Surgical Management of Lumbar Spine Fractures and Dislocations


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**Abstract**

**Background:** Lumbar spine fractures and dislocations, which are part of the thoracolumbar region, are critical injuries with significant morbidity. The epidemiological shift in the median age of injury and the high prevalence of these injuries, particularly in the T10-L2 region, highlight the necessity for effective therapeutic interventions. With advancements in spine biomechanics, imaging technologies, and surgical techniques, there has been a paradigm shift from conservative to surgical management, though high-quality comparative studies remain limited. **Objective:** To synthesize recent data on the epidemiology, evaluation, and management of lumbar spine fractures and dislocations, and to elucidate the comparative efficacy of surgical interventions and conservative approaches in optimizing patient outcomes. **Method:** This paper conducts a comprehensive review of epidemiological data on thoracolumbar traumatic injuries, diagnostic techniques, and management strategies, especially focusing on surgical interventions. The review also details specific surgical techniques utilized for lumbar spine fractures and their underlying rationale. **Findings and Conclusion:** Thoracolumbar injuries primarily affect the transitional zone (T11-L2) and show a higher incidence in males aged between 20 and 40. Imaging, especially CT scans, offers a definitive diagnostic approach, with MRI providing insights on soft tissue interactions. While historically, conservative methods dominated therapeutic interventions, surgical techniques, including Posterior Instrumentation, Anterior Lumbar Interbody Fusion (ALIF), Transforaminal Lumbar Interbody Fusion (TLIF), and Posterior Lumbosacral Interbody Fusion (PLIF), are increasingly being utilized. Some specific fractures even warrant a combined posterior-anterior surgical approach. Notably, certain case studies highlight the potential for superior outcomes with surgical intervention, even in the absence of neurological deficits. Selecting the appropriate management strategy should be tailored to individual patient factors, nature of the injury, and available expertise and resources.

**Keywords:** Management, MRI
1. Introduction

The thoracolumbar region, spanning from T10 to L2, is frequently prone to spinal injuries resulting from trauma, primarily owing to the distinctive biomechanics characterizing this section of the spine. More specifically, this region serves as a transitional zone between the relatively rigid and less mobile thoracic spine—attributable to the attachment of ribs bilaterally—and the more pliable lumbar spine. Damage sustained within this region can lead to enduring neurological impairments, either through nerve root compression or direct injury to the cauda equina or conus medullaris, necessitating immediate attention and assessment. [1]

From both anatomical and functional perspectives, we can categorize the spine into three distinct regions: the thoracic spine (T1-T10), the thoracolumbar junction (T10-L2), and the lumbar spine (L3-L5). The thoracic spine possesses functional rigidity due to facet joints oriented in the coronal plane, slender intervertebral discs, and the presence of the ribcage. Consequently, it demands a substantial amount of energy to incur fractures and dislocations. Furthermore, the narrow spinal canal in this region increases the vulnerability to spinal cord injuries, resulting in a notably elevated incidence of neurological deficits. Conversely, the lumbar spine exhibits a relatively greater degree of flexibility due to thicker intervertebral discs, facet joints oriented sagittally, and the absence of a ribcage. The lower occurrence of neurological injuries in lumbar fractures can be ascribed to the larger size of the neural canal and the increased resilience of the cauda equina nerve roots. [2,3]

Fracture classification systems have been formulated to provide guidance for treatment decisions. These systems assess various factors including spinal stability, neurological deficits, fracture location, the extent of damage to bone structures, and involvement of ligamentous complexes. One of the pioneering models designed to classify traumatic thoracolumbar fractures and their pathomorphology was the three-column system introduced by Denis. In this system, the anterior column comprises the anterior longitudinal ligament, annulus fibrosus, and the anterior part of the vertebral body, while the middle column encompasses the posterior part of the vertebral body, the annulus, and the posterior longitudinal ligament (PLL). The posterior column comprises all structures located posterior to the PLL. At present, three primary classification systems are widely recognized for categorizing traumatic fractures. The Spine Trauma Study Group has developed the Subaxial Injury Classification and Severity scale (SLICS) and the Thoracolumbar Injury Classification and Severity score (TLICS). Additionally, in 1994, the AO spine classification was proposed, which employs a two-column model. However, it is worth noting that the AO spine classification has demonstrated limited intraobserver and interobserver reliability. [4]

The thoracolumbar junction (T10-L2) occupies a distinctive position between the rigid thoracic spine, with its associated ribs and sternum, and the more mobile lumbar spine. This transition from the less mobile thoracic spine to the dynamic lumbar spine exposes the thoracolumbar region to substantial biomechanical stresses. Consequently, fractures occurring in the thoracolumbar region emerge as the most prevalent injuries affecting the vertebral column. [2]

Annually, there are around 5 million fresh cases of vertebral fractures across the globe. In the United States, a significant 72.5% of all spinal fractures affect either the thoracic or lumbar regions. The involvement of the thoracolumbar junction and lumbar spine in spinal injuries can be attributed to specific factors: the thoracolumbar junction serves as a mechanical transition zone, while the lumbar spine lacks stabilizing connections with ribs, adopts a lordotic posture, and features facet joints oriented more sagittally, all contributing to their vulnerability in spinal injuries. [5-8]

Several extensive, multicenter investigations on thoracolumbar fractures have been undertaken. Nevertheless, a consensus on the most suitable approach to management has not been universally established. This lack of agreement is partly attributable to shortcomings in the study designs, where treatment choices were influenced by the treating physicians’ philosophies and personal convictions, despite the primary outcomes being evaluated from a prospective database. Evidently, studies characterized by limited quality fail to offer robust scientific evidence to steer clinical practice effectively. [9]

The primary approach for treating stable thoracolumbar fractures frequently involves non-surgical methods. Surgical intervention is typically advised when there is evidence of spinal instability, which could potentially lead to a loss of appropriate spinal alignment, further neurological deterioration, or hindered progress in terms of mobility and rehabilitation. Conservative treatment is not advisable for cases involving fracture-dislocations of the spine, as these injuries encompass not only fractures but also varying degrees of damage to ligaments and discs. [10]

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Epidemiology:

Before 2000, thoracolumbar traumatic injuries were most frequently observed in individuals aged 15-29 years. However, the median age for such injuries has now increased to 35. These injuries have significant societal implications, as approximately 27% of patients with thoracolumbar junction injuries experience neurological deficits, