cells and its influence on signaling pathways.

Materials and Methods: Preosteoblast cells (MC3T3-E1), bone marrow-derived stromal cells (ST2), and a direct 2D co-culture system were treated with BDNF. The effect of BDNF on cell proliferation was determined using the CCK-8 assay. Osteoblast differentiation was assessed based on alkaline phosphatase (ALP) activity/staining and the protein expression of multiple osteogenic markers. Calcium deposition was examined by Alizarin red S staining. To further investigate whether MAPKs are involved in BDNF-induced osteoblast differentiation in bone marrow stromal cells,the effects of specific MAPK inhibitors (ERK, JNK and p38 MAPK inhibitor) in the presence and absence of BDNF (100 ng/mL) on osteoblast differentiation of ST-2 cells were examined.

Results: BDNF significantly increased ALP activity, calcium deposition, and the expression of osteoblast differentiation-related proteins such as ALP, osteopontin, Runx2 and BMP-2 in both ST-2 and the MC3T3-E1 and ST-2 co-culture systems. BDNF (100 ng/mL) treatment significantly activated JNK, p38 MAPK and slightly induced ERK from 15 min to 1 h, as evidenced by increased phosphorylation. Moreover, the effect of BDNF on osteogenic differentiation was diminished by blocking tropomyosin receptor kinase B (TrkB), as well as inhibiting mainly p38 MAPK signaling.

Conclusions: Our study showed that BDNF increased

osteoblast differentiation and mineralization of bone marrow-derived stromal cells through TrkB receptor and p38 MAPK signaling pathways.

Keywords: BDNF, Osteogenesis, P38 MAPK

S164

AI-Driven Patient-Specific Spinal Digital Twin for Spine Healthcare: Proof-of-Concept Research

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Purpose: Real-time biomechanical assessment of the lumbar spine holds significant promise for enhancing surgical planning, intraoperative guidance, and postoperative monitoring. This study presents a proof-of-concept digital twin framework capable of real-time prediction and visualization of lumbar spine biomechanics in both native and surgically treated conditions.

Materials and Methods: The proposed computational modeling approach integrates multibody dynamics (MBD), finite element analysis (FEA), and surrogate modeling. A hybrid framework was developed by coupling high-fidelity MBD-FE simulations with two sequential Kriging surrogate models: the first predicts spinal loads based on three-dimensional lumbar rotations, while the second estimates von Mises stress and displacement from these predicted loads for both native and postoperative spine models, specifically those treated with transforaminal lumbar interbody fusion (TLIF) and pedicle screw fixation. Model validation was performed through comparison with full-order simulations and benchmarked against literature-reported intradiscal pressure (IDP) values.

Results: Across various lumbar motions—flexion, extension, lateral bending, and axial rotation—the predicted stresses and displacements showed high accuracy, with mean absolute errors below 0.5% for native spines and below 0.2% for postoperative spines. IDP estimates fell within or close to physiologic ranges reported in prior in vivo and in silico studies, supporting the model's biomechanical fidelity.

Conclusions: These results underscore the digital twin framework's potential for clinical translation, offering rapid and reliable biomechanical insights. Future integration with patient-specific imaging data, experimental validation, and streamlined software deployment could allow for personalized surgical simulations, intraoperative mechanical assessments, and long-term follow-up evaluations. Clinically, this system could assist surgeons in identifying abnormal load conditions in real time, enabling preemptive interventions to prevent implant failure or degenerative progression. The study highlights a pathway toward intelligent, adaptive spine care powered by physics-informed surrogate modeling and real-time digital twin technologies.

Keywords: Spinal digital twin, Real-time biomechanical prediction, Physics-informed surrogate modeling, Multibody dynamics, Finite element analysis

S165

Dynamic Variability of Pelvic Incidence in Weight-Bearing 3D CT: A Spinopelvic Analysis in Elderly Patients

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Purpose: Pelvic incidence (PI) is traditionally regarded as a fixed anatomical parameter, but recent evidence suggests that postural and imaging factors may influence its measurement. This study aimed to evaluate changes in spinopelvic parameters, particularly PI, between weight-bearing and non–weight-bearing CT, and to identify contributing clinical and anatomical factors.

Materials and Methods: Fifty elderly patients (mean age: 76.84 years) with degenerative lumbar disorders underwent both weight-bearing CT (WBCT) and non–weight-bearing CT (NWBCT). A 3D analysis framework was used to measure PI, pelvic tilt (PT), sacral slope (SS), and the S1–femur coronal angle (S1FCA). Paired t-tests, correlation, and regression analyses were conducted.

Results: PI was significantly higher in the weight-bearing condition (WBCT PI: 52.04±10.14° vs. NWBCT PI: 49.35±9.90°, p<0.001). PT also increased and SS decreased

under weight-bearing. S1FCA change was moderately correlated with ΔPI (r=0.346, p=0.014) and served as an independent predictor in regression analysis. Patients with prior spinal fusion showed significantly smaller PI changes (–1.55° vs. +2.96°, p=0.021), suggesting restricted sacral mobility. Furthermore, PI values differed significantly between WBCT and standing X-ray (WBXR) even in the same posture (p=0.031), possibly due to projectional distortion.

Conclusions: PI is a dynamic, posture- and modality-dependent parameter affected by coronal rotation and fusion status. These findings challenge its conventional interpretation and support the use of weight-bearing 3D imaging and coronal parameters such as S1FCA for accurate evaluation.

Keywords: Pelvic incidence, Spinopelvic parameter, Weight-bearing Imaging, Adult spinal deformity, Posture

Free Paper: Basic Research (2)

S166

Thrombospondin-1 Plays a Role in Intervertebral Disc Aging and Degeneration

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Purpose: Intervertebral disc degenerative disease (IVDD) is a primary cause of chronic back pain and disability, with aging serving as a critical pathogenic factor. Thrombospondin-1 (TSP1), a multifunctional matricellular protein, is implicated in various degenerative conditions, yet its specific role in IVDD remains unclear. This study aims to elucidate the role of TSP1 in intervertebral disc aging and degeneration, specifically focusing on its impact on oxidative stress, fibrosis, and inflammatory pathways.

Materials and Methods: Nucleus pulposus (NP) tissues were harvested from surgical patients and divided into young (<30 years) and aged (>60 years) groups. TSP1 expression was analyzed using immunohistochemistry and protein assays. To simulate the aging process, an NP cell aging model was established via serial passaging. The biological effects of TSP1 on oxidative stress, fibrosis, and inflammation were further evaluated in vitro.

Results: Experimental results revealed significantly elevated TSP1 expression in aged NP tissues. This elevation correlated with increased levels of oxidative stress markers (Nox1), fibrosis markers (TGF-β, collagen I), and inflammatory cytokines (TNF-α, IL-1). Notably, the application of TSP1 antibodies significantly reduced these aging-related markers in the in vitro model.

Conclusions: This study demonstrates that TSP1 plays a pivotal role in the aging and degeneration of the intervertebral disc by modulating oxidative stress, fibrosis, and inflammation. These findings identify TSP1 as a potential biomarker for IVDD and establish a scientific foundation for future TSP1-targeted therapeutic interventions.

Keywords: Thrombospondin-1, Intervertebral disc degenerative disease (IVDD), Cellular aging, Oxidative stress, Fibrosis and Inflammation

S167

Deep Learning Architectures for Surgical Instrument Segmentation in Endoscopic Spine Surgery: A Comparative Evaluation of Foundation Models and Task-Specific Approaches

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Purpose: To compare the segmentation accuracy of foundation models versus task-specific deep learning architectures for automated surgical instrument detection in endoscopic spine surgery.

Materials and Methods: Seven deep learning architectures were evaluated: U-Net, Attention U-Net, U-Net++, SegFormer, DeepLabV3+, nnU-Net, and MedSAM2. A dataset of 3,848 endoscopic frames with binary segmentation masks was collected from 20 patients undergoing full-endoscopic (n=10) or biportal endoscopic (n=10) lumbar procedures. Images were split into training (n=2,805), validation (n=333), and test (n=710) sets. The Dice Similarity

Coefficient (DSC) served as the primary outcome measure. Pairwise comparisons used Wilcoxon signed-rank tests with Bonferroni correction.

Results: MedSAM2 achieved the highest test set performance (Dice=0.9481), followed by nnU-Net (Dice=0.9204). Both exceeded the 0.90 threshold for excellent segmentation accuracy. MedSAM2 demonstrated superior generalization with improved test performance (+0.7 percentage points), while nnU-Net showed a 3.5 percentage point drop suggesting overfitting. Among conventional architectures, DeepLabV3+ performed best (Dice=0.8845). DeepLabV3+ significantly outperformed all U-Net variants (p<0.001). No significant differences were found among U-Net, U-Net++, and SegFormer.

Conclusions: Foundation model approaches achieve superior surgical instrument segmentation accuracy compared to task-specific architectures in endoscopic spine surgery. MedSAM2 and nnU-Net exceeded thresholds suitable for autonomous assistance applications, with MedSAM2 demonstrating better generalization. These findings support clinical translation of AI-assisted surgical guidance systems while highlighting needs for real-time optimization.

Keywords: Deep learning, Surgical instrument segmentation, Endoscopic spine surgery, Foundation model, MedSAM2, nnU-Net

S168

Synthetic MRI of the Spine – Reconstruction from CT and In Vivo Validation

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Purpose: Using synthesized MRI from CT spine images via artificial intelligence (AI), our focus was to establish robust evaluation metrics and evaluate the potential of the newly devised MR image synthesis.

Materials and Methods: AI-generated MR images were created using a CycleGAN-based model (Polestar Healthcare©, Seoul, Korea) from anonymized CT spine images of adult patients enrolled in Eunpyeong St. Mary's Hospital in Korea who underwent imaging studies for suspected disc herniation or spinal stenosis. The primary outcome was the interrater agreement between synthetic MR images versus the actual MR images, compared to CT images versus the actual MR images in terms of six clinical components regarding the lesion: (1) Level of the lesion in central canal, (2) stenosis degree in central canal, (3) disc pathology in central canal, (4) level of the lesion in neural foramen, (5) laterality of the lesion in neural foramen, (6) stenosis degree in neural foramen. Each assessment was made by either sagittal CT/MR T1, T2WI or axial CT/MR T1, T2WI. Secondary outcomes were determined for the overall image quality of the synthesized MR images: (1) The border of the cortical bone is clearly distinguishable, (2) Nerve root is clearly distinguishable within the foraminal fat, (3) Dural sac boundary is clearly visible, (4) Disc boundary is clearly visible, (5) Spinal cord and cauda equina are clearly distinguishable within the CSF, (6) There are no significant artifacts obscuring the image. All interrater agreements were calculated using Gwet's AC1 coefficient.

Results: A total of 28 patients were included as study participants. Two independent raters (a board-certified orthopedic spine surgeon and a board-certified musculoskeletal radiologist) assessed the primary and secondary outcomes of CT images and the synthesized MR images. Another independent rater (a board-certified musculoskeletal radiologist) evaluated the primary outcomes of the actual MR images. All interrater agreements except the stenosis degree in the central canal and neural foramen were above 0.500 with P values < 0.001 for primary outcomes in synthetic MR images versus actual MR images. Secondary outcomes regarding the quality of the synthesized MR images showed interrater agreement of > 0.70 (all P values < 0.001) across all domains.

Conclusions: MR spine images synthesized via AI technology from CT spine images have been proven to be non-inferior to conventional CT imaging in terms of clinical assessment and image quality.

Keywords: AI, Deep learning, MRI, CT, Spine

S169

Preclinical Evaluation of a Pulsed Electromagnetic Field (PEMF) Device for Enhancing Bone Regeneration in a Rat Defect Model

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Purpose: Pulsed electromagnetic field (PEMF) therapy has been reported to enhance bone healing and regeneration; however, preclinical evidence supporting its efficacy in localized cranial bone defects remains limited. The purpose of this study was to evaluate the bone regenerative potential and underlying biological effects of a PEMF-generating device using both a rat calvarial defect model and in vitro cellular assays.

Materials and Methods: A standardized bilateral calvarial defect was created in Sprague–Dawley rats (8-week-old males). Animals were divided into a PEMF-treated group (G2, n=3) and a non-treated control group (G1, n=3). The experimental group received PEMF stimulation for 20 minutes per session, five times per week, for four weeks. All procedures were approved by the Institutional Animal Care and Use Committee. Bone regeneration was quantitatively assessed using micro–computed tomography (micro-CT), measuring total volume (TV), bone volume (BV), and BV/TV ratio at 4 weeks post-treatment. In vitro studies were conducted using MC3T3-E1 osteoblastic cells to assess osteogenic differentiation through quantitative PCR analysis of osteogenic markers (OCN, OPN, Runx2, and ALP) and alkaline phosphatase activity. Additionally, an LPS-induced inflammatory model using THP-1 cells was employed to evaluate changes in inflammatory cytokine expression (IL-6, IL-1β, TNF-α, and iNOS).

Results: In the animal study, the PEMF-treated group demonstrated a trend toward increased new bone formation compared with the control group. Micro-CT analysis revealed an approximately 17% increase in BV/TV in the PEMF group, although this difference did not reach statistical significance. No treatment-related adverse events, including weight loss or mortality, were observed. In vitro, PEMF exposure significantly upregulated osteogenic gene expression and ALP activity in MC3T3-E1 cells. Furthermore, PEMF treatment attenuated the expression of pro-inflammatory cytokines in LPS-stimulated THP-1 cells, suggesting a potential anti-inflammatory effect.

Conclusions: PEMF stimulation demonstrated a favorable trend toward enhanced bone regeneration in a rat calvarial defect model and promoted osteogenic differentiation while suppressing inflammatory responses at the cellular level. Although limited by small sample size, these preclinical findings support the potential therapeutic role of PEMF in bone regeneration. Further large-scale animal studies and clinical trials are warranted to confirm its efficacy.

Keywords: Pulsed electromagnetic field, Bone regeneration, Bone defect, Micro-CT, Preclinical study

S170

Rotation-Related Deviation in Pelvic Incidence Measurement: A Three-Dimensional Analytical Study

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Purpose: Pelvic incidence (PI) is a key anatomical parameter for understanding spinopelvic sagittal balance in the upright position and is defined as the geometric sum of pelvic tilt (PT) and sacral slope (SS). PT is measured as the angle between a line connecting the midpoint of the S1 superior endplate to the center of the femoral heads and a line perpendicular to the S1 endplate. In conventional plain radiographs, bilateral femoral heads are often not projected orthogonally, resulting in two separated femoral head images. In such cases, the midpoint between the bilateral femoral heads is commonly used for PI measurement. However, the effect of femoral

head rotational displacement on PI measurement accuracy has not been well investigated. This study aimed to evaluate deviations in PI caused by horizontal and vertical rotations of the bilateral femoral heads.

Materials and Methods: Three-dimensional (3D) models of the sacrum, pelvis, and femoral heads were reconstructed within a virtual coordinate system. The orthogonal PI was calculated using a simulated orthogonal alignment of the bilateral femoral heads. Horizontal and vertical rotational movements of the femoral heads were then simulated, and PI was recalculated at each rotational position. Rotational PI values were compared with the orthogonal PI across defined rotation ranges. Friedman test, followed by a linear mixed-effects model was applied to characterize pairwise differences.

Results: The three-dimensional analytical model successfully reproduced the orthogonal pelvic incidence (PI). With increasing bilateral femoral head rotation, horizontal rotation was associated with a gradual increase in measured PI, whereas vertical rotation resulted in a gradual decrease. Compared with the orthogonal PI, rotational PI values demonstrated statistically significant differences in both horizontal and vertical directions (Friedman test, $p<0.05$ for both), the linear mixed-effects model showed a significant fixed effect of the variation ($p<0.05$ for both).

Conclusions: Pelvic incidence measurements are susceptible to variation induced by horizontal and vertical rotational displacement of the femoral heads. While such positional rotation may influence PI measurement, the clinical implications of these variations and their correction into the orthogonal PI warrant further investigation.

Keywords: Pelvic incidence, Femoral head rotation, measurement deviation, Three-dimensional analysis, Aagittal balance

Free Paper: Tumor

S171

The Learning Curve of Total En Bloc Spondylectomy (TES) in a Resource-Limited Setting: A Case Series from Eastern Indonesia

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Purpose: Performing complex spinal oncology surgeries like Total En Bloc Spondylectomy (TES) in developing countries presents unique challenges, including limited resources, high patient expectations, and late presentations. This study describes the institutional learning curve and outcomes for TES performed during the COVID-19 pandemic in a tertiary hospital in Eastern Indonesia.

Materials and Methods: A retrospective case series of six consecutive patients who underwent TES between 2020 and 2022 was analyzed. Demographic data, tumor characteristics (primary vs. metastatic), surgical parameters, complications, and outcomes were evaluated. The setting is the largest tertiary referral hospital in Eastern Indonesia, which serves a vast population with constrained facilities.

Results: Six patients underwent TES: two for primary spinal tumors and four for isolated spinal metastases. All patients presented with advanced disease and high expectations from their families, having traveled significant distances. Despite infrastructural limitations, the procedures were completed. The analysis indicates a steep learning curve, with technical and logistical challenges magnified by the pandemic. The most favorable outcomes and indications were observed in the two primary tumor cases.

Conclusions: TES is a viable but demanding procedure in a resource-limited setting. A significant learning curve exists, impacted by systemic constraints. This series suggests that careful patient selection is critical, with primary spinal tumors representing the best indication for TES in such environments. Centralization of these complex cases to regional referral centers is essential to build expertise and improve outcomes.

Keywords: Total en bloc spondylectomy, COVID-19

pandemic, Tertiary hospital, Spinal tumors, Spinal metastases

S172

Clinical Outcomes of Surgery versus Radiotherapy in Bilsky Grade 3 Metastatic Epidural Spinal Cord Compression

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Purpose: Surgery is generally recommended for higher Bilsky grade metastatic epidural spinal cord compression (MESCC); however, Bilsky grades 2–3 are often grouped together, leaving limited evidence for managing patients with Bilsky grade 3 MESCC who have not developed neurological deficits. This study aimed to evaluate whether, and when, surgery should be performed in Bilsky grade 3 MESCC.

Materials and Methods: This retrospective cohort study included patients diagnosed with Bilsky grade 3 MESCC from January 2021 to January 2025. A total of 138 patients were assigned to a radiotherapy (RT) group (n=54) or a surgery group (n=65) based on initial treatment. Demographics, clinical data, treatment outcomes, and treatment modalities were analyzed. Logistic regression identified risk factors for local progression, motor recovery, and ambulatory outcomes.

Results: Ninety-five patients (70.3%) initially presented with weakness. Among 30 patients diagnosed before neurological deficits, interval from diagnosis to onset was 17.2±14 days. Local progression and survival rates did not significantly differ between the groups. Surgery was associated with a higher likelihood of motor recovery (odds ratio [OR]=10.05, p<0.001) and better ambulatory function (OR=0.433, p=0.003). Higher initial motor grade and lower Eastern Cooperative Oncology Group Performance Status scores were also linked to favorable ambulatory outcomes.

Conclusions: In Bilsky grade 3 MESCC, the mean interval from diagnosis to weakness onset was 17.2 days. Local progression and survival did not differ between RT and surgery; however, surgery provided superior motor recovery and ambulatory outcomes. Early surgery may offer improved functional outcomes in Bilsky grade 3 MESCC.

Keywords: Bilsky grade 3, Metastatic epidural spinal cord compression, Radiation therapy, Surgery, Spinal metastases

S173

Simultaneous Anterior-Posterior En Bloc Spondylectomy Using Rotated Prone Lateral Surgery: A Technical Note and Case Series

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Purpose: En bloc spondylectomy at the thoracolumbar junction, particularly for Weinstein-Boriani-Biagini (WBB) type 3 and 5 en bloc resection, presents a significant surgical challenge. Unlike thoracic levels, the L2-4 nerve roots cannot be sacrificed due to their critical function, often necessitating combined anterior and posterior approaches to safely release the anterior structures and perform reconstruction. Conventionally, this requires staged surgeries or cumbersome intraoperative repositioning. This study introduces a novel technique, rotated prone lateral surgery, which enables simultaneous anterior and posterior access. We demonstrate that this approach facilitates complete tumor resection and reconstruction in a single position, effectively overcoming these anatomical constraints without the need for flipping the patient.

Materials and Methods: We retrospectively reviewed 10 consecutive patients who underwent en bloc spondylectomy using the rotated prone lateral approach at a single institution. Patients were positioned prone on a radiolucent Jackson table, which was then rotated 45° away from the surgical side. This specific orientation utilizes gravity to retract the peritoneal contents and provides simultaneous access to the retroperitoneal/retropleural corridor (for anterior release, diaphragm management and vessel mobilization) and the posterior column (for instrumentation and osteotomy). Patient demographics, tumor pathology (WBB classification), operative time, blood loss, surgical margins, and perioperative complications were analyzed.

Results: The cohort included 10 patients (mean age: 59.7 ± 9.3 years) with oligoprogression metastatic thoracolumbar

tumors. The procedures involved levels from L1 to L4, requiring WBB type 3 or 5 resections. All patients successfully underwent single-stage en bloc resection without intraoperative repositioning. The mean operative time was 7 hours 19 minutes±2 hours 55 minutes, and the mean estimated blood loss was 1117±899 ml. The rotated prone position allowed for simultaneous approach and manipulation for en bloc resection of the spinal tumor. No major approach-related complications (e.g., bowel injury, major vascular injury) occurred, though one patient experienced root injury.

Conclusions: Rotated prone lateral en bloc spondylectomy is a safe and feasible technique that eliminates the need for patient repositioning. It is particularly advantageous for WBB type 3 and 5 tumors in the thoracolumbar/lumbar spine where diaphragm management or nerve root preservation requires a dual approach. By offering improved surgeon ergonomics and simultaneous access, this technique represents a valuable alternative to traditional staged strategies for complex thoracolumbar spinal tumors.

Keywords: En bloc spondylectomy, Rotated prone lateral surgery, WBB classification, Thoracolumbar spine tumor, Single position surgery

S174

Risk Stratification of Spinal Metastasis in Non-Small Cell Lung Cancer Using Treatment Response-Integrated Machine Learning Survival Models

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Purpose: Late detection of spinal metastasis in non-small cell lung cancer (NSCLC) can lead to irreversible neurological damage, yet early risk stratification remains challenging. This study aimed to (1) identify latent clinical phenotypes with distinct metastatic risks and (2) develop interpretable machine learning-based survival models for dynamic risk stratification by integrating initial treatment-related information.

Materials and Methods: We retrospectively reviewed data from 392 NSCLC patients without synchronous spinal metastasis at a single tertiary referral hospital from 2015 to 2025. The cohort was randomly partitioned into train-validation (N=314) and test (N=78) sets. Unsupervised cluster analysis was conducted on the total cohort to explore latent clinical phenotypes and their associations with metastatic risk. Two XGBoost survival models were developed for spinal metastasis risk stratification: a Compact Model that inputs demographic, clinicopathological, and molecular features, and a Complex Model that further integrates initial treatment modalities and responses. Model performance was evaluated using the concordance index (C-index) and time-dependent area under the receiver-operating characteristic curve (t-AUROC). Their interpretability was assessed with Kaplan-Meier curves and Shapley additive explanations (SHAP) analysis.

Results: The mean age of the cohort was 67.8 ± 10.1 years, with 191 (48.7%) being male and 188 (48.0%) having experienced spinal metastasis during follow-up. Cluster analysis identified six distinct groups characterized by unique combinations of clinical attributes. In the test set, the Complex Model achieved a C-index of 0.789 (0.717-0.855) and a mean t-AUROC of 0.833 (0.749-0.905), while the Compact Model showed a C-index of 0.755 (0.680-0.827) and a mean t-AUROC of 0.787 (0.696-0.871). A significant gain in mean t-AUROC (gain: 0.046; 95% CI: 0.004-0.094) was observed, while the C-index improvement was not statistically significant (gain: 0.034; 95% CI: -0.004 to 0.075). Kaplan-Meier analysis confirmed effective risk stratification, with a significant disparity in metastasis-free survival between high- and low-risk subgroups ($p < 0.001$). SHAP analysis identified clinical stage and initial treatment response as the most influential predictors.

Conclusions: The machine learning models effectively stratified spinal metastasis risk in NSCLC patients by integrating clinicopathological, molecular, and therapeutic data. These findings may potentially facilitate personalized surveillance and timely intervention for high-risk individuals.

Keywords: Non-small cell lung cancer, Spinal metastasis, Machine learning, Survival analysis, Risk stratification, Cluster analysis

S175

Intraoperative Neuromonitoring for Spinal Cord Tumors

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Purpose: The objective is to describe and evaluate the clinical importance and role of intraoperative neuromonitoring in spine surgery, with emphasis on its use in the resection of intramedullary and extramedullary spinal cord tumors.

Materials and Methods: This presents institutional experience along with current evidence regarding the use of multimodal IONM including somatosensory evoked potentials (SSEPs), motor evoked potentials (MEPs), electromyography (EMG), and direct waves (D-Waves). Alarm criteria for each modality are discussed, along with the identification of false errors and a troubleshooting algorithm in cases of true signal loss or decrease.

Results: It is widely recognized that resection of spinal cord tumors comes with a significant risk of neurologic morbidity. To prevent the devastating complications of postoperative neurologic deficits, intraoperative neuromonitoring (IONM) has emerged as a critical adjunct to spine surgery, with the goal of early identification of intraoperative neural insults in order to allow early intervention and minimize the irreversible damage to the patient's neurological structures.

Conclusions: In conclusion, IONM can be seen as an indispensable tool used in today's modern spinal cord tumor surgery, and its integration should be considered as a standard of care to both optimize patient safety and lower surgical morbidity.

Keywords: IONM, D-waves, Spinal cord tumors

Free Paper: Trauma

S176

A New Scoring System Incorporating Hounsfield Unit Values to Predict Adjacent Vertebral Fracture After Balloon Kyphoplasty

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Purpose: Several scoring systems have been proposed to predict adjacent vertebral fracture (AVF) after balloon kyphoplasty (BKP); however, none of these systems incorporate indicators reflecting bone mineral density. This limitation is thought to be attributable to the inherent constraints of dual-energy X-ray absorptiometry (DEXA), the conventional method for bone density assessment. Recently, vertebral Hounsfield Unit (HU) values obtained from computed tomography have attracted attention as a novel quantitative indicator of bone quality. The purpose of this study was to develop a new AVF prediction scoring system incorporating HU values and to compare its predictive accuracy with that of existing scoring systems.

Materials and Methods: A total of 159 patients aged ≥60 years who underwent BKP for osteoporotic vertebral fractures after 2011 were retrospectively analyzed. Logistic regression analysis was performed using previously reported scoring variables (age, previous vertebral fracture, and local kyphosis), with the addition of the HU value of the L1 vertebral body (L1 HU). A new scoring system was constructed based on the odds ratios. The association between total score and AVF incidence was evaluated, and predictive performance was compared with that of the conventional scoring system using the area under the receiver operating characteristic curve (AUC).

Results: AVF occurred in 47 of 159 patients (29.6%). Multivariate analysis identified age, previous vertebral fracture, local kyphosis, and L1 HU value (odds ratio=0.973, $p<0.001$) as independent risk factors for AVF. A new

scoring system incorporating HU values (cutoff: 80 HU) demonstrated a clear correlation between total score and AVF incidence (0 points: 0%, 1 point: 9.7%, 2 points: 13.6%, 3 points: 42.2%, 4 points: 59.3%, 5 points: 80.0%). The AUC significantly improved from 0.774 for the conventional score to 0.811 for the new score (p=0.013).

Conclusions: We developed a new AVF prediction scoring system incorporating HU values. The inclusion of HU values significantly improved predictive accuracy, suggesting that this scoring system is useful for predicting adjacent vertebral fractures after balloon kyphoplasty.

Keywords: Osteoporotic vertebral fracture, Balloon kyphoplasty

S177

Can Short-Term Osteoporosis Medication Prevent Vertebral Height Loss in the Acute Phase of Osteoporotic Vertebral Compression Fractures? A 3-Month Longitudinal Analysis

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Purpose: The optimal pharmacological strategy to prevent progressive vertebral collapse during the acute phase of osteoporotic vertebral compression fractures (OVCFs) remains controversial. This study investigated whether short-term osteoporosis medication could mitigate vertebral height loss during the initial 3 months post-injury and identified the primary determinants of radiographic progression.

Materials and Methods: We retrospectively reviewed 123 treatment-naïve patients with single-level acute OVCFs. Patients were stratified into four groups: control (n=26), denosumab (DMAB, n=35), teriparatide (TPTD, n=30), and romosozumab (RM, n=32). The vertebral compression rate (VCR) was measured serially over 3 months. A linear mixed model (LMM) was used to analyze the VCR trajectory, with adjustments for baseline imbalances in the initial VCR. Clinical outcomes were assessed using the Visual Analog Scale (VAS).

Results: In the unadjusted analysis, DMAB appeared to show a slower progression of compression compared to the control group. However, after adjusting for the initial VCR in the LMM, none of the medication groups showed a significant structural benefit in preventing height loss (p>0.05). Instead, the interaction between time and initial VCR (β=-0.033, p=0.003) and unstable fracture morphology (Sugita classification; β=2.758, p<0.0001) were identified as the primary drivers of vertebral collapse. Clinically, the RM group showed significantly lower overall pain levels throughout the follow-up period compared to the control group (p=0.014).

Conclusions: Short-term osteoporosis medication did not significantly alter the radiographic progression of vertebral height loss during the initial 3-month acute phase of OVCF. The trajectory of vertebral collapse was principally determined by baseline structural characteristics, such as fracture morphology and initial severity, rather than pharmacological intervention. While medication provides limited structural protection in the acute phase, romosozumab may offer superior clinical benefit in early pain management.

Keywords: Osteoporotic fractures, Spinal fractures, Romosozumab, Teriparatide, Linear models, Fractures, Compression

S178

Comparison of Effectiveness of Pedicle Screw with Polyaxial/Monoaxial Conversion Capabilities with Conventional Pedicle Screws in the Reduction of Focal Kyphosis of Burst Fracture

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Purpose: This study aims to compare the effectiveness of pedicle screw with polyaxial/monoaxial conversion capabilities with conventional pedicle screws in the reduction of focal kyphosis of thoracolumbar spine burst fracture.

Materials and Methods: This is a retrospective review of patients admitted to the department of Orthopedics and Traumatology of the Prince of Wales Hospital, Hong Kong from 7/2005–12/2024 who underwent surgery for fixation of thoracolumbar burst fracture. Preoperative and postoperative

wedge angle of fractured vertebra were compared between conventional pedicle screw construct and new pedicle screw with polyaxial/monoaxial conversion capability.

Results: There is no statistically significant difference in the improvement of wedge angle of thoracolumbar burst fracture treated with new pedicle screw system with polyaxial/monoaxial conversion capability compared with traditional pedicle screw

Conclusions: Use of New pedicle screw design with polyaxial/monoaxial conversion capability cannot improve the sagittal spinal alignment in patients with burst fracture who received posterior spinal fusion

Keywords: Spinal fractures, Pedicle screws, Fracture fixation, Kyphosis

S179

Comparison of Surgical Outcomes Between Single Day A-P and Staged P-A Approach in Traumatic Thoracolumbar Fractures

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Purpose: Anterior-posterior surgery provides adequate decompression and structural stability for highly unstable burst fractures with neurological deficits. However, hemodynamic instability in major trauma patients makes this approach challenging and the extended surgical time burdensome. There are few studies on staged operations that provide structural support through the anterior approach following posterior decompression and fixation. The purpose of this study was to compare the clinical and radiological outcomes of single-day anterior-posterior surgery (AP group) and staged posterior-anterior surgery (PA group) for thoracolumbar fractures in patients with major trauma.

Materials and Methods A retrospective review was performed on a consecutive series of patients with thoracolumbar burst fractures who underwent anterior surgery, focusing on major trauma patients (injury severity score >15) who visited a level 1 trauma center. Out of the total 57 patients, 14 were in the AP group, and 43 were in the PA group. Surgical outcomes such as operative time, intraoperative blood loss, total hospital length of stay (HOS-LOS), and intensive care unit length of stay (ICU-LOS) were investigated. A neurological assessment was performed by a rating system based on the American Spine Injury Association (ASIA) impairment scale. Radiographic outcomes, including fusion rates and implant failure, were compared between groups.

Results: The average time from hospitalization to the first spinal surgery was significantly shorter in the PA group (96.2±77.5 hour vs. 12.7±19.3 hours), and the amount of blood loss during the first surgery (1282.1±1117.8 ml vs. 778.1±379.8 ml) was lower compared to the AP group ($p<0.01$). There was no difference in HOS-LOS or ICU-LOS between the groups. At the time of the final observation, all patients in both groups showed neurological improvement, except those classified as AIS A. In addition, there was no significant difference in the fusion rate or the incidence of implant failure between the two groups.

Conclusions: Staged posterior-anterior surgery represents a safe and efficient treatment strategy for major trauma patients with unstable thoracolumbar burst fractures.

Keywords: Thoracolumbar fracture, Major trauma, Single day surgery, Staged surgery

S180

Impact of Anti-osteoporosis Medication on Refracture Prevention Following Osteoporotic Vertebral Fracture: A Systematic Review and Meta-analysis

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Purpose: To examine the effects of anti-osteoporosis medications, including bisphosphonates, teriparatide, denosumab, romosozumab, and vitamin D, on refracture prevention in patients with existing OVFs.

Materials and Methods: This systematic review and meta-analysis was conducted in accordance with the PRISMA 2020 guidelines. PubMed, EMBASE, and the Cochrane Library were systematically searched for studies published up

to January 2025 that evaluated the effects of anti-osteoporosis medications on refracture prevention in adult patients with osteoporotic vertebral fractures. Two independent reviewers screened eligible studies and extracted data on subsequent vertebral fracture rates, percentage change in lumbar spine bone mineral density from baseline, and patient-reported clinical outcomes, including pain and functional status assessed by the Visual Analog Scale, Oswestry Disability Index, and Roland Morris Disability Questionnaire. Comparative analyses were performed across seven predefined treatment groups, including bisphosphonates, teriparatide, denosumab, romosozumab, vitamin D, and control regimens. Random-effects meta-analyses were conducted to calculate odds ratios for refracture outcomes and mean differences, with heterogeneity assessed using the I^2 statistic and publication bias evaluated by funnel plots and Egger's test when applicable.

Results: Compared with control, bisphosphonates significantly reduced subsequent vertebral fracture rates at 1 year (OR=0.29, 95% CI 0.20–0.43) and at final follow-up (OR=0.35, 95% CI 0.26–0.48), and increased lumbar spine BMD (MD=3.46% at 1 year and 5.42% at 3 years). Bisphosphonates were also associated with modest improvements in pain and function, with lower VAS scores at 6–12 months and improved ODI at 12 months. Teriparatide showed a significantly lower risk of subsequent vertebral fractures compared with both control (OR=0.39, 95% CI 0.16–0.97) and bisphosphonates (OR=0.41, 95% CI 0.30–0.56), and provided greater early pain relief than bisphosphonates at 3 months (VAS MD=−14.11). Vitamin D supplementation improved functional outcomes at 3 months compared with control (RMDQ MD=−1.59). In patients undergoing vertebral augmentation, romosozumab was associated with a significantly lower risk of subsequent vertebral fractures than bisphosphonates (OR=0.21, 95% CI 0.09–0.51).

Conclusions: We suggest teriparatide as the first-line treatment for patients with OVF in the secondary prevention of fractures. For patients who have undergone vertebral augmentation romosozumab should be considered as a treatment modality. Bisphosphonates can be used as a second-line treatment for patients with contraindications to teriparatide or romosozumab.

Keywords: Osteoporotic vertebral fracture, Bisphosphonate, Teriparatide, Romosozumab, Refracture

Invited Lecture VI

S181

Awake Robotic Spinal Fusion – A New Paradigm in Minimally Invasive Spine Surgery

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Purpose: Redefining Spine Surgery through precision comfort and conscious care. While great strides have been made in the field of minimal invasive spine surgery with the aid of enabling technologies like navigation and robotics, true value care delivery requires a conscious effort to relook the entire surgical care journey. We share our early experience with awake spine surgery for 1-2 level lumbar spinal fusions utilizing our navigation based robotic system.

Materials and Methods: We embarked on a pilot of 20 cases utilizing robotic guided precision with Spinal and local anaesthesia. We share our development of a workflow together with our anaesthesia colleagues to make this possible.

Results: We successfully performed 19 cases of awake robotic spinal fusion with 1 failure. All 19 cases had no complications with excellent outcomes with regards to post operative early mobilization and opioid analgesia requirements and no PONV.

Conclusions: We propose that 1-2 level lumbar spinal fusions with robotic guidance can be safely performed without the need for General Anesthesia.

Keywords: Spine, MIS, Robotic, Awake

Symposium IV. Deformity: Frailty and ERAS in Spinal Deformity Surgery

S182

Frailty in Spinal Deformity Surgery: Why It Matters More Than Age

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As the surgical population for adult spinal deformity (ASD) continues to age, chronological age alone has proven to be an insufficient surrogate for perioperative risk stratification. Frailty — a multidimensional syndrome reflecting diminished physiological reserve across musculoskeletal, nutritional, cognitive, and cardiopulmonary domains — has emerged as a far more robust and actionable predictor of surgical outcomes than age in years.

Multiple validated instruments have been developed to quantify frailty in the surgical population. The modified Frailty Index (mFI-11), introduced by Velanovich et al. using the NSQIP database, maps eleven deficit variables to the original Canadian Study of Health and Aging Frailty Index.[1] Its streamlined successor, the 5-factor mFI (mFI-5), demonstrated equivalent predictive validity across surgical subspecialties and has gained widespread clinical adoption for its practicality. The Clinical Frailty Scale (CFS), developed by Rockwood et al., offers a pragmatic, judgment-based 9-point global assessment of fitness and frailty that correlates strongly with deficit-accumulation models. The Fried phenotype — defined by five physical criteria: unintentional weight loss, exhaustion, low activity, slowness, and weakness — provides a complementary phenotypic framework particularly suited to functional assessment.

In the ASD-specific context, Leven et al. demonstrated that the mFI is a significant independent predictor of major complications and mortality following ASD surgery, outperforming chronological age as a standalone variable.[5] Frail patients face substantially elevated risks of prolonged hospital stay, non-home discharge, 30-day readmission, and revision surgery — with odds ratios for major adverse events ranging from 2 to 4 — risks that age-based criteria entirely fail to capture. Critically, two patients of identical chronological age may carry profoundly different biological risk profiles.

Beyond its prognostic value, frailty stratification is directly actionable within the framework of Enhanced Recovery After Surgery (ERAS) protocols. Frailty assessment provides the basis for individualized perioperative pathway calibration: optimizing nutritional status, adjusting analgesia strategies, and titrating early mobilization targets to each patient's biological reserve. Emerging evidence demonstrates, however, that even within structured ERAS frameworks, frail patients continue to experience significantly higher rates of adverse outcomes compared to non-frail counterparts — underscoring that ERAS alone cannot substitute for frailty-informed perioperative planning.

The integration of frailty assessment into routine ASD surgical decision-making represents a paradigm shift: from asking “Is this patient too old for surgery?” to asking “Is this patient biologically prepared — and is our perioperative pathway calibrated to their reserve?”

S183

ERAS in Pediatric Spinal Deformity Surgery

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Introduction: Enhanced Recovery After Surgery (ERAS) has emerged as a multimodal perioperative care pathway aimed at improving clinical outcomes and accelerating recovery after major surgery. While widely adopted in adult populations, its application in pediatric spinal deformity—particularly adolescent idiopathic scoliosis (AIS)—continues to evolve. This review aims to examine the principles, protocols, and clinical outcomes of ERAS in AIS, and to highlight key factors for successful implementation.

Main Body: Preoperative strategies include patient education, physical preconditioning, pharmacologic optimization (e.g., anxiolytics and preemptive analgesics such as gabapentin), and anemia correction. Intraoperative management emphasizes

multimodal analgesia (intrathecal, epidural, and intravenous agents), blood loss reduction using tranexamic acid, and goal-directed fluid therapy. Postoperative care focuses on early mobilization (sitting on postoperative day 0 and ambulation on day 1 without bracing), early oral intake, and rapid transition from intravenous to oral analgesics. Implementation of ERAS protocols in AIS patients has been associated with significantly improved clinical outcomes. These include reduced length of hospital stay, with discharge by postoperative day 3 increasing from 1% to 62% in some studies, and decreased ICU admission rates. ERAS also leads to earlier mobilization, with time to first ambulation reduced by an average of 37.4 hours, and earlier removal of urinary catheters. Pain control is improved, particularly in the immediate postoperative period, alongside reduced opioid consumption and fewer opioid-related adverse effects. Blood loss reduction has been reported, although the clinical significance remains debatable due to potential confounding factors such as differences in deformity severity. Most available studies are retrospective, highlighting the need for high-quality randomized controlled trials.

Conclusions: ERAS protocols in AIS surgery demonstrate promising benefits in enhancing recovery, reducing hospital stay, and improving perioperative outcomes. Successful implementation requires adherence to a multimodal "bundle" approach and long-term sustainability. Rather than enforcing early discharge, the primary goal should be ensuring patient readiness for safe discharge. Initiating ERAS with feasible interventions—such as preemptive gabapentin, tranexamic acid, and local anesthetic techniques—may facilitate broader adoption and improved outcomes in pediatric deformity surgery.

Keywords: Enhanced recovery after surgery, Deformity, Adolescent idiopathic scoliosis, Length of hospital stay, Complication

S184

ERAS in Adult Spinal Deformity Surgery

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Adult spinal deformity (ASD) surgery is one of the most complex procedures in spine surgery and is frequently associated with substantial physiologic stress, major blood loss, prolonged operative time, high complication rates, and delayed functional recovery. Unlike routine lumbar fusion, patients undergoing ASD surgery are often elderly and medically vulnerable, with frailty, malnutrition, anemia, diabetes, smoking history, poor bone health, and chronic opioid use contributing to perioperative risk. Therefore, enhanced recovery after surgery (ERAS) in ASD should not be understood merely as a fast-track discharge protocol, but rather as a comprehensive risk-optimization pathway.

This presentation reviews the role of ERAS in ASD surgery across the entire perioperative timeline. In the preoperative phase, multidisciplinary assessment and optimization of modifiable risk factors are emphasized, including frailty, nutritional status, anemia, glycemic control, smoking cessation, and osteoporosis management. In the intraoperative phase, ERAS focuses on minimizing physiologic insult through blood-loss reduction strategies, tranexamic acid use, opioid-sparing multimodal analgesia, normothermia, euvolemia, hemodynamic stability, and efficient standardized surgical workflow. In the postoperative phase, the priority shifts toward functional recovery through early mobilization, early nutritional support, multimodal analgesia, prevention of opioid-related complications, and timely removal of urinary catheters and drains.

Current evidence suggests that ERAS pathways in ASD surgery may reduce postoperative complications, opioid consumption, and readmission rates, although the effect on length of stay remains inconsistent. Thus, the primary goal of ERAS in ASD surgery should not be limited to shortening hospitalization, but should include safer surgery, fewer complications, and faster restoration of functional independence.

Keywords: Adult spinal deformity, Enhanced recovery after surgery, Perioperative optimization

S185

AI-Based Spinal Deformity Surgery

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Purpose: To review current evidence on artificial intelligence (AI) in adult spinal deformity (ASD) surgery and to define its practical value within an enhanced recovery after surgery (ERAS) framework.

Materials and Methods: A focused narrative review was performed using recent peer-reviewed studies and society-level guidance relevant to AI, machine learning, ERAS, and ASD. The review emphasized automated radiographic measurement, patient phenotyping, perioperative prediction of length of stay, intensive care use, transfusion, discharge disposition, proximal junctional complications, mechanical complications, and postoperative recovery pathways.

Results: The most mature AI applications in ASD are automated alignment measurement and predictive analytics. Recent studies suggest that machine-learning models can support estimation of length of stay, intensive care unit utilization, transfusion needs, discharge disposition, proximal junctional kyphosis risk, and broader mechanical complications. Emerging clustering and multimodal models further suggest that age, frailty, physical function, mental health, bone quality, and soft-tissue factors may better reflect postoperative recovery potential than alignment alone. In parallel, ERAS pathways in ASD have been associated with shorter hospitalization and improved early recovery in selected cohorts. Taken together, these findings suggest that AI may provide its greatest near-term value when used to personalize ERAS intensity, including prehabilitation, blood management, postoperative monitoring, and discharge planning, rather than to replace surgeon judgment.

Conclusions: In adult spinal deformity surgery, the most clinically meaningful role of AI is pathway-level decision support. By combining radiographic, physiologic, and frailty-related variables, AI may help tailor perioperative recovery strategies and reduce avoidable complications. However, current evidence remains limited by retrospective design, heterogeneous datasets, and insufficient external validation. Prospective multicenter studies are needed before routine implementation.

Keywords: Spine, Adult spinal deformity, Risk assessment, Artificial intelligence, Enhanced recovery after surgery

Invited Lecture VIII

S186

Management Strategies in Pediatric Spinal Tubercular Deformity Correction

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Background and Introduction: Pediatric age group is significantly vulnerable to get infected with tubercular bacilli. There is increasing incidence of children getting infected primarily with multi-drug resistant bacilli. Destruction of pediatric spine poses challenging issues of resultant severe spinal deformity and neurological deficit. Cartilaginous nature of bone, miniature bone, need of pediatric implant, poor body reserve and poor tolerance to blood loss pose extra challenges in the management of pediatric tubercular deformity. Authors present an algorithm to manage these effectively.

Main Body: It is a series of 72 pediatric patients who presented with spinal deformity due to tubercular destruction of spine. It varied in regional distribution (CVJ -4 , Cervical spine -5 , Dorsal and DL region -59 , LS spine -4) This study spanned from 1996 to 2022. Out of 72 patients 51 patients had neurological deficit. Out of 72 patients, 26 patients presented with healed rigid spinal deformity while 46 presented with deformity but lesion was not yet healed fully and were on medical treatment. The age ranged from 3 yrs to 13 years. There were 39 females and 33 male patients. In 6 patient (3 - CVJ , 3 - cervical) deformity could be corrected with supervised surface traction (syre's) and later managed with rigid brace. In rest of the cases surgical intervention was done to achieve neural decompression and correction of the deformity. In healing lesion with deformity and deficit

in dorsal spine, column was exposed through versatile approach where through a single curvilinear incision anterior decompression and reconstruction was done while column was fixed posteriorly with sublaminar wire and Hartshill rectangle. Out of 26 healed and rigid kyphotic deformity, in 2 cases only internal gibbectomy was done. In rest of 24 cases rigid kyphotic deformity was corrected (Egg shell procedure -2 , closed wedge osteotomy -3 VCR - 19). VCR was done with step of controlled anterior distraction (with cage as spacer) and posterior compression after excision of apex of deformity. There was no neurological deterioration. All patients recovered neurologically. One patient had persistent spasticity but was able to ambulate independently. 2 patients had superficial wound infection which healed with dressing and medications. 2 patients had backing out of implant, one had breakage of sublaminar wire and these were revised. 2 patients had blackening of wound edges, it was excised and secondary suturing was done later.

Conclusions: With the understanding of vulnerability of pediatric patients and specific nature of pediatric spine, neural decompression and deformity correction can be done safely following the principle of spinal deformity correction in pediatric age group.

Keywords: Pediatric spine, Tubercular deformity, Decompression, Reconstruction, Fusion

Free Paper: Infection

S187

Efficacy and Modality of Antibiotics Administration Within 24 Hours After Spine Surgery

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Purpose: While guidelines recommend limiting prophylactic antibiotics to within 24 hours post-surgery, adherence still varies and the impact of strict duration limits on large-scale outcomes requires thorough validation. This study utilized the nationwide Health Insurance Review and Assessment (HIRA) Service database to evaluate the efficacy of prophylactic antibiotic administration discontinued within 24 hours versus prolonged administration in preventing surgical site infections (SSIs) following major spinal procedures.

Materials and Methods: This retrospective nationwide cohort study analyzed data from the 6th to 9th Quality Assessment (QA) waves of the HIRA database. The study population consisted of 59,003 patients who underwent spinal decompression, instrumented fusion, vertebroplasty, or kyphoplasty. Patients were categorized into two groups based on the duration of prophylaxis: those discontinued within 24 hours of surgery (n=9,754) and those receiving antibiotics for more than 24 hours (n=49,249). The primary outcome was the incidence of SSIs, defined by standardized clinical, microbiological, and radiological criteria. Multivariate logistic regression was employed to calculate odds ratios (OR) for SSIs, adjusting for potential confounders such as age, sex, comorbidities (diabetes, hypertension, malnutrition), hospital type, and antibiotic class.

Results: The overall incidence of SSIs in the study population was 1.54% (906 out of 59,003). The SSI rate was significantly lower in the group where antibiotics were discontinued within 24 hours (0.19%) compared to the prolonged administration group (1.80%; $p<0.05$). In the multivariate logistic regression analysis, prolonged antibiotic use (>24 hours) was associated with markedly higher odds of SSI (adjusted OR [aOR]: 15.250; 95% CI: 9.538–24.383; $p<0.05$) compared to the <24-hour group. Other independent risk factors for SSI included surgery performed at tertiary hospitals (aOR: 3.141; 95% CI: 2.591–3.809; $p<0.05$), malnutrition (aOR: 1.784; 95% CI: 1.275–2.498; $p<0.05$), and the use of combined antibiotic regimens (aOR: 4.514; 95% CI: 3.899–5.225; $p<0.05$) versus first- or second-generation cephalosporins alone.

Conclusions: Adherence to prophylactic antibiotic guidelines limiting duration to within 24 hours post-surgery is not associated with an increased risk of SSI in spinal decompression and fusion procedures.

Keywords: Antibiotics, Antibiotic prophylaxis, Surgical wound infection, Surgical site infection, Spine surgery

S188

Neurological Recovery After Surgical Intervention in Neglected Spinal Tuberculosis with Long-Standing Neurological Deficits: A Retrospective Case Series

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Purpose: In endemic regions, spinal tuberculosis often presents late with severe neurological deficits, raising questions about the potential for recovery with surgical intervention. This case series describes the neurological outcomes of ten patients with neglected spinal tuberculosis who underwent late surgical decompression and stabilization.
Materials and Methods: We retrospectively reviewed ten consecutive patients (7 female, 3 male; mean age 37.1 years) with confirmed spinal tuberculosis and chronic preoperative neurological deficits (Frankel grades B-D, mean duration 4.4 months). All patients underwent surgical intervention consisting of posterior decompression, debridement, and instrumented fusion. The primary outcome was neurological improvement, measured by changes in Frankel grade and ambulatory status at follow-up.
Results: At a mean follow-up of 12 months, neurological improvement was observed in all patients. Preoperatively, three patients were Frankel B, six were Frankel C, and one was Frankel D. Postoperatively, seven patients achieved independent ambulation (Frankel D/E), while the remaining three patients achieved assisted ambulation. All three patients with the most severe preoperative deficit (Frankel B) regained ambulatory ability. No major surgical complications were reported.
Conclusion: This case series demonstrates that meaningful neurological recovery, including the restoration of ambulatory function, is achievable with surgical management even in patients with neglected spinal tuberculosis and chronic neurological deficits of several months' duration. These findings suggest that surgical intervention remains a viable and effective option for improving functional outcomes in this challenging patient population, supporting its consideration despite delayed presentation.
Keywords: Spinal tuberculosis, Decompression, Surgical, Spinal fusion, Recovery of function, Treatment outcome

S189

Tuberculous Spondylodiscitis During Pregnancy: Challenges and Lessons From Two Case Reviews

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Purpose: Tuberculous (TB) spondylitis during pregnancy presents a unique clinical challenge, requiring a careful balance between maternal spinal stability, neurological preservation, and fetal safety. This study reports the successful surgical and medical management of two pregnant women with TB spine, both presenting in the second trimester with varying degrees of neurological compromise.
Materials and Methods: Two pregnant patients in their second trimester presented with TB spondylitis at different spinal levels and neurological statuses. Case 1: TB spine at T3 with an ASIA B neurological deficit. Case 2: Upper cervical TB spondylitis at C1–C2 with ASIA E status. Both patients underwent comprehensive preoperative evaluation, including radiological assessment and multidisciplinary consultation involving orthopaedic surgery, obstetrics, and infectious disease specialists. Surgical intervention consisted of posterior spinal instrumentation for stabilization, performed with intraoperative neurophysiological monitoring. Anti-tuberculous therapy was initiated according to standard protocols, with modifications appropriate for pregnancy to avoid teratogenic agents. Both patients received the standard four-drug anti-TB regimen with careful monitoring throughout the treatment course.
Results: Both patients demonstrated excellent surgical outcomes with significant neurological improvement. Case 1 achieved complete neurological recovery, improving from ASIA B to ASIA E at one-year follow-up. Spinal stability was successfully maintained throughout pregnancy, with no instrumentation failure or disease progression. Both pregnancies progressed to full term without obstetric complications, and normal vaginal deliveries were achieved in both cases. The newborns showed no evidence of congenital abnormalities. Anti-tuberculous treatment was completed successfully at 12 months postoperatively, with radiological evidence of bony fusion and resolution of infection. No adverse effects related to anti-TB medications

or intraoperative neurophysiological monitoring were observed in either mother or infant.

Conclusions: Surgical management of TB spine during pregnancy, when indicated, can be performed safely with excellent maternal and fetal outcomes. Posterior instrumentation and decompression provide adequate stability for neurological recovery while allowing pregnancy to progress to term. A multidisciplinary approach—combining careful surgical planning, appropriate anti-tuberculous therapy, and close monitoring—enables successful treatment of this challenging condition without compromising maternal neurological function or fetal development. The use of intraoperative neurophysiological monitoring during pregnancy is uncommon due to the rarity of such cases. Careful consideration of its safe application is essential.

Keywords: Tuberculous spondylitis, Pregnancy

S190

Clinical Outcomes of Surgical Management in Spinal Tuberculosis: An 11-Year Retrospective Study from a Tertiary Care Center

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Purpose: To identify the surgical outcome of the patient who failed antitubercular therapy and presenting with neurological deficits, severe pain, or spinal instability.

Materials and Methods: A retrospective cohort study was conducted on 55 consecutive patients with confirmed spinal TB who underwent surgical management at a tertiary care center in Nepal between January 2014 and December 2024. All patients had a minimum follow-up of 12 months. Outcomes assessed included pain (Visual Analogue Scale, VAS), functional status (Oswestry Disability Index, ODI), neurological recovery (ASIA impairment scale), kyphotic deformity correction, complications, and duration of antitubercular therapy (ATT). Paired t-tests were used for comparison of pre- and postoperative parameters.

Results: The mean age was 46.4±16.5 years with male predominance (65.5%). The lumbar/lumbosacral region was most commonly affected (49%), followed by lower dorsal (31%). Mean preoperative VAS improved from 8.09±0.67 to 0.31±0.54 at 1 year ($p<0.0001$), and ODI improved from 28.0±2.7% to 96.2±1.5% ($p<0.0001$). Mean kyphotic angle reduced from 42.7° to 19.2° (mean correction 23.5°, $p<0.0001$). Neurological improvement was significant ($p=0.006$) with 4 patients with ASIA D improving to ASIA E, 1 ASIA C to ASIA D, 2 ASIA C to ASIA E and 1 ASIA B to ASIA D, however 2 patients with ASIA A neurology did not show improvement. Complications occurred in 6 patients (10.9%), including two surgical site infections. Mean duration of ATT was 14.0±4.2 months. Subgroup analysis by spinal region showed uniformly excellent pain relief and functional recovery across all levels, with greater kyphosis correction in dorsal lesions.

Conclusions: Surgical management of spinal tuberculosis, combined with appropriate ATT, provides excellent clinical outcomes with significant pain relief, near-complete functional restoration, substantial deformity correction, and favorable neurological recovery across all spinal regions. Complication rates remain low.

Keywords: Spinal tuberculosis, Surgical management, Antitubercular therapy, VAS, ODI

S191

Climatic Risk Factors for Surgical Site Infection Across Orthopedic Procedures: A Multicenter Big Data Study

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Purpose: Building upon previous research focused solely on spine surgery, this study aims to investigate the influence of clinical and meteorological factors on surgical site infection (SSI) rates across a comprehensive range of orthopedic procedures. By integrating medical big data with regional weather information from the Korea Meteorological Administration (KMA), we sought to identify broader environmental risk patterns in orthopedic surgery.

Materials and Methods: We conducted a large-scale retrospective analysis of patients who underwent various orthopedic surgeries, including hip and knee arthroplasty (primary and revision), shoulder procedures (arthroplasty, revision, and rotator cuff repair), tibia/fibula fracture fixations, and cervical and thoracolumbar spine surgeries. Data were extracted from a multi-institutional clinical data warehouse (CDW). SSI was identified through diagnostic codes and postoperative antibiotic administration. Regional meteorological data, specifically temperature and humidity, were synchronized with surgery dates and patient locations to assess environmental correlations.
Results: Among the 35,864 patients, 854 (2.38%) patients developed an SSI. The infection cohort was characterized by a higher mean age, higher BMI, and significantly longer operative times compared to the non-infection group. Analysis of procedure types revealed that thoracolumbar spine surgery and revision procedures (hip and knee) had a higher proportional representation in the infection group. Regarding environmental factors, a positive correlation was observed between climatic conditions and infection rates. Specifically, increases in ambient temperature and humidity levels were directly associated with a higher incidence of SSI. This relationship suggests that higher thermal and moisture levels in the environment during the perioperative period contribute to an elevated risk of postoperative complications across diverse orthopedic sub-specialties.
Conclusions: This study demonstrates that SSI risk is influenced not only by patient-specific clinical factors, such as age, BMI, and surgical duration, but also by external environmental conditions. The direct relationship between increased temperature/humidity and higher SSI rates highlights the importance of considering climatic variables in infection control protocols. These findings advocate for heightened perioperative vigilance and potentially tailored environmental management strategies for all orthopedic patients, particularly during warmer and more humid seasons.
Keywords: Surgical wound infection, Temperature, Humidity, Climate, Orthopedic procedures

Free Paper: Infection & Miscellaneous

S192

Outcomes of Spine Surgery in Chronic Liver Failure Patients at a Tertiary Care Liver Transplant Center: A 10-Year Retrospective Analysis

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Purpose: Chronic liver disease is an often encountered co-morbidity in patients with spinal disorders needing surgical treatment. Liver cirrhosis itself also increases the risk of spinal infections, secondary osteoporosis resulting in vertebral compression fractures. Surgical treatment of these patients is challenging due to the high risk of further worsening of liver failure, impaired immunity, altered coagulation profile and poor healing capacity due to hypoproteinemia, post-transplant immunosuppression etc. The literature on this aspect is inadequate and needs more studies to standardise the treatment in such patients.
Materials and Methods: A retrospective analysis of patients with chronic liver failure who underwent spinal surgery at a liver transplant centre over a ten year period (2015-2025). The spectrum of indications for spine surgery, stage of liver disease, pre or post liver transplant status, perioperative management and surgical outcomes were analysed.
Results: The most common indication for surgical intervention was vertebral compression fractures secondary to secondary osteoporosis (12 cases). The other indications included infective spondylodiscitis (nine cases), pseudarthrosis after thoracolumbar burst fracture(one case), metastatic hepatocellular carcinoma (three cases), intramedullary abscess (one case) etc. Vertebral augmentation procedure was the most common surgical intervention performed followed by pedicle screw fixation, debridement and fusion, transforaminal endoscopic debridement, metastatic tumour surgery and intramedullary surgery.
Conclusions: The perioperative management needs an experienced hepatology and anaesthesia teams well versed

with management of liver failure. The outcomes of surgical treatment are good when performed at well equipped centres with experienced multidisciplinary teams, although there is a higher risk of perioperative complications.

Keywords: Liver failure, Cirrhosis, Spine surgery, Spondylodiscitis, L iver transplant

S193

Development of a Rabbit Model for Investigating Biofilm Formation in Implant Infections

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Purpose: Infections associated with orthopedic implants require careful management as they may promote microbial genetic mutations and transmission of resistance genes. Many studies have been conducted to inhibit biofilm formation by preventing initial microbial adhesion, either through the application of antimicrobial agents or surface modifications of the implants. However, due to the complex characteristics of biofilms, further investigations still remain necessary. This study aims to establish an infection model using experimental animals for future research into infection management and treatment strategies.

Materials and Methods: In this study, 7- to 8-month-old New Zealand white rabbits (weighing approximately 4.5 kg) were used, and all procedures were conducted in accordance with protocols approved by the Institutional Animal Care and Use Committee (IACUC). A cortical screw (D: 2.3 mm, L: 10 mm) was surgically inserted into the pedicle of the lumbar spine. The screws were coated with Staphylococcus aureus diluted to an OD value of 0.811 at 600 nm after being cultured at 37°C, and then implanted into the pedicle. Inflammation sites were debrided and irrigated with saline at 5 days and 3 weeks postoperatively, followed by wound closure. The animals were sacrificed one week after the final procedure, and HE and TRAP staining was performed.

Results: Postoperative WBC levels increased progressively. Upon inspection of the surgical sites, inflammation at 3 weeks postoperatively was more severe than at 5 days. Functional loss was observed in the surrounding muscle tissue near the pedicle where the screws were inserted. Histochemical assessments using HE and TRAP staining revealed significant bone loss around the surgical site and increased osteoclastic activity 3 weeks after S. aureus infection.

Conclusions: This study demonstrates that S. aureus infections can induce osteomyelitis, and the pathogen's destructive impact on bone tissue.

Keywords: Infection, Inflammation, Osteomyelitis, Bone tissue

S194

Early Surgical Stabilisation Significantly Improves Outcomes in Spinal Tuberculosis (Pott's Disease)

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Purpose: This study evaluates the paradigm shift towards early surgical stabilisation as an adjunct to ATT, assessing its impact on preventing deformity, improving neurological recovery, and enhancing overall quality of life compared to delayed or conservative management.

Materials and Methods: Spinal tuberculosis causes progressive vertebral destruction and deformity, with 60–70% of untreated patients developing kyphosis >30° and loss of ≥1.5 vertebral bodies predicting severe progression. Early surgical stabilisation, performed within 6–12 weeks of ATT, is indicated for instability, neurological deficit (seen in 30–50% of cases), large abscesses (>2 cm), or multi-segment involvement. Evidence shows early fusion corrects kyphosis from 35–40° to 15–20° and achieves neurological recovery in 70–85% of patients, compared to progression beyond 40–60° and recovery rates of only 40–55% with delayed or conservative care, highlighting its role in preventing disability.

Results: Clinical evidence shows that early surgical stabilisation in spinal tuberculosis provides superior outcomes compared to delayed or conservative management, as it significantly reduces the final kyphotic angle and prevents progression to fixed gibbus deformity, enhances

neurological recovery through timely decompression and stabilisation, delivers rapid pain relief and enables early ambulation which lowers systemic complications, and minimizes long-term morbidity by preventing chronic pain, restrictive pulmonary dysfunction, and late-onset paraplegia, thereby avoiding the need for complex corrective surgeries later in life.

Conclusions: Early instrumented stabilisation with ATT prevents deformity, enhances neurological recovery and function, and reduces long-term morbidity.

Keywords: Pott disease, Instrumented fusion, Kyphosis prevention, Anti-tubercular therapy, Functional outcomes

S195

Evolution of Surgical Strategy in Unilateral Biportal Endoscopy for Extensive Spinal Epidural Abscess: From Multi-level Decompression to Limited Approach with Catheter Drainage

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Purpose: To evaluate the clinical outcomes of Unilateral Biportal Endoscopy (UBE) for extensive spinal epidural abscess (SEA), focusing on technical modifications to minimize invasiveness in high-risk patients.

Materials and Methods: We retrospectively reviewed four consecutive patients diagnosed with extensive SEA accompanied by neurological deficits. All patients presented with significant comorbidities. The surgical strategy was modified during the study period to minimize surgical trauma. The initial cases were treated with extensive multi-level UBE laminectomies covering the major abscess levels. Conversely, the subsequent cases underwent a limited single-level laminectomy at the most caudal or strategic level, combined with catheter-assisted irrigation and drainage for the cephalad extension. Notably, a staged operation was employed for a patient with discontinuous anterior thoracic and posterior lumbar abscesses to ensure safety. Concurrent psoas or paraspinal abscesses were managed via percutaneous catheter drainage (PCD) or direct portal drainage.

Results: The operative time was significantly reduced in the limited approach group (108 min) compared to the initial multi-level group (avg. 215.5 min). In the staged operation case, the complex abscess was successfully managed without neurological complications. Radiologically, the limited approach group achieved complete resolution of the abscess on follow-up MRI, whereas the multi-level group showed partial resolution. One patient in the initial group expired due to septic shock from an unrelated cause, highlighting the high-risk nature of the disease. However, all patients in the limited approach group showed significant neurological recovery and normalization of inflammatory markers without recurrence.

Conclusions: UBE is an effective treatment for extensive SEA. We demonstrated that a modified strategy utilizing limited laminectomy with catheter drainage is a viable alternative to extensive multi-level decompression. This approach, along with staged operations for complex lesions, ensures comprehensive infection control with reduced surgical invasiveness, offering a significant advantage for medically compromised patients.

Keywords: Spine, Spondylitis, Spinal epidural abscess, Biportal endoscopic decompression, Drainage

S196

Epidemiological and Microbiological Profile of Spine Infection in Northern Malaysia: A 5-year Retrospective Study

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Purpose: Spine infection is a potentially serious condition with varied aetiology and outcomes, particularly in tuberculosis-endemic regions. Differentiating tuberculous from pyogenic spine infection and identifying factors associated with mortality remain clinically challenging. The aim of this study was to review local epidemiology data of spine infection and to identify factors associated with different types of spine infection

Materials and Methods: This retrospective single-centre study included 113 adult patients diagnosed with spine infection

over a five-year period. Demographic characteristics, comorbidities, microbiological findings, laboratory parameters, and outcomes were analyzed. Associations were assessed using chi-square or Fisher's exact tests. Multivariable logistic regression was performed to identify independent predictors of tuberculous spine infection and in-hospital mortality.

Results: Tuberculous spine infection accounted for 32.7% of cases. Patients aged ≤40 years were significantly more likely to have tuberculous infection compared to pyogenic infection (p=0.005). On multivariable analysis, age ≤40 years remained independently associated with tuberculous infection (adjusted OR 4.0, 95% CI 1.34–11.91, p=0.013), while gender was also an independent predictor (adjusted OR 0.20, 95% CI 0.05–0.86, p=0.030). Smoking status and intravenous drug use were not independently associated with infection type. There was no significant association between the type of infection and the location of spinal involvement (p=0.584). Microbiological culture patterns differed significantly between pyogenic and tuberculous infections (p=0.005). Mortality was not associated with infection type, microbiological aetiology, dialysis modality, inflammatory markers, or intravenous drug use. Multivariable logistic regression did not identify any independent predictors of mortality (overall model p=0.139).

Conclusions: Younger age is a strong independent predictor of tuberculous spine infection in a tuberculosis-endemic setting. Mortality appears to be influenced by multifactorial clinical factors rather than microbiological aetiology alone, underscoring the importance of early diagnosis and comprehensive patient management.

Keywords: Tuberculous spine infection, Tuberculous infection, Spine infection, Pyogenic infection

E-Poster

E001

10-Year Follow-up of Watertight Dural Patch Repair for an Iatrogenic Dural Defect During Spinal Intradural Arachnoid Cyst Excision: A Case Report

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Purpose: Spinal arachnoid cysts (SACs) are rare intradural lesions that can cause radiculopathy or myelopathy via mass effect. Surgical excision is the standard of care but carries the risk of incidental durotomy, particularly when arachnoid adhesions are dense. While primary suture repair is preferred, large or complex defects often require patch reinforcement to prevent cerebrospinal fluid (CSF) leakage and associated complications such as pseudomeningocele or infection. Although short-term outcomes of dural patches are established, data regarding their long-term structural durability over a decade remain limited. We report a successful 10-year follow-up of a patient who underwent dural patch repair for an iatrogenic defect during L2-3 arachnoid cyst excision.

Materials and Methods: A male presented with a severe lower back pain and left lower extremity radiating pain resulting in neurogenic claudication. Physical examination revealed a positive straight leg raise (Left 30°) and motor weakness of the left extensor hallucis longus (Grade 4). MRI demonstrated a 1.4×1.1×2.4 cm intradural cystic lesion at the L2–3 level compressing the cauda equina, consistent with an arachnoid cyst, alongside concomitant lumbar spondylosis and mild retrolisthesis. The patient underwent L2–3 posterior decompression and posterolateral fusion with microscopic cyst excision. During adhesiolysis, a significant dural tear occurred. A watertight repair was achieved using a suturable dural patch reinforced with nylon sutures. Intraoperative Valsalva maneuver confirmed the integrity of the closure.

Results: Postoperative recovery was uneventful. The patient reported complete resolution of preoperative symptoms and demonstrated no neurological deficits. He remained

asymptomatic during early follow-up but was lost to long-term follow-up until 10 years postoperatively. At that time, MRI demonstrated an intact dural repair with no evidence of pseudomeningocele, CSF leak, or cyst recurrence. The patient maintained full neurological function and reported a return to normal daily activities.

Conclusions: This case illustrates that watertight dural patch suturing repair with nylon can provide excellent and durable long-term outcomes in the management of iatrogenic durotomy during intradural spinal procedures. A watertight closure confirmed intraoperatively, combined with appropriate postoperative management, effectively prevented CSF-related complications and recurrence. Given the relative scarcity of decade-long follow-up data, this report adds to the growing body of evidence supporting the use of dural patch reinforcement techniques in spine surgery. Surgeons should be aware of and prepared for incidental durotomy, and should apply meticulous repair strategies to optimize patient outcomes over the long term.

Keywords: Spinal arachnoid cyst, Incidental durotomy, Dural repair, Dural patch, Long-term follow-up

E002

Unstable C1-C2 Fracture Dislocation in an Elderly Patient: A case Report

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Purpose: Cervical spine fractures account for approximately 5% of falls in the geriatric population. Cervical immobilization is the mainstay of treatment, with surgery advised when injury is unstable or when it produces neurologic deficit. Presented is a case of a right-sided C1 and C2 articular process fracture with C1 lateral mass displacement, successfully managed with occiput to C4 posterior instrumented fusion.

Materials and Methods: A 79-year-old female with Parkinson's disease, rheumatoid arthritis, and osteoporosis presented with torticollis and dysesthesia to left upper extremity, with intact motor status, after a fall at home. Cervical spine CT revealed a complete, displaced fracture of right C1 and C2 lateral mass with entire C1C2 facet displaced 5 mm laterally and 5 mm inferiorly. The right occipitocervical joint remained intact. Surgery carried out prone on Trios table using Mayfield clamps. Skull positioned to achieve horizontal gaze. A posterior midline approach done exposing the occipital protruberance, C1 posterior arch, posterior elements of C2, and up to the lateral masses of C3 and C4. Bilateral lateral mass fixation was achieved on C3 and C4, with C2 transpedicular fixation of the contralateral pedicle using the Magerl technique. A pre-contoured VertexMax plate rod was applied over the occipital protruberance and secured with 6 occipital screws. Final fixation was achieved distally with minimal reduction force. A tricortical iliac bone graft was harvested, contoured, and applied between the decorticated occipital protruberance, posterior arch of C1, and spinous process of C2, and then subsequently stabilized with non-absorbable sutures (modified Gallie). Decortication of posterior elements of C3C4 were done followed by additional morselized bone graft. Intraoperative cord monitoring was stable all throughout the procedure.

Results: Radiographic parameters measured preoperatively and postoperatively showed occipitocervical angle (OCA) of 34° to 32°, occipitocervical distance (OCD) of 30 mm to 37.5 mm, and occipitocervical inclination (OCI) of 62.6° to 70.9°, respectively. Immobilization maintained via Philadelphia collar with conversion to soft cervical collar at 1 month. Tolerated walker ambulation with assistance at 2 months. Radiographs showed good consolidation of C2-C3 facet joints with no screw pullout at 4 months. Patient consistent with physical therapy and is able to carry out daily activities with minimal assistance by 6 months.

Conclusions: A right-sided C1 and C2 articular process fracture, with C1 lateral mass displacement, poses a complex challenge in upper cervical fractures. Occipitocervical fusion for unstable C1-C2 injuries poses good clinical and functional outcomes.

Keywords: Cervical trauma, Elderly trauma, Unstable cervical fractures

E003

Amendment for Progressive Kyphotic Deformity in Spinal Tuberculosis: Challenges and Outcomes

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Purpose: Progressive kyphotic deformity remains one of the most severe and disabling complications of spinal tuberculosis, often leading to chronic pain, neurological impairment, cardiopulmonary compromise, and cosmetic deformity. Surgical management in such cases is challenging due to extensive vertebral destruction, instability, and variable disease activity. This study aimed to evaluate the clinical, radiological, and functional outcomes of surgical correction performed for progressive kyphosis secondary to spinal tuberculosis, and to highlight the key challenges encountered during treatment.

Materials and Methods: This retrospective study was conducted at NITOR and BSOH between 2021 and 2024. A total of 11 patients, aged 9–67 years, who presented with progressive kyphotic deformity resulting from spinal tuberculosis were included. All patients underwent surgical correction based on deformity severity, neurological status, and radiological progression. Surgical procedures involved posterior instrumentation, decompression, pedicle subtraction osteotomy (PSO), vertebral column resection (VCR), and anterior column reconstruction with bone grafts or cages when required. Preoperative and postoperative kyphotic angles, neurological status using the ASIA scale, pain assessment, and complication profiles were analyzed. Minimum follow-up duration was 12 months.

Results: Significant correction of kyphotic deformity was achieved in all cases, with notable improvement in sagittal alignment on postoperative imaging. Neurological recovery was observed in the majority of patients, with at least one-grade improvement on the ASIA scale in those who presented with deficits. Pain scores demonstrated marked reduction following surgery, contributing to improved functional mobility and quality of life. Fusion was achieved in all patients by the final follow-up. Challenges encountered included rigid deformity, severe vertebral collapse, limited bone stock for instrumentation, and difficulty in achieving balanced correction in long-standing cases. Minor postoperative complications such as superficial wound infection and transient neurological irritation occurred in a few patients but were managed successfully. No major neurovascular complications were noted.

Conclusions: Surgical amendment of progressive kyphotic deformity in spinal tuberculosis is both feasible and effective, providing substantial improvements in alignment, neurological function, and pain outcomes. Despite the technical challenges, deformity-specific surgical strategies such as osteotomy and anterior reconstruction yield favorable results when applied appropriately. Early recognition of deformity progression and timely surgical intervention are essential to prevent severe disability and optimize long-term outcomes.

Keywords: Spinal tuberculosis, Progressive kyphosis, Deformity correction, Osteotomy

E004

Clinical Outcomes and Cost-Effectiveness of Demineralized Bone Matrix–Augmented Vertebroplasty for Osteoporotic Vertebral Compression Fractures

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Purpose: To compare the clinical outcomes and cost-effectiveness of vertebroplasty augmented with demineralized bone matrix (VPDBM) and conventional bone cement vertebroplasty (VPBC) in osteoporotic vertebral compression fractures (OVCFs).

Materials and Methods: One hundred eighty-seven patients with acute OVCFs were reviewed (VPDBM, n=103; VPBC, n=84). Clinical outcomes were assessed using visual analog scale (VAS) and Koval grade, and radiographic outcomes included vertebral kyphotic angle (VKA), local kyphotic angle (LKA), and correction angle. Treatment failure was defined as refracture requiring hospitalization or reoperation, persistent or worsening pain or function, or radiographic deterioration. Deterioration-free survival (DFS) was analyzed using Kaplan–Meier and Cox regression. Cost-effectiveness

was evaluated from the hospital perspective.

Results: Both groups showed significant postoperative improvement in VAS and Koval grade, without between-group differences at 12 months. Immediate correction angle favored VPBC (p=0.041), but this was not sustained. Composite treatment failure was lower with VPDBM (12.6% vs 27.4%), with odds ratio 0.38 (95% CI, 0.18–0.81), risk ratio 0.46 (95% CI, 0.25–0.85), and absolute risk reduction 14.8% (NNT 6.8; p=0.010). Kaplan–Meier analysis showed superior DFS in VPDBM (log-rank p=0.034). Adjusted Cox regression showed no significant difference (aHR 0.58; 95% CI, 0.24–1.39; p=0.222). VPDBM was cost-effective, with ICER ₩43,978 ($32.0) per 1% DFS gain, below common willingness-to-pay thresholds.

Conclusions: VPDBM reduced treatment failures and improved DFS compared with VPBC, while remaining cost-effective in OVCF management.

Keywords: Osteoporotic vertebral compression fracture, Vertebroplasty, Demineralized bone matrix, Cost-effectiveness, Deterioration-free survival

E005

An Obstetrical and Gynaecological Insight to Measure the Gender Specific Issues Including Menstrual Disorders in Patients with Scoliosis – A Genuine Step Towards Empowering Women's Inclusive Health

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Purpose: Scoliosis has systemic implications beyond musculoskeletal changes. Its potential impact on hormonal, menstrual, reproductive, and obstetrical health in females remains underexplored. The objective of this study is to evaluate and compare the menstrual, reproductive, and obstetrical health of females with different subtypes of scoliosis and to identify associated gynaecological abnormalities

Materials and Methods: The study was conducted at a tertiary care centre between January 2021 and November 2022. A total of 292 female scoliosis patients with 50 age matched controls were included. Participants were assessed through clinical evaluation, questionnaires, and ultrasonographic examination. Parameters studied included age at menarche, cycle regularity, bleeding characteristics, physical/psychological symptoms, and ultrasonographic findings (endometrial thickness, ovarian morphology) and obstetric outcomes. Statistical tests included Fisher's exact test and Bartlett's test for variance

Results: Mean age at menarche was delayed in scoliosis patients, especially in congenital scoliosis (12.5 ±0.77 years) compared to controls (12.04±0.75 years, p<0.01). Menstrual irregularities, menorrhagia, and dysmenorrhea were significantly higher in congenital and syndromic scoliosis groups. Physical complaints were significantly more common in scoliosis groups than controls (p=0.003), but psychological symptoms showed no statistical difference. Endometrial thickness and incidence of follicular cysts/bulky ovaries were significantly elevated in congenital and syndromic scoliosis groups. 13 out of 15 patients had unplanned caesarean sections; no cases of spontaneous abortion or infertility were recorded.

Conclusions: Scoliosis, particularly of congenital and syndromic origin, is associated with delayed menarche, menstrual irregularities, and gynaecological abnormalities. Although obstetrical data were limited, trends suggest potential complications that merit further investigation.

Keywords: Scoliosis, Menstrual irregularities, Reproductive health, Obstetric outcomes

E006

Association Between ABO Blood Group and Risk of Adolescent Idiopathic Scoliosis in Surgically Treated Patients: A Case-Control Study

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Purpose: Adolescent Idiopathic Scoliosis (AIS) is a 3D spinal deformity affecting 1–3% of children aged 10–16 years. Its exact etiology remains unclear, though genetic factors are known to contribute. The ABO blood group system is a well-

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established genetic marker associated with various diseases. However, its relationship with AIS has not been adequately investigated. This study aimed to evaluate the association between ABO blood group types and the risk of AIS in surgically treated patients

Materials and Methods: This retrospective case-control study included 133 surgically treated AIS patients (40 males and 93 females, aged 10–20 years) with Cobb's angle >45°, and 140 age- and sex-matched healthy controls without spinal deformity. ABO blood groups were recorded for all subjects. Statistical analysis was performed using Pearson's chi-square test to determine the association between blood group distribution and AIS.

Results: Among AIS patients, the distribution of blood groups was A+ (24.81%), B+ (28.57%), AB+ (10.52%), O+ (32.33%), and negative groups (3.75%). The control group showed similar distribution patterns. Although O+ blood group appeared slightly more frequent in AIS cases, the difference was not statistically significant (p=0.882). Gender distribution differences were also not significant (p=0.266).

Conclusions: No significant association was found between ABO blood group type and the risk of AIS in surgically treated patients. Larger multicentric studies across the full clinical spectrum of AIS are recommended to assess genetic correlation.

Keywords: Adolescent idiopathic scoliosis, ABO blood group, Genetic marker, Case-control study, Chi-square distribution

E007

Clinical and Microbiological Characteristics of Pyogenic Spondylodiscitis: A Retrospective Study

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Purpose: To analyze the clinical presentation, diagnostic features, and microbiological profile of patients diagnosed with pyogenic spondylodiscitis treated at our institution over a defined period of time.

Materials and Methods: We retrospectively reviewed 19 patients with culture-positive PS treated at Manmohan Memorial Teaching Hospital from January 2017 to December 2024. Data on demographics, comorbidities, inflammatory markers (CRP/ESR), pathogen identity, treatment modality, and clinical outcome were collected. Statistical analysis was performed using SPSS.

Results: The mean age was 58.8±15.4 years, and 78.9% were male. Neurological deficits were observed in 7 patients (36.8%). Lumbar/Dorso-lumbar spine involvement was most common (63.2%). Mean initial C-Reactive Protein (CRP) and Erythrocyte Sedimentation Rate (ESR) were 148.6±50.3 mg/L and 68.7±11.2 mm/h, respectively. The dominant pathogens were Staphylococcus aureus (47.4%) and Escherichia coli (31.6%). Surgical intervention was required in 52.6% of patients. The overall clinical success rate was 94.7%.

Conclusions: The high prevalence of Gram-negative organisms, particularly E. coli and endemic pathogens like Salmonella typhi, mandates that local empirical antibiotic protocols in Nepal ensure adequate coverage for Gram-negative bacilli. Aggressive, pathogen-specific treatment leads to excellent outcomes in this population.

Keywords: Pyogenic spondylodiscitis, Nepal

E008

Delayed Presentation of Pediatric Atlantoaxial Subluxation with Cervical Myelopathy After Clavicle Fracture - A Case Report

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Purpose: Atlantoaxial rotatory subluxation (AARS) is an uncommon but potentially devastating condition in children and may be overlooked when torticollis occurs after non-cervical trauma. This report aims to emphasize the diagnostic pitfalls, clinical progression, and consequences of delayed recognition of AARS following pediatric clavicle fracture surgery.

Materials and Methods: We retrospectively reviewed the clinical course, imaging findings, and surgical management of a 10-year-old girl who developed persistent torticollis

after operative fixation of a midshaft clavicle fracture. Serial clinical evaluations, radiographs, computed tomography, and magnetic resonance imaging were analyzed to identify factors contributing to delayed diagnosis and neurological deterioration.

Results: Postoperative torticollis was initially attributed to muscle spasm, protective posture, and hardware irritation, resulting in delayed cervical evaluation. Over a 3-month period, the patient developed progressive neck deformity and acute cervical myelopathy. Imaging demonstrated severe atlantoaxial rotation with anterior displacement, widening of the atlanto-dental interval, rupture of stabilizing ligaments, and spinal cord compression, consistent with Fielding and Hawkins type III AARS. Closed reduction was unsuccessful, and emergency posterior C1–C2 fusion was required. Neurological function improved postoperatively, and stable alignment was maintained at 1-year follow-up with mild residual limitation of neck rotation.

Conclusions: Persistent torticollis after pediatric clavicle fractures warrants careful evaluation for possible AARS. Awareness of this rare coexistence and timely imaging are essential to avoid invasive surgery and serious complications.

Keywords: Atlantoaxial rotatory subluxation, Atlantoaxial rotatory fixation, Pediatric cervical myelopathy, Pediatric clavicle fracture

E009

Tuberculous Spondylitis Following Percutaneous Endoscopic Lumbar Discectomy (PELD): A Case Report

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Purpose: Tuberculous spondylitis, also known as Pott's disease, remains a significant public health concern, particularly in regions with high prevalence of tuberculosis (TB), such as the Philippines. It accounts for approximately 50% of extrapulmonary TB cases and often results in vertebral destruction, spinal deformity, and neurological deficits if not promptly diagnosed and adequately managed. Conventional treatment involves prolonged anti-Koch's therapy combined with surgical intervention when indicated, such as stabilization and decompression of neural elements. The occurrence of TB spondylitis following endoscopic spine surgery is an exceedingly rare but significant complication that warrants careful consideration. This underscores the need for heightened awareness, early diagnosis, and appropriate management. Presented here is case report describing a rare instance of tuberculous spondylitis developing after endoscopic spine surgery – highlighting potential mechanisms, diagnostic challenges, and the importance of vigilance in postoperative care.

Materials and Methods: A 30-year-old female underwent percutaneous endoscopic lumbar discectomy L5-S1 on the left, for lumbar disc herniation, eight months prior; with noted resolution of radiculopathy. At nine months postoperative, however, noted persistence of a 1x1 cm tender, non-pruritic, open wound with soft, friable discharge on previous surgical site. This was associated with new onset low back pain and radiculopathy. Patient denies history of pulmonary TB but household exposure to a child with a bacteriologically-confirmed TB, undergoing anti-Koch's treatment, was elicited. Plain lumbosacral spine MRI revealed multiple heterogenous mixed-intensity paraspinal collections encompassing L3-S2, likely representing abscess formation.

Results: Patient underwent open debridement, posterior decompression, L5-S1. Posterior midline longitudinal incision done over L3-S1 with noted consolidated, caseating abscess at subcutaneous tissue, extending up to L5-S1 disc space and left facet joint. Ligamentum flavum was adherent with areas of caseating abscess. Subsequent debridement, exploration, and facetectomy done. All areas of abscess debrided and samples sent for laboratory evaluation. Intraoperative specimen was positive for Xpert MTB/RIF and TB culture. Thus, patient was treated as a case of bacteriologically-confirmed extrapulmonary TB and was started on 12-month anti-Koch's regimen. Noted clinical improvement of symptoms upon initiation of TB treatment.

Conclusions: Possible etiologies for postoperative TB spondylitis include hematogenous spread of Mycobacterium tuberculosis in immunocompromised patients or latent TB activation triggered by surgical stress. This underscores the importance of early recognition and prompt treatment, and how clinicians must remain vigilant, regarding this rare

complication.

Keywords: Infection, Endoscopic surgery, Tuberculosis, mycobacterium, Pott's disease

E010

Evaluation of Deep Learning for Scoliosis Pre-Screening Using Preprocessed Chest X-ray Images

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Purpose: Scoliosis is a three-dimensional deformation of the spine that is a deformity induced by physical or disease related causes as the spine is rotated abnormally. Early detection has a significant influence on the possibility of nonsurgical treatment.

Materials and Methods: To train a deep learning model with preprocessed images and to evaluate the results with and without data augmentation to enable the diagnosis of scoliosis based only on a chest X-ray image. The preprocessed images in which only the spine, rib contours, and some hard tissues were left from the original chest image, were used for learning along with the original images, and three CNN(Convolutional Neural Networks) models (VGG16, ResNet152, and EfficientNet) were selected to proceed with training.

Results: The results obtained by training with the preprocessed images showed a superior accuracy to those obtained by training with the original image. When the scoliosis image was added through data augmentation, the accuracy was further improved, ultimately achieving a classification accuracy of 93.56% with the ResNet152 model using test data.

Conclusions: Through supplementation with future research, the method proposed herein is expected to allow the early diagnosis of scoliosis as well as cost reduction by reducing the burden of additional radiographic imaging for disease detection.

Keywords: Scoliosis, Chest X-ray, Deep learning model, Preprocessed image, Data augmentation

E011

Measurement of Lumbar Lordosis Using a Deep Learning- Based Artificial Intelligence Model

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Purpose: To develop and validate a deep learning–based artificial intelligence (AI) model for automated measurement of lumbar lordosis (LL) angles from whole spine lateral radiographs.

Materials and Methods: A total of 888 lateral spine X-rays (2019–2021) were retrospectively collected and annotated with four anatomical keypoints (L1 and S1 vertebral landmarks). An AI model using Detectron2 with a Keypoint R-CNN and ResNeXt-101 backbone was trained with data augmentation. Performance was evaluated on 50 test images, comparing AI results to manual annotations by two orthopedic surgeons using intraclass correlation coefficient (ICC), Pearson's correlation, and Bland–Altman analysis.

Results: The model achieved an average precision of 71.63 for bounding boxes and 86.61 for keypoints. ICCs between AI and human raters ranged from 0.918 to 0.962. Pearson correlation coefficients were r=0.849 and r=0.903. Bland–Altman analysis showed minor underestimation biases (–3.42° and –4.28°) with acceptable agreement.

Conclusions: The AI model showed excellent agreement with expert measurements and high reliability in LL angle assessment. Despite a slight underestimation, it offers a scalable, consistent tool for clinical use. Further studies should evaluate generalizability and interpretability in broader settings.

Keywords: Lumbar lordosis, Artificial intelligence, Deep learning

E012

Deep Learning–based AI Analysis of the Correlation Between Lumbar Lordosis and Age

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Purpose: To evaluate the association between lumbar lordosis and age using an AI-based automated measurement model applied to a large dataset of standing lateral spinal radiographs.

Materials and Methods: This retrospective study analyzed 904 high-quality radiographs selected from 2,397 images acquired between 2019 and 2021. Lumbar lordosis was defined as the angle between the superior endplates of L1 and S1 and automatically measured using a validated deep learning model. Subjects were categorized into nine age groups. One-way ANOVA compared lumbar lordosis across age groups, and Pearson correlation assessed the relationship between age and lumbar lordosis.

Results: Lumbar lordosis ranged from 0° to 84° (mean 45.9°±13.4°). The highest mean value was in the 10–19-year group (52.1°), and the lowest in the ≥80-year group (39.6°). Minimum values decreased to 0° in individuals aged ≥60 years. No significant differences were found across age groups (p=0.561). A weak but significant negative correlation was observed between age and lumbar lordosis (r=–0.247, p<0.0001).

Conclusions: AI-based automated measurement enabled efficient large-scale analysis and revealed a wide distribution of lumbar lordosis with a gradual age-related decline. These findings highlight the value of AI in spinal alignment assessment.

Keywords: Lumbar lordosis, Aging, Artificial intelligence, Deep learning, Spinal alignment

E013

Is There Correlation Between Kyphotic Deformity and Pain in Thoracolumbar Osteoporotic Compression Fractures?

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Purpose: To investigate the correlation between pain and kyphotic deformity in patients with single-level thoracolumbar osteoporotic compression fractures treated conservatively.

Materials and Methods: A retrospective analysis was conducted on 33 patients who underwent conservative treatment for a single-level thoracolumbar osteoporotic compression fracture between 2022 and 2023. Lateral radiographs obtained at outpatient follow-up 3 months after the fracture were used to measure the local kyphotic angle (LKA), Cobb angle (CA), and compression ratio (CR), and patients were classified according to the life insurance criteria for spinal deformity disability. Pain severity was assessed using the visual analog scale (VAS), and analgesic medication use was recorded. Statistical analyses were performed to evaluate the correlations of radiographic kyphotic deformity parameters with both pain VAS scores and analgesic medication use.

Results: The mean age was 71.8 years, and 84.8% were female. The mean LKA, CA, and CR were 18.6°, 16.3°, and 37.2%, respectively. CR demonstrated a weak correlation with analgesic medication use (r=0.353, p=0.044), and LKA also showed a weak correlation with marginal significance (r=0.340, p=0.053). No significant correlations were found between LKA, CA, or CR and pain VAS scores. Pain VAS scores and analgesic use did not differ significantly among the deformity severity groups.

Conclusions: In patients with thoracolumbar osteoporotic compression fracture, CR and LKA showed a weak association with analgesic use, whereas CA and Korean life insurance criteria for spinal deformity disability were not significantly correlated with pain. Pain following thoracolumbar osteoporotic compression fracture appears to vary individually and may not directly correspond to the

severity of kyphotic deformity. Further prospective studies with larger cohorts and longer follow-up are warranted.

Keywords: Osteoporotic compression fracture, Kyphotic deformity, Pain, Compression rate

E014

Contextualizing Chest Radiograph–Based Pulmonary Function Estimation in Scoliosis Using Multimodal Deep Learning

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Purpose: Thoracic deformity associated with scoliosis can lead to impaired pulmonary function; however, the availability of pulmonary function testing (PFT) is often limited. We propose a multimodal deep learning framework to estimate pulmonary function in scoliosis patients using chest radiographs and clinical information. This study evaluates whether routinely acquired posteroanterior chest radiographs, combined with basic clinical variables, can accurately predict key spirometric parameters such as forced vital capacity (FVC) and forced expiratory volume in one second (FEV1). It also assesses the ability to identify restrictive ventilatory patterns and clarifies the incremental value of image-derived features.

Materials and Methods: We retrospectively analyzed patients with scoliosis who underwent PFT and posteroanterior chest radiograph at a single institution from December 2013 to June 2025. Three families of models were developed to predict forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1): S-Model, which only processes clinical data; E-Model, which further inputs manual radiographic measurements; and M-Model, which also includes X-ray images as input.

Results: The cohort included 336 patients (mean age, 31.0 years±24.1 [standard deviation], 125 male). The EfficientNetV2-B3-based M-Model achieved the best performance for FVC prediction, yielding mean absolute error (MAE) of 0.31 liters on the test set. For FEV1 estimation, the EfficientNetV2-B0-based M-Model performed the best, with MAE of 0.37 liters. Significant improvement in FVC prediction error was observed with increasing model complexity (S-Model vs. E-Model, p=0.04; E-Model vs. M-Model, p=0.002). For restrictive ventilatory pattern classification, the ResNet-34-based M-Model achieved test accuracy, sensitivity, and specificity of 0.90, 0.85, and 0.93, respectively, on the test set. Image-derived features accounted for approximately 25% of the total contribution to FVC prediction.

Conclusions: We have identified that pulmonary function of scoliosis patients can be estimated by leveraging routinely-collected data. The models may serve as a complementary screening and risk stratification tool for scoliosis patients. In particular, multimodal deep learning demonstrated strong performance in estimating forced vital capacity, highlighting the relevance of thoracic structural information embedded in chest radiographs. While this approach does not replace formal pulmonary function testing, it provides a noninvasive method for functional assessment when spirometry is unavailable or impractical. These findings support the clinical utility of chest radiograph–based pulmonary function estimation in structure-driven respiratory disorders.

Keywords: Scoliosis, Pulmonary function testing, Chest radiograph, Multimodal deep learning

E015

Fusion Outcomes Following Two-Level Anterior Cervical Decompression and Fusion with Autologous Iliac Crest Bone Graft and Plating

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Purpose: Achieving solid fusion remains a critical determinant of success in two-level anterior cervical decompression and fusion (ACDF). Although standalone cages have been associated with higher subsidence and lower fusion rates, the use of autologous bone graft and anterior cervical plating has been advocated to enhance stability and promote fusion. However, limited prospective data exist on fusion outcomes

and their clinical relevance in two-level disease.
The purpose of the study is to assess fusion rates, fusion time, and the relationship between fusion status and clinical outcomes following two-level ACDF with autologous iliac crest bone graft and plating.

Materials and Methods: A prospective outcome study was conducted involving 26 patients with two-level degenerative cervical disc disease who underwent ACDF with autologous iliac crest graft and anterior cervical plating at Yangon Orthopedic Hospital between September 2020 and August 2023. Patients were followed for a minimum of 10 months. Fusion was assessed using serial upright lateral and dynamic flexion-extension cervical radiographs obtained at 2, 4, 6, 8, and 10 months postoperatively. Clinical outcomes were evaluated using mJOA score, NDI, and VAS for neck and radicular pain. Subgroup analysis was performed to compare clinical and radiological outcomes between fused and incompletely fused patients.

Results: No patients achieved fusion within the first four months postoperatively. Fusion was observed in 23.1% of patients at six months, 61.6% by eight months, and 84.6% by ten months. The mean fusion time was 8±1.5 months. Four patients (15.4%) demonstrated incomplete fusion at final follow-up. Despite differences in fusion status, both fused and incompletely fused groups showed significant improvement in neurological function, pain, and disability scores. There was no statistically significant difference in clinical or sagittal alignment parameters between the fused and non-fused groups at final follow-up.

Conclusions: Two-level ACDF using autologous iliac crest graft and anterior cervical plating provides a high fusion rate with acceptable fusion time and favorable outcomes. Clinical improvement was observed irrespective of fusion status within the short-term follow-up period, suggesting that early neurological and functional recovery may not be solely dependent on radiographic fusion. Nevertheless, the achieved fusion rate supports the continued use of autograft and plating as a reliable strategy for enhancing stability and fusion in two-level degenerative cervical disc disease. Longer follow-up and larger studies are recommended further to clarify the long-term clinical impact of fusion status.

Keywords: Cervical spine fusion, Two-level anterior cervical decompression and fusion, Autologous iliac crest bone graft, Anterior cervical plating, Fusion rate

E016

Clinical Profile of Chronic Low Back Pain Patients After Unilateral Biportal Endoscopic (UBE) Spine Surgery: A Retrospective Cohort Study

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Purpose: To determine the functional outcomes and complication rates of chronic low back pain patients who underwent UBE spine surgery. Unilateral biportal endoscopic (UBE) spine surgery has shown favorable outcomes as a minimally invasive technique, but local data in the Philippines remain scarce. This study was conducted to describe the clinical and functional outcomes of CLBP patients who underwent UBE surgery in the Philippine setting.

Materials and Methods: A retrospective cohort study was conducted on 56 patients with chronic low back pain secondary to lumbar stenosis, lumbar disc herniation, or degenerative disc disease. Pain and disability were assessed using the Numerical Rating Scale and Oswestry Disability Index (ODI) preoperatively and at follow-up. Complications related to the procedure were recorded and analyzed.

Results: A total of 56 patients with chronic low back pain underwent Unilateral Biportal Endoscopic (UBE) spine surgery between June 2023 and December 2024. The majority were males (53.6%) with a mean age of 47.18 years, and most were overweight or obese. Lumbar disc herniation was the most common diagnosis (66.1%), followed by lumbar stenosis (26.8%) and degenerative disc disease (7.1%). Significant improvement in pain was observed across all groups, with Numerical Rating Scale (NRS) scores decreasing from moderate to severe preoperative levels to minimal or no pain by six months postoperatively. Functional outcomes measured by the Oswestry Disability Index (ODI) also improved substantially, showing marked gains in mobility and daily activity. The overall complication rate was 8.9%, including one reoperation, one dural tear, and one pneumonia-related mortality, with most complications being minor and manageable.

Conclusions: UBE spine surgery is a safe and effective minimally invasive alternative to open procedures for chronic

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low back pain secondary to lumbar stenosis, disc herniation, and degenerative disc disease. It provides significant pain relief, functional recovery, and an acceptable complication profile, supporting its broader application in spine surgery practice.

Keywords: Chronic low back pain, Lumbar stenosis, Lumbar disc herniation, Degenerative disc disease, Numerical rating scale and oswestry disability index (ODI)

E017

Unilateral Biportal Endoscopic (UBE) for Preservation of Flip Flavum Ligament in in Lumbar Disc Herniation

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Purpose: Microdiscectomy has long been the gold standard for surgical treatment of the lumbar disc herniation. In microdiscectomy, techniques to preserve the flavum have been reported. While, recent techniques have applied the endoscopic techniques, such as Unilateral Biportal Endoscopic spine surgery. By this method, we can perform the UBE by flip the flavum to preserve the flavum. As known that the epidural fibrosis is still a common complication that influence the outcome and make a difficult & challenge if revision surgery is needed. This study is to show that this technique could be an option to prevent the epidural fibrosis in the future.

Materials and Methods: This study showed 10 patients diagnosed with lumbar disc herniation who underwent surgery during 2025 in my hospital. The patients underwent endoscopic surgery with flavum preservation. Preoperative imaging, including X-rays, computed tomography, and magnetic resonance imaging were performed. Functional scores were evaluated with Visual Analog Scale. Postoperative magnetic resonance imaging was conducted at three months to evaluate epidural fibrosis.

Results: The rate of epidural fibrosis was significantly lower in the flavum sparing. Functional scores and radiology significantly improved postoperatively in evaluation.

Conclusions: The preservation of flavum during UBE surgery results in less epidural fibrosis. The results suggest that preserving flavum during endoscopic spine surgery may reduce epidural fibrosis formation and promote better recovery, supporting the benefits of minimally invasive techniques in lumbar disc herniation surgery.

Keywords: Epidural fibrosis, Flavum sparing, Flip the flavum, Lumbar disc herniation, Unilateral biportal endoscopy

E018

Impact of Polyester Mesh-Containing Tissue Adhesive on C-Reactive Protein Kinetics and Antibiotic Stewardship in Instrumented Spinal Fusion

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Purpose: To compare the incidence of surgical site infection (SSI) and postoperative C-reactive protein (CRP) kinetics between a polyester mesh-containing tissue adhesive system (Dermabond Prineo®) and conventional wound dressings in patients undergoing instrumented spinal fusion.

Materials and Methods: We reviewed 246 consecutive patients who underwent posterior lumbar instrumented fusion between January 2021 and August 2025. Patients with trauma, tumors, or active infections were excluded to isolate the inflammatory response. Patients were categorized into the Conventional Group (n=194) and the Tissue Adhesive Group (n=52). The primary outcome was the incidence of SSI, and secondary outcomes included the time interval from surgery to infection diagnosis and postoperative CRP kinetics.

Results: Baseline patient demographics and operative variables were comparable between groups. The overall incidence of SSI did not differ significantly between the Conventional Dressing Group and the Tissue Adhesive Group (3.6% vs. 3.3%, p=0.987). Furthermore, there was no statistically significant difference in the time to infection diagnosis between the two groups (p=0.250). Among patients without SSI, postoperative CRP levels demonstrated distinct kinetic patterns. The Tissue Adhesive Group showed significantly lower CRP values at both the first and second

postoperative follow-up assessments compared with the Conventional Dressing Group (both p<0.001), indicating earlier normalization of systemic inflammatory signaling.

Conclusions: The use of polyester mesh-containing tissue adhesive in instrumented spinal fusion is non-inferior to conventional dressings regarding both the incidence and timing of infection. Notably, patients treated with the tissue adhesive system exhibited more rapid postoperative normalization of CRP, suggesting earlier resolution of systemic inflammatory signaling. These findings support the safety of tissue adhesive use in instrumented spinal surgery and suggest a potential role in modulating postoperative inflammatory responses without compromising infection control.

Keywords: Spinal fusion, Surgical site infection, Dermabond, 2-octyl cyanoacrylate, Wound dressing, C-reactive protein

E019

Temporary Internal Distraction, a Softer Alternative to Severe Rigid Scoliosis: Early-Onset Scoliosis with Delayed Treatment

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Purpose: Different surgical techniques are available for treating rigid kyphoscoliosis. Halo traction, either used with gravity or anchored to the pelvis, are well established methods to achieve gradual pre-operative traction to optimize correction before the definitive fusion surgery. This technique may be supplemented with multi-level facetectomies and osteotomies ranging from multi- Ponte osteotomies to vertebral column resection. On the other hand, temporary internal distraction is another option that avoids the complications related to halo traction and may preclude the utilization of morbid vertebral column resections. This is a case of an early onset scoliosis presenting late with severe rigid kyphoscoliosis. He was treated with temporary internal distraction without the need for vertebral column resection.

Materials and Methods: This is a 17-year-old boy who had early onset scoliosis and started bracing at 9-years-old. He was lost to follow-up. Upon initial presentation 6 years later, the kyphoscoliosis was measured at 117 degrees and progressed to 132 degrees after another 11 months. Temporary internal distraction technique was utilized to aid in curve correction.

Results: Total operative time was 16 hours and 47 minutes. Blood loss was 2.5 liters. An intra-operative fracture on the 6th rib which was used as 1 of 2 proximal anchors during distraction of the concave side occurred. No pulmonary complications nor post-operative infection was noted. Total hospital stay was 13 days; 3 days were spent at the pediatric ICU for close post-operative monitoring. Repeat radiograph 2 months post-operatively showed kyphosis to be at 61 degrees (from CT Cobb's angle of 132 degrees) 53% correction.

Conclusion: In this case report, temporary internal distraction has demonstrated to be a safe and reliable adjunct to reduction and re-alignment of rigid kyphoscoliosis.

Keywords: Temporary internal distraction, Severe rigid scoliosis

E020

Biportal Endoscopic Spinal Surgery via Interlaminar Approach for Symptomatic Conjoined Nerve Root: A Technical Note and Case Series

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Purpose: Conjoined nerve roots (CNR) present a significant challenge in minimally invasive spine surgery due to their anomalous course, tethering effect, and immobility. Inadequate visualization or forceful retraction can lead to iatrogenic nerve injury or incomplete decompression. This study aims to demonstrate the safety and efficacy of Biportal Endoscopic Spinal Surgery (BESS) for treating lumbar disc herniation associated with CNR, highlighting a wide decompression technique that ensures nerve safety while preserving stability.

Materials and Methods: We present a technical note on two cases of lumbar disc herniation involving CNR. Preoperative MRI signs raised the index of suspicion for anomalies. The

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surgeries were performed using the BESS interlaminar approach. The key technique involved wide lateral decompression: the endoscope was sufficiently inclined from medial to lateral to undercut the medial side of the superior articular process (SAP), thereby fully exposing the conjoined root. A burr was used to undercut the medial facet to expose the medial aspect of the pedicle. This unroofing technique created a safe zone, allowing the immobile CNR to migrate without forceful manual retraction. Even though the surgical goal was decompression, the facet joint was preserved as much as possible; in our cases, we were able to leave approximately 70% of the facet compared to the contralateral side.

Results: In both cases, the panoramic visualization of BESS allowed for the clear identification of the anomalous roots and safe execution of the procedure. The wide bony decompression successfully created adequate space for the CNR, permitting safe discectomy in the axillary zone. Postoperatively, patients reported immediate and significant relief from radicular pain, showing an improvement in the Visual Analog Scale (VAS) score. Postoperative MRI confirmed adequate decompression, and dynamic radiographs obtained at the 3-year follow-up demonstrated no evidence of segmental instability.

Conclusions: BESS is a safe and effective modality for managing lumbar disc herniation in the presence of CNR. The independent viewing and working portals facilitate early identification of anomalies and allow for precise, wide lateral decompression. We recommend inclining the scope from medial to lateral to undercut the SAP medial side for full CNR exposure, and undercutting the facet joint to the medial pedicle line to create sufficient space for the nerve root, thereby avoiding excessive retraction and minimizing the risk of neural injury, while preserving the facet joint as much as possible (approximately 70% compared to the contralateral side in our cases) to prevent instability.

Keywords: Conjoined lumbosacral nerve roots, Lumbar disc herniation, Biportal endoscopic spinal surgery, Nerve root anomalies, Technical note

E021

Novel Use of Combined Spinal and Erector Spinae Plane Block for Long Segment Thoracolumbar Fusion

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Purpose: We report the first documented case in Malaysia of successful long-segment spinal fusion and decompression under combined SA and ESPB anesthesia in a 24-year-old male with L1 and L2 vertebral metastases secondary to testicular cancer.

Materials and Methods: The patient presented with mechanical instability, severe spinal canal stenosis, and conus medullaris compression, alongside significant tracheal deviation from carinal tumor involvement, rendering general anaesthesia contraindicated.

Results: Following detailed preoperative counseling, posterior instrumentation from T10 to L5 with L1-L2 laminectomy was performed uneventfully under combined SA and ESPB with sedation, utilizing a dual-surgeon approach.

Conclusions: This case highlights the viability of combined SA and ESPB as an alternative anesthetic strategy for urgent lumbar spine surgery when GA is not feasible, demonstrating favorable perioperative outcomes.

Keywords: Pathological lumbar fracture, Posterior long segment fusion, Palliative surgery, Erector spinae plane block (ESPB), Spinal anaesthesia

E022

Outcomes of Posterior Indirect Decompression in Acute Thoracolumbar Burst Fracture with Incomplete Neurological Deficit

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Purpose: Outcome study.

Materials and Methods: Interventional prospective analytical

study.
Results: Find out the canal encroachment improvement, AVH,cobb angle and neurological outcomes.
Conclusions: Satisfactory outcomes.
Keywords: AVH - anterior vertebral body height

E023

Biportal Endoscopic TLIF at L5–S1 Isthmic Spondylolisthesis: Technical Strategies for Anterior Column Support and Segmental Lordosis Restoration

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Purpose: Isthmic spondylolisthesis at L5–S1 poses technical challenges due to anatomical distortion, high pelvic incidence, and frequent foraminal stenosis, often requiring direct decompression while preserving or restoring segmental lordosis. This technical note aims to describe a standardized and reproducible surgical strategy for biportal endoscopic transforaminal lumbar interbody fusion (BE-TLIF) in L5–S1 isthmic spondylolisthesis, focusing on posterior implementation of anterior column support and segmental lordosis restoration.
Materials and Methods: This technical note is based on consecutive cases of L5–S1 isthmic spondylolisthesis treated with BE-TLIF. Surgical indications included persistent back pain or radiculopathy refractory to conservative treatment, predominantly Meyerding grade I–II slips, and conditions unfavorable for anterior or anterolateral approaches. The procedure emphasized precise level confirmation using a guide pin, a right-sided biportal approach, and endoscopic direct decompression of both exiting L5 and traversing S1 nerve roots. After meticulous discectomy and endplate preparation under endoscopic visualization, a lordotic 3D-printed porous titanium cage was inserted using a cage rotation technique to achieve anterior placement within the disc space. Percutaneous pedicle screw fixation was subsequently performed, with particular attention to optimized S1 screw trajectory and length. Strategies for graft management under continuous irrigation and controlled hemostasis were incorporated to enhance fusion stability.
Results: BE-TLIF was successfully completed in all cases without conversion to open surgery. No major neurological or mechanical complications, including nerve injury, cage migration, or instrumentation failure, were observed. Postoperative imaging demonstrated stable anterior cage positioning, restoration of disc height, and improvement of L5–S1 segmental lordosis, which were maintained during follow-up. Radiographic fusion progression was observed during follow-up, and no clinically significant cage subsidence requiring revision occurred. Clinically, patients showed consistent improvement in back and leg pain as well as functional outcomes.
Conclusions: In L5–S1 isthmic spondylolisthesis, BE-TLIF can be safely and reproducibly performed despite challenging anatomical conditions. By maintaining a posterior approach while achieving anterior cage placement through a rotation technique and utilizing a lordotic porous titanium cage, anterior column support and segmental lordosis restoration may be facilitated. This technical framework provides practical guidance for enhancing the safety, reproducibility, and alignment outcomes of BE-TLIF in this demanding clinical context.
Keywords: Isthmic spondylolisthesis, L5–S1, Biportal endoscopic spine surgery, BE-TLIF (biportal endoscopic transforaminal lumbar interbody fusion)

E024

Prevalence of Tandem Spinal Stenosis in Korean Males over the Past 10 Years

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Purpose: Tandem spinal stenosis (TSS), defined as concurrent narrowing of the spinal canal in at least two distinct regions (most commonly cervical and lumbar), is reported in up to 60% of patients with spinal stenosis in selected cohorts. Delayed diagnosis can lead to severe

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neurological complications and significantly influence surgical planning, particularly regarding the prioritization of cervical myelopathy. This large-scale cohort study aimed to determine the prevalence of radiographic TSS in Korean males and its association with clinical cervical myelopathy and symptomatic lumbar spinal stenosis (LSS), thereby providing evidence for the necessity of MRI screening of the contralateral asymptomatic region in patients presenting with symptomatic stenosis in one spinal segment.

Materials and Methods: A retrospective review was conducted on 1,832 male patients who underwent both cervical and lumbar spine MRI at a single institution from December 2015 to December 2025. Patients with prior cervical or lumbar surgery, duplicate examinations, or female gender were excluded. Spinal stenosis was graded qualitatively on MRI using the Lee classification for both cervical and lumbar regions. Moderate or severe central canal stenosis was considered clinically meaningful compression. Radiographic TSS was defined as the presence of moderate or severe stenosis in both cervical and lumbar regions concurrently. Clinical diagnoses of cervical myelopathy and symptomatic LSS required corresponding neurological symptoms in addition to radiographic findings.

Results: A total of 1,832 male patients were included in the analysis. Radiographic cervical cord compression (moderate or severe) and radiographic lumbar spinal stenosis (moderate or severe) were each observed in a substantial proportion of patients. Radiographic tandem spinal stenosis was identified in a notable subset. Among patients with radiographic TSS, concurrent cervical myelopathy and symptomatic LSS were present in some cases, while others exhibited symptoms in only one region. Coexisting cervical myelopathy was observed in a portion of patients with symptomatic LSS.

Conclusions: As one of the largest cohort studies on tandem spinal stenosis in an Asian population, this study demonstrates that clinically meaningful TSS is frequently encountered in Korean males. A considerable proportion of patients with symptomatic stenosis in one segment harbor asymptomatic but significant stenosis in the contralateral region. These findings strongly support routine MRI screening of the asymptomatic spinal segment particularly the cervical spine in patients presenting with symptomatic stenosis in one region. Systematic cervico-lumbar evaluation enables early detection of potential cervical myelopathy, appropriate surgical prioritization, and prevention of irreversible neurological deficits, ultimately contributing to improved patient outcomes.

Keywords: Tandem spinal stenosis, Magnetic resonance imaging, Cervical myelopathy, Lumbar spinal stenosis, Cervical cord compression

E025

Long-Term MRI Assessment of Multifidus Muscle Changes Following Biportal Endoscopic Spinal Surgery

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Purpose: This study aimed to characterize long-term alterations in the multifidus muscle (MFM) following biportal endoscopic spinal surgery (BESS) using serial magnetic resonance imaging (MRI). Unlike previous work that focused primarily on short-term postoperative changes, we evaluated whether MFM signal abnormalities and muscle volume changes persist, recover, or progress over an extended follow-up period of up to three years.

Materials and Methods: A retrospective review was conducted on 75 patients who underwent single-level BESS between April 2022 and November 2025. All patients had three standardized MRI evaluations: preoperative, immediate postoperative, and final follow-up imaging. On axial T2-weighted images, the multifidus muscle signal intensity ratio (SIR), normalized to the psoas muscle, and cross-sectional area (CSA) were measured separately on the operated and contralateral sides. Patients were categorized into three groups based on their final follow-up duration (<6 months, 6–12 months, >24 months). Side-to-side differences and temporal changes in SIR and CSA were compared, and correlations between operative time and postoperative MFM signal changes on the operated side were analyzed.

Results: Both sides of the MFM demonstrated increased T2 SIR immediately after surgery, and longer operative time

was associated with a greater rise in postoperative SIR. Over time, the SIR gradually declined across all groups, with the >24 month group showing the most substantial return toward preoperative baseline. MFM CSA did not show a significant reduction at any time point, and no consistent evidence of muscle atrophy was observed during long-term follow-up.
Conclusions: MFM signal changes following BESS appear prominent in the early postoperative period but tend to normalize over extended follow-up intervals. Additionally, long-term CSA measurements suggest that BESS does not lead to meaningful MFM atrophy, supporting its muscle-preserving nature. This study expands upon earlier short-term evaluations by providing the longest MRI-based follow-up to date, offering a more comprehensive understanding of postoperative MFM recovery.
Keywords: Biportal endoscopic spinal surgery (BESS), Multifidus muscle, Magnetic resonance imaging (MRI), Lumbar spine, Long-term follow-up

E026

Surgical Strategies for Osteoporotic Vertebral Fractures: Balancing Stability and Biology

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Purpose: Osteoporotic vertebral fractures (OVFs) are a growing clinical challenge due to the aging population and increasing life expectancy. These fractures often result in severe pain, spinal deformity, and neurological deficits, significantly affecting quality of life. Surgical management is complex because of poor bone quality, comorbidities, and the risk of implant failure. To review and analyze current surgical strategies for osteoporotic vertebral fractures, focusing on stability restoration, pain relief, and prevention of postoperative complications.
Materials and Methods: A literature-based synthesis of contemporary surgical techniques including vertebral augmentation (vertebroplasty and kyphoplasty), posterior instrumentation with cement-augmented pedicle screws, anterior reconstruction, and minimally invasive stabilization procedures. The selection criteria, biomechanical considerations, and outcome predictors were critically evaluated.
Results: Minimally invasive cement augmentation techniques (e.g., balloon kyphoplasty) are effective for pain relief and partial restoration of vertebral height in stable fractures. In unstable or progressive collapse with neurological compromise, posterior fixation with cement-augmented screws provides superior stability. Hybrid constructs using short-segment fixation with intermediate screws or vertebral body reconstruction reduce the risk of implant loosening and adjacent-level fractures. Recent advances in expandable screws, calcium phosphate cement, and navigated MIS approaches have improved surgical safety and outcomes.
Conclusions: Optimal surgical management of osteoporotic vertebral fractures requires an individualized approach balancing mechanical stabilization and biological integrity. Cement augmentation and minimally invasive techniques remain the mainstay, while emerging biomaterials and fixation strategies hold promise for enhancing long-term stability in osteoporotic spines.
Keywords: Osteoporosis, Vertebral fracture, Cement augmentation, Pedicle screw fixation, Kyphoplasty

E027

The Surgical Learning Curve and Technical Evolution Across 100 levels of Cervical Disc Replacements

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Purpose: This study aimed to characterize the learning curve of a single fellowship-trained spine surgeon performing CDA and to describe technical refinements, tips, and pearls developed over the first 100 CDA procedures.
Materials and Methods: This was an Institutional Review Board-exempt retrospective cohort study conducted at a single tertiary institution. The first 100 cervical disc arthroplasties performed by a single surgeon between January 2024 and January 2026 were reviewed. Patients undergoing single-, double-, or triple-level CDA, as well as hybrid procedures involving CDA and fusion, were included.

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Preoperative demographics and surgical indications, intraoperative variables, and postoperative outcomes were extracted from clinical records. Intraoperative and postoperative imaging were also reviewed.

Results: A total of 52 patients encompassing 100 cervical disc levels were included. Mean patient age was 54.38±13.27 years, with radiculopathy being the most common indication for surgery. The most frequently treated levels were C5/6 (38%) and C4/5 (36%), with fewer cases at C6/7 (16%) and C3/4 (10%). Procedures included 6 single-level CDAs, 22 two-level CDAs, and 9 three-level CDAs, in addition to 15 hybrid procedures combining CDA and ACDF. Operative duration increased with the number of levels treated but demonstrated a general downward trend over successive cases. Notably, operative time for two-level CDA decreased by 54%, and for three-level CDA by 41.7% over the study period. LOS increased with procedural complexity (p=0.011) and was significantly longer in patients with myelopathy compared with non-myelopathy patients (p=0.015).

Conclusions: Through accumulated experience, several key technical principles were identified as critical to successful CDA. These include neutral preoperative patient positioning, accurate and parallel Caspar pin placement, judicious endplate preparation to minimize heterotopic ossification, precise midline implant positioning in both coronal and sagittal planes, and thoughtful implant selection tailored to individual endplate morphology. Our cohort also demonstrated a clear graded relationship between procedural complexity and perioperative metrics, with both operative duration and LOS increasing stepwise with increasing procedural complexity. The presence of myelopathy was also associated with significantly prolonged LOS, reflecting greater postoperative recovery demands. Notably, operative times decreased progressively over successive cases, reflecting the presence of a learning curve and the potential for experience to partially offset the demands of more complex surgery. Attention to these factors may help optimize prosthesis alignment, preserve physiologic motion, reduce implant-related complications, and guide structured adoption of CDA in clinical practice.

Keywords: Cervical disc replacement, Spine, Motion-preservation

E028

Massive Pleural Effusion and Ascites Causing Decompensated Respiratory Failure Following Biportal Endoscopic Spine Surgery in Multilevel Degenerative Lumbar Pathologies: A Case Report

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Purpose: Biportal endoscopic spine surgery (BESS) has emerged as a favored minimally invasive technique for the treatment of degenerative spinal disorders. While generally safe, the high-pressure irrigation system carries the inherent risk of fluid extravasation. This report aims to describe a life-threatening case of massive pleural effusion and ascites following multilevel BESS and to discuss its possible mechanisms and preventive considerations.

Materials and Methods: An 81-year-old female underwent multilevel BESS from L3 to S1 for lumbar spinal stenosis. Postoperatively, she presented with acute respiratory distress, altered mental status, and severe abdominal distension. Clinical evaluation included arterial blood gas analysis, radiographic studies, computed tomography of the chest and abdomen, and ascitic fluid analysis. Therapeutic interventions consisted of endotracheal intubation, percutaneous catheter drainage of the pleural effusion, paracentesis, and intensive supportive care.

Results: Plain radiographs and computed tomography scans revealed massive bilateral pleural effusion and extensive intraperitoneal fluid accumulation compressing the lungs and abdominal viscera. Arterial blood gas analysis demonstrated severe decompensated respiratory acidosis. Fluid analysis confirmed that the ascites was consistent with irrigation saline used during BESS. Following drainage and intensive care management, the patient's respiratory status and mental condition gradually improved, allowing successful extubation on hospital day 4. She recovered without further complications and was discharged in stable condition.

Conclusions: Our case suggests that massive pleural effusion and ascites are rare but potentially fatal complications

following multilevel BESS, capable of progressing to decompensated respiratory failure. Surgeons must carefully select the appropriate minimally invasive option tailored to the specific patient group. Furthermore, maintaining a high index of suspicion for fluid extravasation is crucial to prevent such fatal complications.

Keywords: BESS, Fluid extravasation, Ascite, Pleural effusion, Respiratory failure

E029

Infectious Spondylitis with L1 Collapse Caused by Methicillin-Resistant Staphylococcus argenteus in a Patient with Crohn's Disease Treated with Expandable Cage and Posterior Instrumentation: A Case Report

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Purpose: To report a rare case of aggressive infectious spondylitis caused by MR-S. argenteus in an immunocompromised Crohn's disease patient and to evaluate the efficacy of combined anterior-posterior reconstruction using an expandable titanium cage.

Materials and Methods: A 68-year-old female with Crohn's disease (on azathioprine) presented with progressive L1 vertebral collapse and conus medullaris syndrome. Following initial stabilization with intravenous antibiotics, a single-staged combined surgical approach was performed: anterior debridement and reconstruction with an expandable titanium cage, followed by posterior pedicle screw fixation.

Results: Intraoperative cultures confirmed Methicillin-resistant Staphylococcus argenteus. Targeted antibiotic therapy was maintained for 12 weeks. Postoperatively, the patient showed significant neurological recovery (Ankle dorsiflexion Grade III to V) and pain relief. 12-month follow-up imaging demonstrated restored sagittal alignment (Cobb angle correction) and stable interbody fusion without recurrence of infection.

Conclusions: In immunocompromised patients, MR-S. argenteus can cause rapid structural failure of the spine. A multifaceted approach—early diagnosis, pathogen-specific antibiotics, and combined anterior-posterior stabilization using an expandable cage—is a reliable strategy for restoring mechanical stability and ensuring successful fusion.

Keywords: Staphylococcus argenteus, Crohn's disease, Infectious spondylitis, Expandable titanium cage, Vertebral body collapse

E030

Microscopic Lumbar Foraminal Decompression Via Wiltse Approach for Foraminal or Extraforaminal Stenosis: Risk Factor Analysis for Poor Outcome

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Purpose: The traditional operative management for foraminal and extraforaminal stenosis utilizes a midline approach and entails resection of the facet joint to reach the pathology. The Wiltse approach has allowed facet-sparing access to the far lateral compartment through the inter-transverse extraforaminal corridor. The Wiltse approach has also significantly decreased the amount of tissue dissection and blood loss, and the duration of post-operative recovery. The purpose of this study was to present the outcome of the microscopic lumbar foraminal decompression via Wiltse approach for foraminal or extra foraminal stenosis. We investigated risk factors associated with poor outcome of microscopic lumbar foraminal decompression.

Materials and Methods: A single-center retrospective comparative study was designed to identify the risk factors associated with poor outcome of microscopic lumbar foraminal decompression. 37 consecutive patients who underwent single-level microscopic lumbar foraminal decompression with an average of 19-month follow-up were divided into two study groups based on clinical outcomes; group 1 (8 patients with poor outcomes, postoperative VAS was over 3), group 2 (29 patients with good outcomes, postoperative VAS was under 3). Changes of lumbar spinal alignment on plain standing radiographs were compared and analyzed between two study groups to investigate the pathology and risk factors associated with poor outcome.

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Results: Preoperative disc wedging (DW) angle was significantly larger in group 1 than in group 2 (4.2±1.0° vs 1.8±0.2°, p<0.01). Postoperatively, disc height (DH) and foraminal height (FH) decreased (p<0.05) significantly in group 1, while there were no significant changes in group 2. Lumbar lordosis improved postoperatively in group 2 (21.3±7.0 to 29.0±7.0, p<0.001), contrary to limited improvement in group 1 (23.5±7.2 to 26.2±10.0, p=0.45). Postoperative lumbar lordosis is a predictive factor for poor outcome. Decrease in DH or progression of DW was contributing to poor outcome.

Conclusions: The microscopic lumbar foraminal decompression via Wiltse approach provides excellent visualization of the pertinent anatomy while utilizing familiar tools. It is a safe and effective surgical option for treatment of foraminal and extraforaminal stenosis. Lumbar foraminal and extraforaminal stenosis presenting with large DW and small lumbar lordosis should be excluded from surgical indications for microscopic lumbar foraminal decompression.

Keywords: Foraminal stenosis, Extraforaminal stenosis, Wiltse approach, Microscopic lumbar foraminal decompression

E031

Triple Level Cervical Disc Arthroplasty: An Effective Alternative to ACDF or Hybrid Procedures in Multilevel Cervical Degenerative Disc Disease

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Purpose: Cervical disc arthroplasty (CDA) aims to not only achieve neural decompression and segmental stability, but also preserves motion at the operated level. Studies have shown single level CDA to be a safe and effective procedure compared with ACDF, whilst mitigating the risk of adjacent segment disease. This benefit may also be sustained in triple level CDA, however current evidence is limited.

Materials and Methods: We conducted a retrospective cohort study of patients who underwent triple level CDA, ACDF, and hybrid procedures (both CDA and ACDF) at a tertiary institution by four fellowship trained spine surgeons. Patients were assessed pre-operatively, then post-operatively at 1 month, 3 months, 6 months, and 12 months. Outcome measures included length of stay, operative time, global lordosis, Neck Disability Index (NDI), Short-form-12 for Physical Component Summary (SF12-PCS) and Mental Component Summary (SF-12-MCS), Visual Analogue Score (VAS) for neck and arm pain, post-operative neurological success and adverse events.

Results: A total of 27 patients were included, of which 14 underwent CDA, 4 underwent ACDF, and 9 underwent hybrid procedures. A mean improvement in global lordosis was observed, with the highest in CDA (10°), followed by hybrid (4.11°), and ACDF (3.75°). Similarly, the mean length of stay was shortest in CDA (4 days), followed by hybrid (6 days), and ACDF (10 days). The mean operative time was shortest in CDA (216 minutes), followed by ACDF (228 minutes), and hybrid (237 minutes). All procedures were effective in reducing neck and arm pain, with neurological success. At 1 month post-operatively, the mean VAS improved by 3.75 (neck) and 4.88 (arm). Among the CDA group, the mean NDI was 5.4, mean SF12-PCS was 35.7, mean SF12-MCS was 51.5 at the last post-operative follow-up.

Conclusions: Triple level CDA is an effective procedure to treat multilevel cervical degenerative disc disease, with superior outcomes in correction of lordosis when compared with ACDF and hybrid procedures.

Keywords: Cervical disc arthroplasty, Motion preservation

E032

Outcomes of Vertebroplasty Versus Conservative Treatment of Acute Osteoporotic Vertebral Fracture

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Purpose: To compare the outcome of vertebroplasty with conservative treatment in terms of functional and radiological outcomes.

Materials and Methods: Sixty patients with acute osteoporotic vertebral fracture were enrolled with balanced allocation of 30 participants in vertebroplasty group (Group A) and conservative group (Group B) according to block

randomization. Both groups were treated at YGH and YOH from January 2024 to June 2025. VAS score, ODI score, kyphotic angle and vertebral height were compared between two groups before treatment, post-treatment 1week, 4 weeks, 12 weeks and 24 weeks.

Results: Demographic data of the study population such as age, gender and level of fracture were not statistically significant. The mean VAS score, ODI score before treatment were not statistically significant between two groups. At the 1st week, the mean (SD) VAS score decreased to 2.80 (0.48) in the PVP group and 4.83 (0.79) in the CT group, with a statistically significant difference ($p<0.001$). At the 4th, 12th, and 24th weeks, the mean (SD) VAS scores remained lower in the PVP group compared to the CT group, and these differences were also statistically significant ($p<0.001$). At the 1st week, the mean (SD) ODI score decreased to 39.53 (7.51) in the PVP group and 57.2 (4.85) in the CT group, with a statistically significant difference ($p<0.001$). At the 4th, 12th, and 24th weeks, the mean (SD) ODI scores continued to be lower in the PVP group compared to the CT group, and these differences were statistically significant ($p<0.001$). At the 4th, 12th, and 24th weeks, the mean (SD) AVH in the PVP group remained stable at 39.9 (1.40) mm, whereas in the CT group, it decreased to 27.27 (3.18) mm. The differences at all follow-up points were statistically significant ($p<0.001$). Mean kyphotic angle of PVP group and CT group post treatment 24 weeks was 9.67 (2.61) versus 17.43 (3.41). There was statistically significant difference between two groups ($p<0.001$). Cement leakage was found in three patients but were asymptomatic.

Conclusions: The functional and radiological outcomes of vertebroplasty are different from conservative treatment of acute osteoporotic vertebral fracture.

Keywords: Vertebroplasty, Conservative treatment, Acute osteoporotic vertebral fracture, Functional and radiological outcomes

E033

Microsurgical Resection of a Thoracolumbar Dumbbell-Type Schwannoma With Preservation of the Functional Nerve Root

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Purpose: We present a case of a thoracolumbar dumbbell-type schwannoma to demonstrate a microsurgical technique focused on preservation of the functional nerve root during tumor resection at the thoracolumbar junction.

Materials and Methods: We report the case of a 51-year-old male presenting with lower back pain and left-sided radicular symptoms involving the anterior thigh, lateral thigh, and foot, with morning aggravation. Neurological examination revealed mild weakness of left hip flexion (L2, grade IV), while other motor functions were intact. Magnetic resonance imaging demonstrated a 2.1×1.5 cm fusiform intradural extramedullary mass at the L1–2 level, suggestive of a neurogenic tumor involving the conus medullaris region. Microsurgical resection was performed with an intraoperative strategy focused on preservation of the functional parent nerve root.

Results: Gross total resection was achieved through meticulous microsurgical dissection under high magnification. The nerve root sheath was preserved during tumor removal, maintaining anatomical continuity of the involved nerve root, with intraoperative findings suggesting functional continuity. Frozen-section and permanent pathological examinations confirmed schwannoma. Postoperatively, the patient experienced relief of radicular pain without new neurological deficits.

Conclusions: Meticulous, nerve root–oriented microsurgical technique may allow effective resection of thoracolumbar dumbbell-type schwannomas while preserving the functional nerve root and minimizing neurological morbidity.

Keywords: Thoracolumbar schwannoma, Dumbbell tumor, Functional nerve root preservation, Microsurgical technique

Video Session

Cervical

Cervical Laminoplasty

Kyung-Soo Suk

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Vertebral Body Sliding Osteotomy

Dong-Ho Lee

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Spinal Cord Tumors

Jae Hyuk Shin

Department of Orthopaedics Surgery, St. Vincent's Hospital, The Catholic University of Korea, Suwon, Korea

Anterior Vertebral Artery Mobilization and Oblique Corpectomy for Cervical Dumbbell Tumor

Hyoungmin Kim

Department of Orthopaedics Surgery, Seoul National University Hospital, Seoul, Korea

Thoracic

Minimally Invasive Surgical Management for Thoracic Spine Pathology

Joo Young Lee

Department of Orthopaedic Surgery, University of Ulsan, Ulsan, Korea

Lumbar

Biportal Endoscopic Revision Surgery After Lumbar Spine Surgery: Tailored Approaches for Diverse Failure Situations

Seung-Hyun Choi

Department of Orthopaedics Surgery, Busan Keun Hospital, Busan, Korea

MIS

Prone Single-Position OLIF with ACR Technique and O-arm-Guided PPF

Jin-Sung Park

Department of Orthopaedic Surgery, Samsung Medical Center, Sungkyunkwan University, Seoul, Korea

Technical Tips for Anatomic Reduction of Spondylolytic Spondylolisthesis Using Biportal Endoscopic Approach

Min Seok Kang

Department of Orthopaedic Surgery, Konkuk University Medical Center, Seoul, Korea

Deformity

Anterior-Posterior Combined Surgery for ASD

Nam-Su Chung

Department of Orthopaedics Surgery, Ajou University Hospital, Suwon, Korea

O-arm–Guided Pedicle Screw Placement in AIS Surgery

Ji-Won Kwon

Department of Orthopaedics Surgery, Yonsei University, College of Medicine, Seoul, Korea

Tumor

Multilevel Total Enbloc Spondylectomy for Thoracic Spinal Sarcoma Involving T10-T12

Se-Jun Park

Department of Orthopaedic Surgery, Samsung Medical Center, Sungkyunkwan University, Seoul, Korea

Removal of Intradural Dumbbell Tumor Using Dual Separate Dural Incisions

Sam Yeol Chang

Department of Orthopaedics Surgery, Seoul National University Hospital, Seoul, Korea

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Osteoporosis treatment proven for its efficacy and safety through a clinical trial including Korean participants[1)]

- Treatment of osteoporosis in postmenopausal women[2)]
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- Treatment of glucocorticoid-induced osteoporosis[2)]
- Treatment of bone loss in patients with non-metastatic prostate cancer receiving androgen deprivation therapy[2)]
- Treatment of bone loss in women with breast cancer receiving adjuvant aromatase inhibitor therapy[2)]

※ This information is approved by the MFDS (KR). For information approved by the FDA and EMA, please refer to the respective country's product label.

Product Information[2)]

Dosage Forms and Strengths	Injection: 60 mg/mL solution in single-dose prefilled syringe	Dosage and Administration	Administer 60 mg every 6 months as a SC injection	Packaging Information	1 X prefilled syringe(1 mL)/box
Duration of Use	36 months from the date of manufacture	Storage Conditions	Refrigerate at 2-8°C in a hermetic container. Protect from light. Do not freeze.		

BMD: bone mineral density **SC:** subcutaneous

Ref 1) Langdahl B, et al. *J Clin Endocrinol Metab*. 2024 Sep;dgae611. **2)** The Ministry of Food and Drug Safety (KR). Obodence 60mg solution for injection in pre-filled syringe [product approval information]. Cheongju: MFDS; 2023 [cited 2025 Apr 16].

[Dosage forms] Injection: clear, colorless to slightly yellow solution in a single-dose prefilled syringe **[Ingredients and amounts]** Injection: 60 mg/mL solution in single-dose prefilled syringe, Active ingredient: denosumab, Inactive ingredients: histidine, histidine hydrochloride monohydrate, polysorbate 20, sorbitol, and water for injections **[Indications and usage]** **1.** Treatment of osteoporosis in postmenopausal women **2.** Treatment to increase BMD in men with osteoporosis **3.** Treatment of glucocorticoid-induced osteoporosis **4.** Treatment of bone loss in patients with non-metastatic prostate cancer receiving androgen deprivation therapy **5.** Treatment of bone loss in women with breast cancer receiving adjuvant aromatase inhibitor therapy **[Dosage and administration]** The recommended dose of Obodence is 60 mg administered as a single subcutaneous injection once every 6 months. Administer Obodence via subcutaneous injection in the upper arm, the upper thigh, or the abdomen. All patients should receive calcium 1000 mg daily and at least 400 IU vitamin D daily. If a dose of Obodence is missed, administer the injection as soon as the patient is available. Thereafter, schedule injections every 6 months from the date of the last injection. **[Precautions for use]** Obodence(denosumab) is biosimilar to Prolia (denosumab).(omitted) **[Packaging information]** 1 X prefilled syringe(1mL)/box **[Storage Conditions]** Refrigerate at 2-8°C in a hermetic container. Protect from light. Do not freeze. **[Duration of use]** Do not use Obodence after the expiry date printed on the label. **[Importer]** Samsung Bioepis Co., Ltd., 76, Songdogyoyuk-ro, Yeonsu-gu, Incheon, 21987, Republic of Korea **[Legal manufacturer]** Samsung Bioepis Co., Ltd., 76, Songdogyoyuk-ro, Yeonsu-gu, Incheon, 21987, Republic of Korea

※ For detailed drug information, please refer to the Ministry of Food and Drug Safety's Drug Integrated Information System (https://nedrug.mfds.go.kr → 'Drug Information' → 'Drug and Cosmetic Product Information' → 'Drug Information Search').

※ Any changes made after the date of this document's creation (revision) can be found on the Ministry of Food and Drug Safety's Drug Integrated Information System (https://nedrug.mfds.go.kr).

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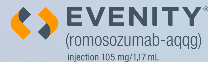

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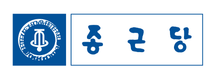

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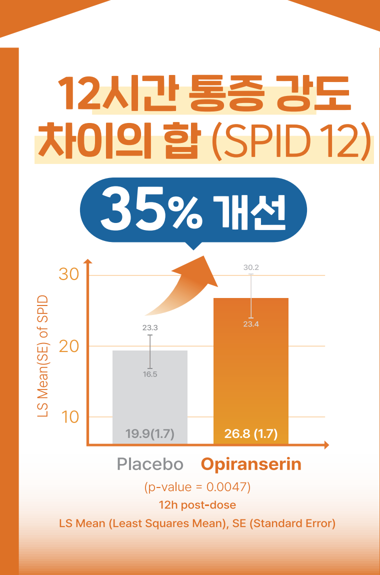

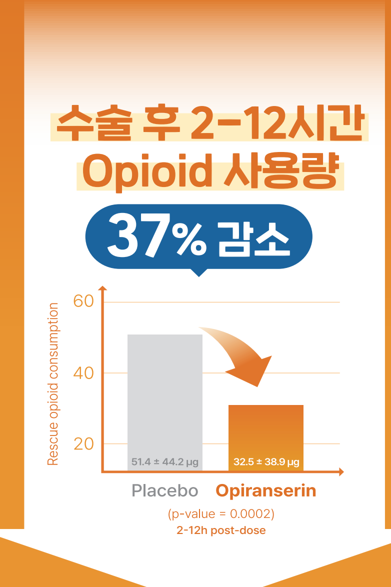

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SPID (Sum of Pain Intensity Difference)

어나프라®주 투여군은 위약군 대비 **수술 후 2~12시간 동안** PCA 및 구제 진통제의 **OPIOID 사용량을 유의하게 감소**시켰습니다.

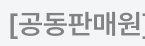
PCA (Patient-controlled analgesia)

Study objective: VVZ-149 is a small molecule that inhibits the glycine transporter type 2 and the serotonin receptor 5-hydroxytryptamine 2 A. In this Phase 3 study, we investigated the efficacy and safety of VVZ-149 as a single-use injectable analgesic for treating moderate to severe postoperative pain after laparoscopic colectomy. Design: Randomized, parallel group, double-blind, Phase 3 clinical trial (Trial no. NCT05764525). Setting: 5 tertiary referral centers in South Korea. Patients: 284 patients undergoing laparoscopic colectomy. Interventions: A continuous 10-h intravenous infusion of VVZ-149 (n = 141) or placebo (n = 143) administered after emergence from anesthesia. Measurements: Pain intensity was assessed using a numeric rating scale (NRS) from the start of infusion for 48 h. The primary efficacy measure was the Sum of Pain Intensity Difference (SPID) for the first 12 h after the start of drug infusion. Other efficacy measures included SPID at other time points, opioid consumption via on-demand patient-controlled analgesia (PCA) and rescue medication, and proportion of patients who did not require rescue opioids for 48 h post-dose.

[제품명] 어나프라®주 / UNAFRA®inj. **[주성분]**오피란제린염산염 1,000mg/100ml **[효능·효과]**성인에서 수술 후 중등도에서 중증의 급성통증 조절을 위한 단기요법 **[용법·용량]**이 약은 성인에서 수술 후 중등도에서 중증의 급성통증 조절을 위해 단회투여한다. 필요시, 수술 후 초기 통증 조절을 위해 통증자가조절법(patient-controlled analgesia: PCA)을 사용할 수 있다. 부하용량으로 160 mg을 30분간 정맥 점적투여하고, 유지용량으로 840 mg을 9시간 30분간 정맥 점적투여한다. 최대 1,000 mg을 초과해서는 안된다. 이 약 1,000 mg에 해당하는 100 mL을 생리식염주사액 400 mL에 희석하여 총 500 mL을 10시간 동안 말초 정맥을 통해 점적주입한다. 조제된 정맥주입용액은 48시간 이내에 사용해야 한다. 경막외 및 척수투여는 하지 않으며, 재투여에 대한 안전성.유효성은 평가된 바 없다. **[사용상의 주의사항]**1.금기 1)이 약에 과민반응이 있는 환자 2)불안정 협심증, 울혈성 심부전 환자, 심전도 측정치 중 QRS > 200msec 이거나 QTcF > 450msec(남성) 또는 QTcF > 470msec(여성)인 자 3)중등도-중증의 신장애 환자 4)중등도-중증의 간장애 환자 5)18세 미만 소아 환자 6)임부 및 수유부 7)PR 또는 QRS 간격을 증가시킨다고 알려진 약물을 투여한 환자 8)강력한 CYP3A4 억제제를 투여한 환자 2.이상반응 복강경 대장절제술 환자를 대상으로 진행된 3상 임상시험(K301시험)에서 총 284명(이 약 투여군 141명, 위약군 143명)을 대상으로 이 약 1,000 mg을 10시간 동안 정맥 점적투여하여 안전성을 평가한 결과, 이 약 1,000 mg을 투여받은 환자 중 101명(71.6%), 위약을 투여받은 환자 중 98명(68.5%)에서 이상반응이 확인되었다. 대부분의 이상반응은 경증에서 중등도였다. 가장 흔하게 보고된 이상반응은 구역(34.0%), 시술 후 열(31.9%), 구토(13.5%)였다. 이 약을 투여받은 수술 후 통증 환자(이 약 투여군 468명, 위약군 409명) 대상 안전성 분석 결과, 이 약을 투여받은 환자 중 364명(77.8%), 위약을 투여받은 환자 중 290명(70.9%)에서 이상반응이 확인되었다. 가장 흔하게 보고된 이상반응은 구역(45.1%), 구토(15.6%), 두통(14.5%), 시술 후 열(11.5%), 어지러움(10.5%), 졸림(6.0%)이었다. 흔하지는 않지만 심전도 PR 연장(1.3%)과 QRS 복합 연장(0.9%)이 보고되었다. **[개정년월일]**2024년 12월 12일 ※본 정보는 요약된 일부의 정보입니다. 따라서 자세한 사항은 제품 설명서 전문을 참고하시거나 의약품안전나라(nedrug.mfds.go.kr)의 의약품 정보를 참고해주십시오.

VPH-COP-U25-001
P25-261-2027.09-V1

[Reference] Lee, Ho-Jin, et al. "Reduction of Postoperative Pain and Opioid Consumption by VVZ-149, First-in-Class Analgesic Molecule: A Confirmatory Phase 3 Trial of Laparoscopic Colectomy." *Journal of Clinical Anesthesia* 101 (2025): 111729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다양한 국내/외 가이드라인[†]에서
신경병증성 통증 1차 치료제 중 하나로 권고된 리리카[3-12]

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[†]**Abbreviations: AAN,** American Academy of Neurology; **ADA,** American Diabetes Association; **CPS,** Canadian Pain Society; **EFNS,** European Federation of Neurological Societies; **ESMO,** European Society for Medical Oncology; **IASP,** International Association for the Study of Pain; **JSPC,** Japan Society of Pain Clinicians; **KSSS,** Korean Society of Spine Surgery; **NICE,** National Institute for Health and Care Excellence; **KDA,** Korean Diabetes Association.

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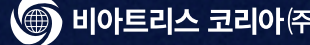
[수입자/판매자] 
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References **1.** 조인스에프정 국내 허가사항 (최신 개정일자: 2023.12.21) **2.** 대한슬관절학회. 슬관절학 Arthrology of the Knee. 4th Edition. 903-931p. **3.** 대한통증학회. 통증의학 Textbook of Pain Medicine. 6th Edition. 249p. **4.** 대한류마티스학회. 류마티스학. KCR Textbook of Rheumatology. 3rd Edition. 454p. **5.** 가톨릭대학교 의과대학 내과학교실. 임상진료지침. Current Principles and Clinical Practice of Internal Medicine. 5th Edition. 918p. **6.** Jung YB, et al. four-week, randomized, double-blind trial of the efficacy and safety of SKI306X: A herbal antiarthritic agent versus diclofenac in osteoarthritis of the knee. Am J Chin Med 2004;32(2):291-301. **7.** Park YB, et al. Efficacy and Safety of Celecoxib and a Korean SYSADOA (JOINS) for the Treatment of Knee Osteoarthritis: A Systematic Review and Meta-Analysis. J Clin Med. 2025 Feb 7;14(4):1036. **8.** Kim JI, et al. Efficacy of JOINS on Cartilage Protection in Knee Osteoarthritis: Prospective Randomized Controlled Trial. Knee Surg Relat Res 2017;29(3):217-224.

제품요약정보 [제품명] 조인스에프정300밀리그램 **[원료약품 및 분량]** 이 약 1정 중 조인스에프정 유효성분: 위령선 • 괄루근 • 하고초 30%에탄올건조엑스(40→1) (별규) - 300 mg **[효능효과]** 골관절증(퇴행관절질환)의 증상 완화 **[용법용량]** 성인 : 1회 1정을 1일 2회 경구투여한다. **[사용상의주의사항]** 1. 다음 환자에는 신중히 투여할 것. 1) 감염상태 또는 감염의 원인이 있는 환자(감염에 대한 자체 저항력이 감소될 가능성이 있음을 고려해야 하며, 이런 경우에는 감염의 진행을 억제하는 처치를 취해야 한다. 2) 임부 또는 임신하고 있을 가능성이 있는 여성 및 수유부 3) 이 약(위령선 • 괄루근 • 하고초) 성분에 과민증이 있는 자 (후략) **[제조자]** 에스케이케미칼(주) 충청북도 청주시 흥덕구 산단로 149 **[판매자]** 에스케이케미칼(주) 경기도 성남시 분당구 판교로 310 ※처방하시기 전 제품설명서 전문을 참고하십시오.

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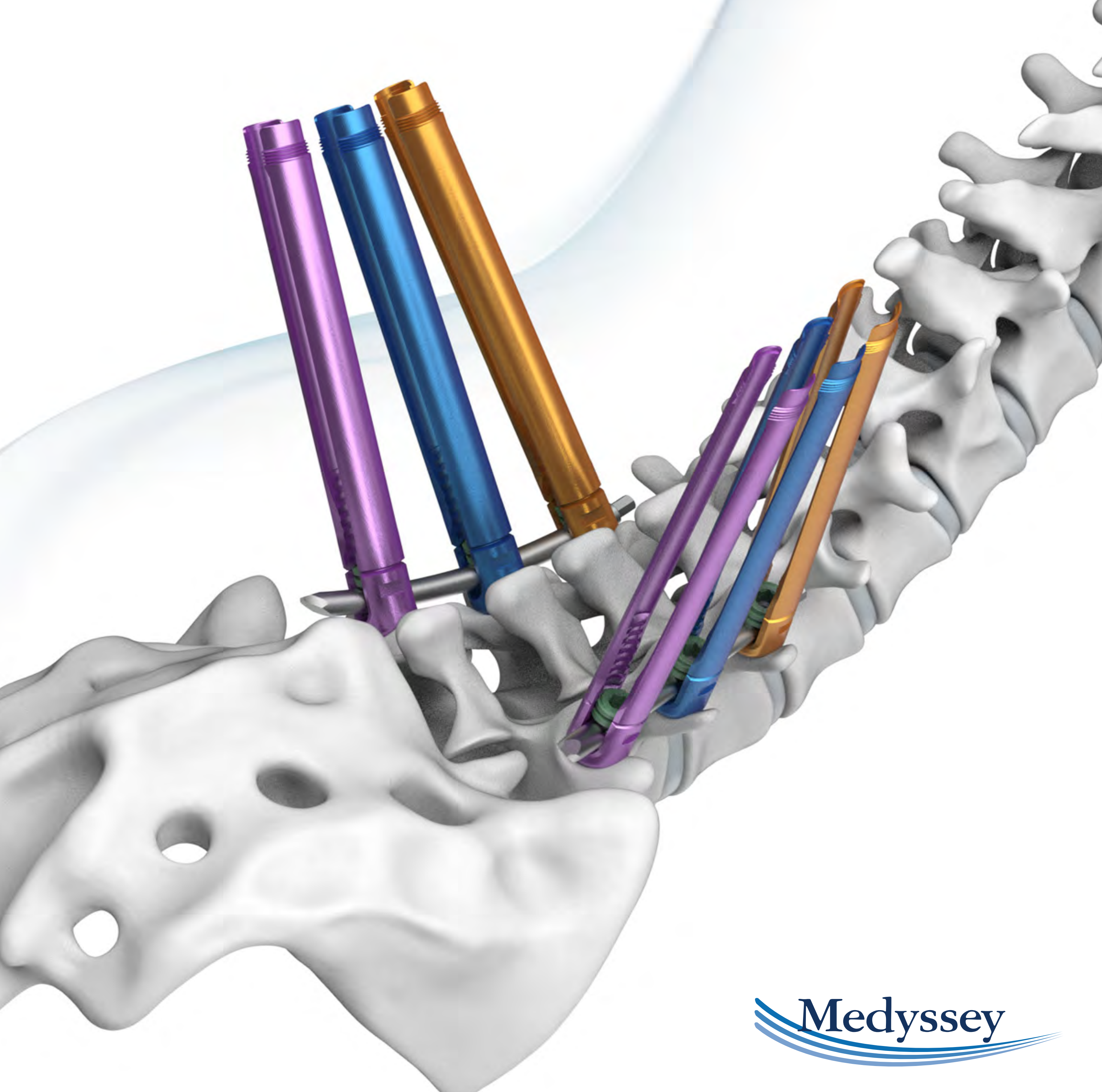

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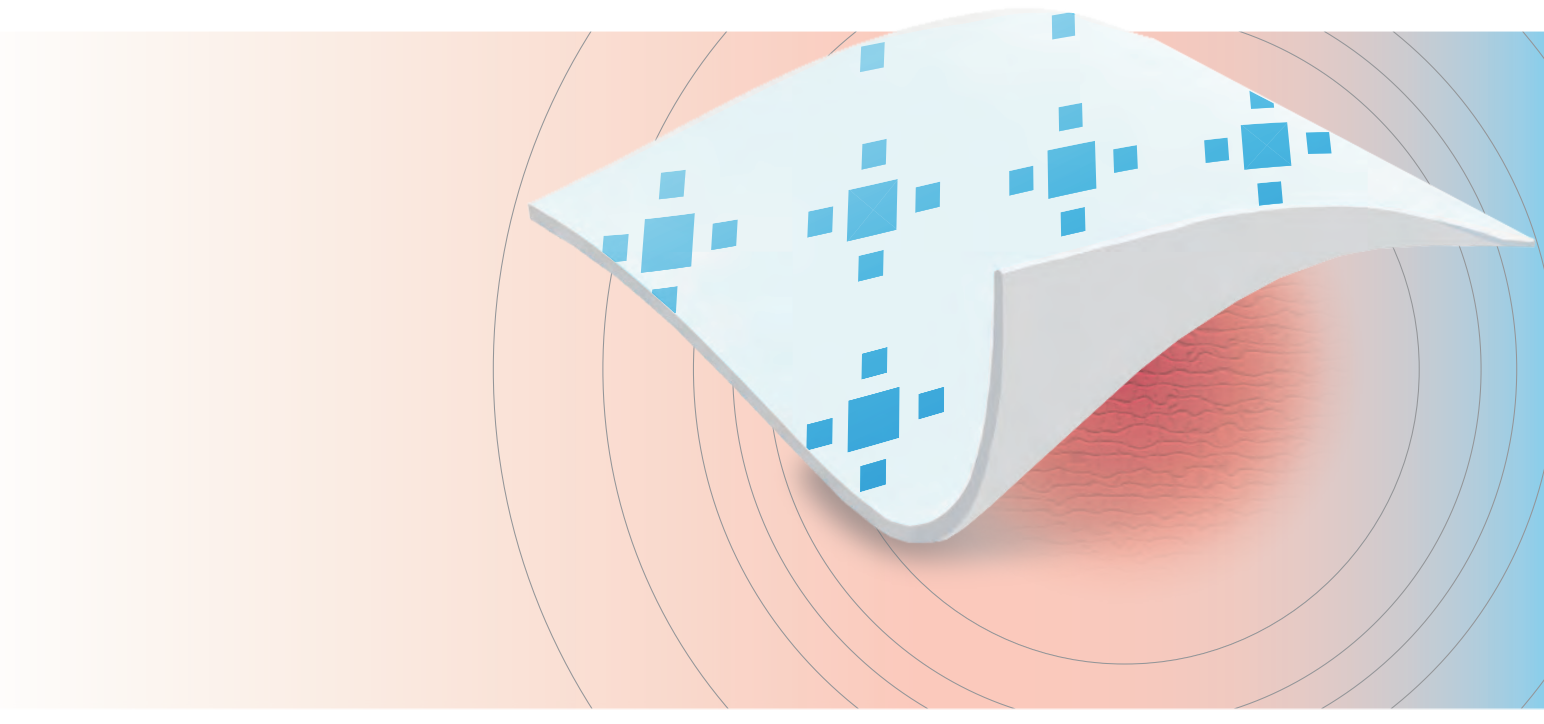

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2. Tackett, Scott M., et al. "Real-world outcomes of hemostatic matrices in cardiac surgery." Journal of cardiothoracic and vascular anesthesia 28.6 (2014): 1558-1565.

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3. 섬유근육통의 치료

용법 • 용량

이 약은 프레가발린으로서 1일 총 투여용량을 1일 2회로 나누어 음식물과 상관없이 경구 투여한다. 이 약은 주로 신장으로 배설되므로, 신기능이 저하된 환자에 대해서는 용량이 조절되어야 한다. 1. 신경병증성 통증 1) 말초 신경병증성 통증(성인): 이 약은 시작용량으로 1일 150mg을 투여할 수 있다. 개개 환자에서의 반응과 내약성에 근거하여 3일 내지 7일 후에 1일 300mg까지 증량할 수 있다. 필요하다면, 이후 7일 간격으로 1일 최대 600 mg까지 증량할 수 있다. 2) 중추 신경병증성 통증(성인): 이 약은 시작용량으로 1일 150mg을 투여할 수 있다. 개개 환자에서의 반응과 내약성에 근거하여 1주일 후에 1일 300mg까지 증량할 수 있다. 추가로 1주일 후에 목표 1일 용량인 600mg까지 증량할 수 있다. 목표 1일 용량에서 내약성을 나타내지 않을 경우 용량 감소가 고려될 수 있다. 2. 간질(성인): 이 약은 시작용량으로 1일 150mg을 투여할 수 있다. 개개 환자에서의 반응과 내약성에 근거하여 일주일 후에 1일 300mg까지 증량할 수 있다. 필요하다면, 이 후 7일 간격으로 1일 최대 600mg까지 증량할 수 있다. 3. 섬유근육통: 이 약의 권장 용량은 1일 300mg~450mg 이다. 이 약은 시작 용량으로 75mg씩 1일 2회(1일 150mg)를 투여하며, 유효성과 내약성에 근거하여 1주일 이내에 150mg씩 1일 2회(1일 300mg) 까지 증량할 수 있다. 1일 300mg의 용량에서 충분한 유익성을 경험하지 못한 환자의 경우에는 1주일 이내에 225mg씩 1일 2회(1일 450mg) 까지 증량할 수 있다. 1일 600mg의 용량에서도 임상 연구가 실시되었으나, 이 용량에서의 부가적인 유익성이나 충분한 내약성에 대한 증거는 없다. 용량 의존적인 이상반응을 고려하면, 1일 450mg을 초과하는 용량 투여는 권장되지 않는다.

사용상의 주의사항

1. 경고 1) 자살충동과 자살행동 (1) 항간질약을 복용한 환자에서 자살충동 또는 자살행동을 보이는 위험성이 증가되므로 항간질약을 치료받은 환자는 자살충동 또는 자살행동, 우울증의 발현 또는 악화 및 기분과 행동의 비정상적 변화에 대하여 모니터링되어야 한다.(2) 항간질약을 처방받는 간질과 다른 많은 질병은 그 자체가 이환 및 사망, 치료기간 동안의 자살충동과 자살행동의 위험성증가와 관련된다. 따라서 처방자는 항간질약 처방시 환자의 치료기간 동안 자살충동 또는 자살행동과 치료될 질병간의 연관성 유무 및 이 약의유효성을 함께 고려한다. 2. 다음 환자에는 투여하지 말 것 1) 프레가발린 또는 이 약의 성분에 과민한 환자 2) 이 약은 유당을 함유하고 있으므로, 갈락토오스 불내성 (galactose intolerance), Lapp 유당분해효소 결핍증 (Lapp lactase deficiency) 또는 포도당-갈락토오스 흡수장애 (glucose-galactose malabsorption) 등의 유전적인 문제가 있는 환자에게는 투여하면 안 된다.

* 기타 자세한 사항은 제품설명서를 참고하십시오.

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Reference **1.**『약제 급여 목록 및 급여 상한금액표』보건복지부 고시 제 2017-133호 (2017년 8월 15일 시행) **2.** 카발린캡슐 허가사항

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PMS, post-marketing surveillance; RWE, real-world evidence.

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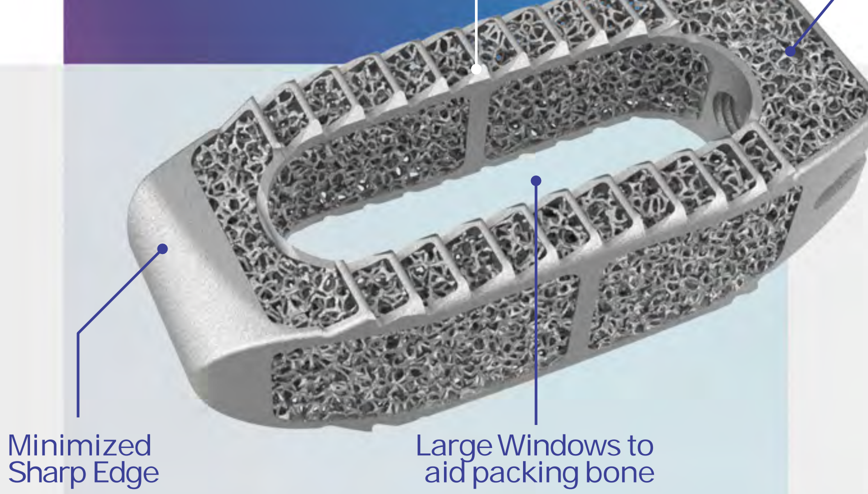

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효능·효과	폐경 후 여성의 골다공증 치료	1. 폐경 후 여성의 골다공증 치료와 예방 2. 남성의 골다공증 치료	폐경 후 여성의 골다공증 치료와 예방
용법·용량	**주 1회 식사와 관계없이 경구투여**	주 1회 경구투여 (아침식사 최소 30분 전에 복용하거나 또는 하루 중에 어떤 때라도 음식물이나 음료수의 섭취 전후로 최소 2시간 떨어져서 복용한다)	월 1회 경구투여 (충분한 흡수를 위해 하루 중 처음으로 음식물 또는 물 이외의 음료수를 섭취하기 최소 30분 전에 복용한다)
제품코드	644503330	644503310	644503320

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Reference

1. 악토넬EC정 허가사항 (23.06월 기준, 의약품안전나라 의약품 정보- 용법용량(성인) : 리세드론산나트륨으로서 1회 35 mg을 주 1회 식사와 관계없이 아침에 경구 투여한다.) **2.** McClung MR et al. Efficacy and safety of a novel delayed-release risedronate 35 mg once-a-week tablet. Osteoporos Int. 2012 Jan;23(1):267-76. **3.**악토넬EC정 35mg 허가사항 (23년 11월 기준) **4.** 악토넬정 35mg 허가사항 (23년 11월 기준) **5.** 악토넬정 150mg 허가사항 (23년 11월 기준)

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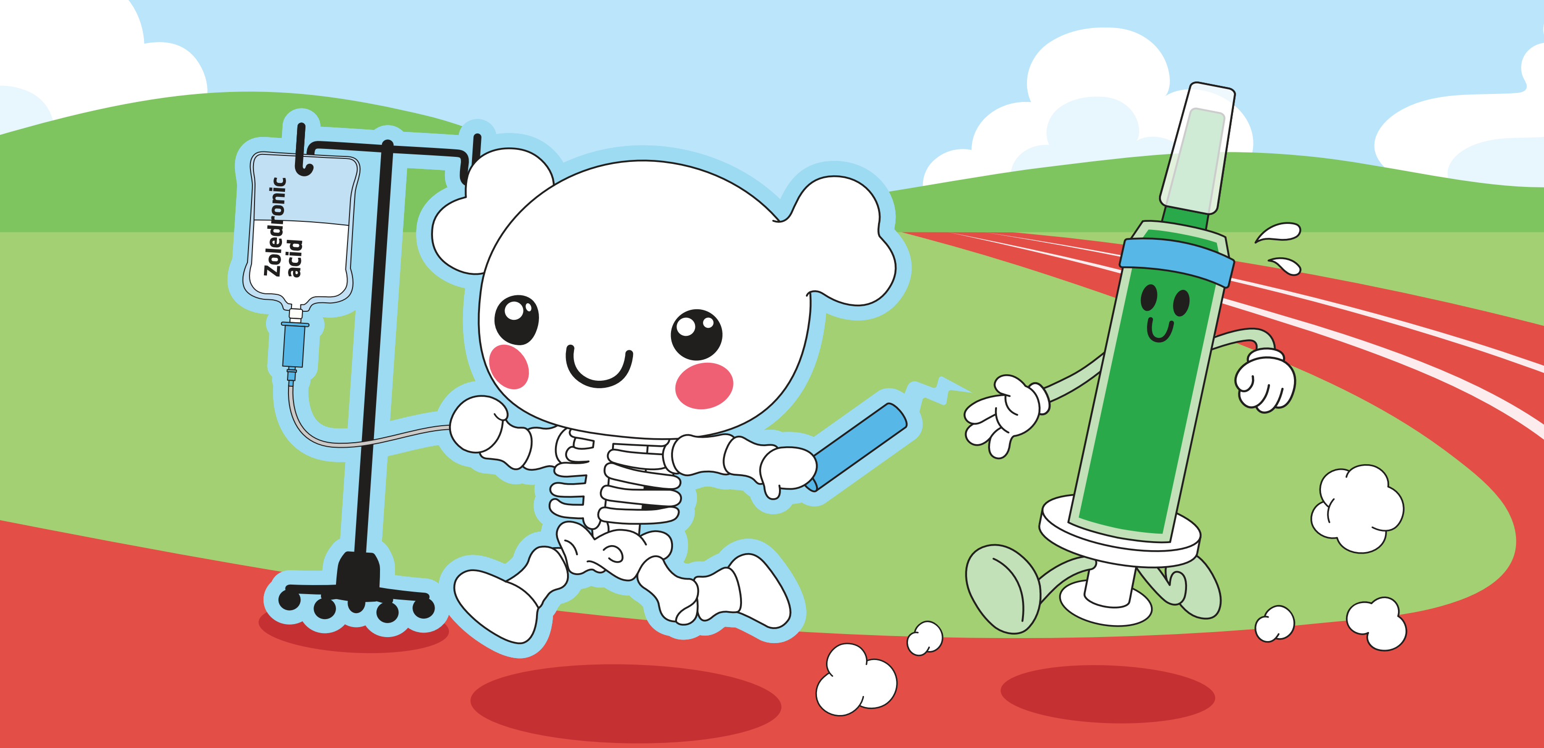

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Ref.> 1. 대웅졸레드론산주사액 5mg/100mL 제품설명서_식약처 허가사항.
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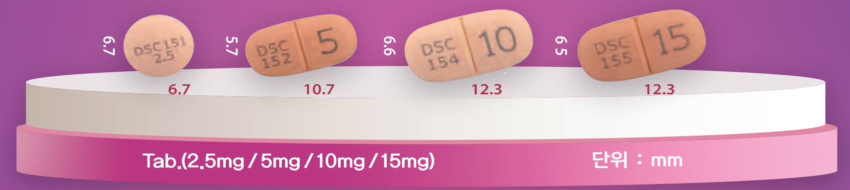

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References

1. Finnerup NB, et al. Pharmacotherapy for neuropathic pain in adults: a systematic review and meta-analysis. Lancet Neurol. 2015 Feb;14(2); 162-73.
2. 뉴론틴®정 제품설명서 개정년월일2024.05.13 **3.** 뉴론틴®캡슐 제품 설명서 개정년월일 2024.09.21

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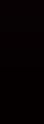

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Biopsy specimen images provided by Y.Jiang. UCSF.

※ 65세 여성의 뼈 생검 결과 치료 전과 포스테오 21개월 후의 Micro CT 이미지 (Micro CT image of iliac crest bone biopsies)
실제 환자 케이스는 일반 환자군에서의 임상적 결과와 다를 수 있습니다.

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포스테오®주(테리파라타이드) [원료의 명칭 및 분량] 1mL 중 주성분: 테리파라타이드(유전자 재조합) (별첨 규격) 250㎍ (숙주: E.coli K12 RQ228, 벡터 : pHMM193) 보존제 : 메타크레졸(유에스피) 3.0mg **[효능 · 효과]** · 폐경기 이후 여성 및 골절의 위험이 높은 남성에 대한 골다공증의 치료 · 골절의 위험이 높은 여성 및 남성에 있어서 지속적인 글루코코르티코이드 요법과 관련된 골다공증의 치료 **[용법 · 용량]** 권장용량은 1일 1회 이 약 20㎍을 대퇴부 또는 복부에 피하주사한다. 환자들은 올바른 주사 방법에 대하여 교육을 받아야 한다. 환자에게 펜의 정확한 사용을 지도하기 위한 사용자 안내서(User manual)도 있다. 이 약의 사용기간은 최대 24개월이다. 한 환자의 일생에서 이 약의 24개월 과정을 반복해서는 안 된다. 만일 음식 섭취 가 불충분한 경우에는, 환자들은 칼슘과 비타민D 보조제를 추가적으로 섭취하여야 한다. 이 약의 치료가 끝난 후에는 환자들은 다른 골다공증 치료를 계속할 수 있다. **[사용상의 주의사항]** 1. 다음 환자에는 투여하지 말 것 – 테리파라타이드 또는 이 약의 부형제 성분에 대하여 과민반응 – 중증의 신장 기능 손상 – 임부 및 수유부 – 골격 악성종양 또는 골 전이가 있는 환자 – 기존의 고칼슘혈증 – 충분히 설명되지 않은 alkaline phosphatase의 상승 – 일차적인 골다공증 이외에 대사성 골질환 (부갑상선 기능 항진증 및 뼈의 Paget's disease 포함) – 이전에 골격에 방사선 치료를 한 경우 **[제조원]** 전공정 위탁제조(제조의뢰자) : Eli Lilly Nederland B.V, Papendorpseweg 83, 3528 BJ Itrecht, Netherlands 일부공정위탁제조(제조자) [원료의약품] Boehringer-Ingelheim RCV GmbH & Co KG Dr.-Boehringer-Gasse 5-11 1121 Vienna, Austria, Lilly del Caribe 65th Infantry Rd., Km. 12.3(PR05), Carolina, Puerto rico [완제의약품] Lilly France S.A.S Rue du Colonel Lilly, 67640 Fegershim, France 제품설명서 개정일자: 2021.01.25
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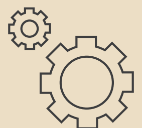

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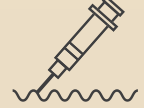

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효능 • 효과

1. 성인에서 말초와 중추 신경병증성 통증의 치료
2. 간질 : 성인에서 이차적 전신증상을 동반하거나 동반하지 않은 부분 발작의 보조제
3. 섬유근육통의 치료

용법 • 용량

이 약은 프레가발린으로서 1일 총 투여용량을 1일 2회로 나누어 음식물과 상관없이 경구 투여한다. 이 약은 주로 신장으로 배설되므로, 신기능이 저하된 환자에 대해서는 용량이 조절되어야 한다. 1. 신경병증성 통증 1) 말초 신경병증성 통증(성인): 이 약은 시작용량으로 1일 150mg을 투여할 수 있다. 개개 환자에서의 반응과 내약성에 근거하여 3일 내지 7일 후에 1일 300mg까지 증량할 수 있다. 필요하다면, 이후 7일 간격으로 1일 최대 600 mg까지 증량할 수 있다. 2) 중추 신경병증성 통증(성인): 이 약은 시작용량으로 1일 150mg을 투여할 수 있다. 개개 환자에서의 반응과 내약성에 근거하여 1주일 후에 1일 300mg까지 증량할 수 있다. 추가로 1주일 후에 목표 1일 용량인 600mg까지 증량할 수 있다. 목표 1일 용량에서 내약성을 나타내지 않을 경우 용량 감소가 고려될 수 있다. 2. 간질(성인): 이 약은 시작용량으로 1일 150mg을 투여할 수 있다. 개개 환자에서의 반응과 내약성에 근거하여 일주일 후에 1일 300mg까지 증량할 수 있다. 필요하다면, 이 후 7일 간격으로 1일 최대 600mg까지 증량할 수 있다. 3. 섬유근육통: 이 약의 권장 용량은 1일 300mg~450mg 이다. 이 약은 시작 용량으로 75mg씩 1일 2회(1일 150mg)를 투여하며, 유효성과 내약성에 근거하여 1주일 이내에 150mg씩 1일 2회(1일 300mg) 까지 증량할 수 있다. 1일 300mg의 용량에서 충분한 유익성을 경험하지 못한 환자의 경우에는 1주일 이내에 225mg씩 1일 2회(1일 450mg) 까지 증량할 수 있다. 1일 600mg의 용량에서도 임상 연구가 실시되었으나, 이 용량에서의 부가적인 유익성이나 충분한 내약성에 대한 증거는 없다. 용량 의존적인 이상반응을 고려하면, 1일 450mg을 초과하는 용량 투여는 권장되지 않는다.

사용상의 주의사항

1. 경고 1) 자살충동과 자살행동 (1) 항간질약을 복용한 환자에서 자살충동 또는 자살행동을 보이는 위험성이 증가되므로 항간질약을 치료받은 환자는 자살충동 또는 자살행동, 우울증의 발현 또는 악화 및 기분과 행동의 비정상적 변화에 대하여 모니터링되어야 한다.(2) 항간질약을 처방받는 간질과 다른 많은 질병은 그 자체가 이환 및 사망, 치료기간 동안의 자살충동과 자살행동의 위험성증가와 관련된다. 따라서 처방자는 항간질약 처방시 환자의 치료기간 동안 자살충동 또는 자살행동과 치료될 질병간의 연관성 유무 및 이 약의유효성을 함께 고려한다. 2. 다음 환자에는 투여하지 말 것 1) 프레가발린 또는 이 약의 성분에 과민한 환자 2) 이 약은 유당을 함유하고 있으므로, 갈락토오스 불내성 (galactose intolerance), Lapp 유당분해효소 결핍증 (Lapp lactase deficiency) 또는 포도당-갈락토오스 흡수장애 (glucose-galactose malabsorption) 등의 유전적인 문제가 있는 환자에게는 투여하면 안 된다.

* 기타 자세한 사항은 제품설명서를 참고하십시오.

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Reference **1.**『약제 급여 목록 및 급여 상한금액표』보건복지부 고시 제 2017-133호 (2017년 8월 15일 시행) **2.** 카발린캡슐 허가사항

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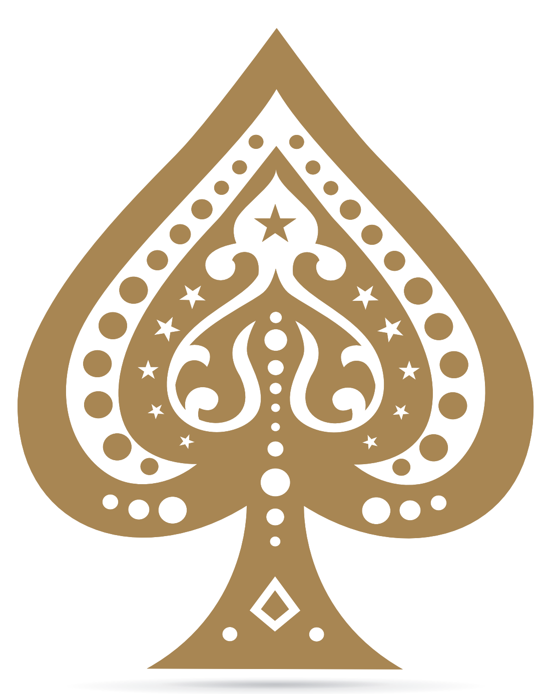

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Reference

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사내 교육용

피부 수분 유지와 상처 보호를 위한

국소 하이드로겔 창상피복재

#All in one #Something NEW

#병의원전용 #수술 후 상처관리

#감염예방 및 상처치유

FDA

Neo Surgi Gel은 FDA 승인 받은 실손보험 적용이 가능한 천연성분의 안전한 상처치료재입니다.

NEW GENERATION OF WOUND CARE SKIN REGENERATION AND PAIN REDUCTION

윤메디텍
010-4168-3644

Compression Sleeve

건강보험 급여 제품

보험코드 K7301045

품명	Venoplus Arm Sleeve	사이즈	S, M, L, XL, 2XL, 3XL
모델명	YA101, YA201, YA301	포장단위	1 pair
색상	베이지	압력	20~30mmHg

TEL : 02-3664-1188

일회용 의료기기 | 재사용 금지 | 멸균제품

endovision

NUvella™

Chitosan + Sodium Polynucleotide + EGF + bFGF

- 외음부, 회음부 피부 손상 방지
- 버섯유래 키토산, 연어유래 PN (Sodium Polynucleotide) 함유
- 손상된 피부를 보호하는 점착성 투명 창상 피복재
- 도포가 편리한 튜브 타입

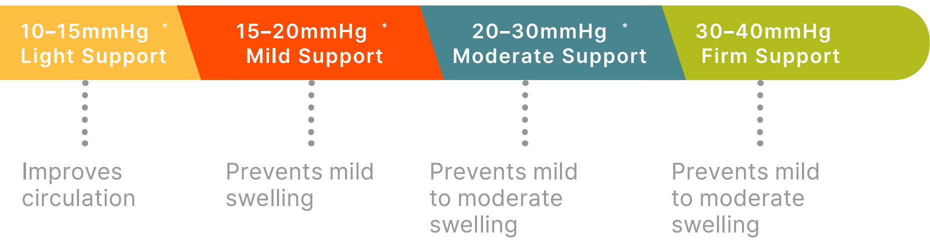
판매자 : LunaBio 서울시 강동구 고덕비즈밸리로 51, 1115호
Tel : 033-765-2269 | Fax : 033-765-2279

endovision
infinite vision of the medical device

1. Soft comfort band is non-restrictive while staying in place all day
2. Ultra-stretchy Core-Spun yarns make sock easier to put on
3. Two-way stretch nylon and spandex blend
4. Moisture wicking fibers provide a comfortable coolness
5. Reinforced toe for durability
6. Delivers lab tested true gradient compression to promote better blood flow, prevent mild to moderate swelling, and relieve tired, achy legs and feet

LYCRA® and COOLMAX® are registered trademarks of The LYCRA Company.

Compression Levels Available



MEGAMED

주식회사 메가메드 경기도 용인시 수지구 수풍로 57-5 3F **H.** www.megamed.kr **T.** 031-897-4849 **E.** master@megamed.kr

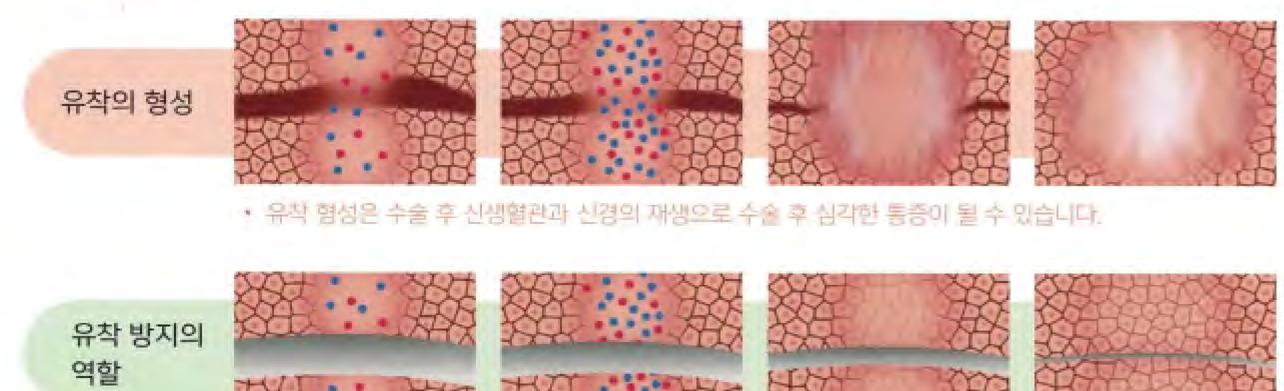
STERILE | Refer to instruction for use | GMP

McSHIELD

Crosslinked hyaluronic acid with MDM® Tech

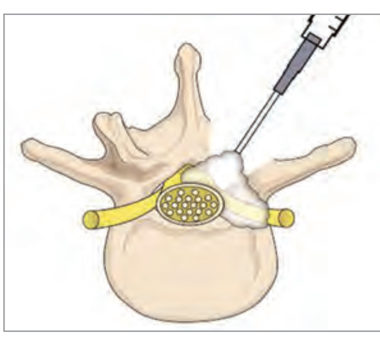
About McSHIELD®

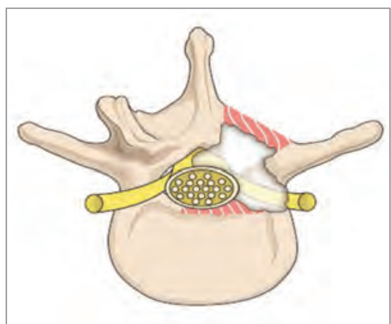
McSHIELD®(Anti-Adhesion Gel)은 수술 후 손상된 조직 간의 유착 방지 장벽을 형성하여 **유착 형성을 줄이는데 도움**을 줍니다.
또한 **히알루론산(HA) 제조 특허 기술인 MDM® tech.가 적용**된 생체적합성이 뛰어난 유착방지제입니다.
McSHIELD®은 수술 부위의 초기 치유 단계부터 **유착형성을 억제하는 동시에 정상적인 상처 치유에 도움**이 됩니다.



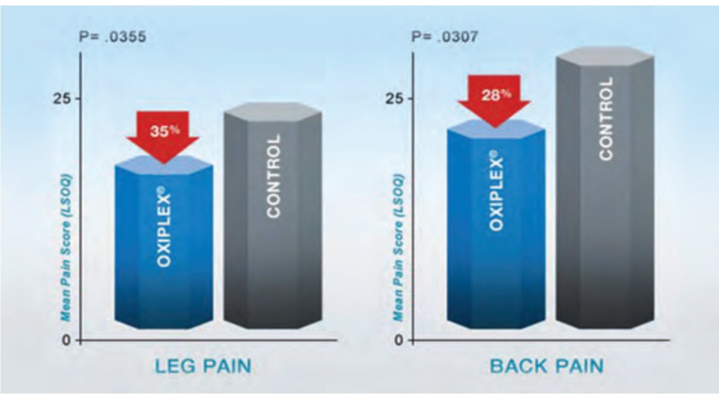
The Leading Adhesion Barrier for Spine Surgery Worldwide

(척추용 유착방지제)





Oxiplex is intended to be placed around neural tissues following spine surgery to reduce adhesion formation and related symptoms such as pain.



- Less residual leg and back pain
- Fewer neurological symptoms
- No post-op CSF leaks
- Fewer re-operations
- Enhanced patient satisfaction

(주)더블유에스아이
TEL 02)3447-9660

동아ST

전문의약품

불이 켜졌습니다.
걸어야 할 시간입니다.

오팔몬(Limaprost) 은,
요부척추관협착증 환자의
보행거리를 개선합니다.

OMT-23L038

CGBIO,

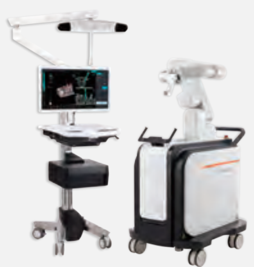
From Precision to Predictable Outcomes.

Refine
Every Detail.
Elevate
Every Surgery.

PRECISION. PASSION. PERFECT OUTCOMES.

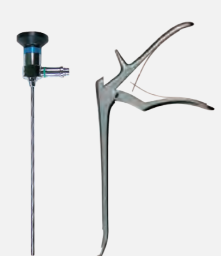
Plan & Guide : CUVIS-Spine Navigation & Robot system

Navigate with Confidence.
Real-time 3D guidance for safer, more precise procedures.



See & Access : Solendos Endoscope system

Direct Vision. Targeted Access.
Endoscopic clarity to see the pathology and reach it — minimally invasive.



Expand & Stabilize : EXCENDER Expandable Cage

Restore Height. Rebuild Stability.
In-situ expandable technology for optimal disc space restoration.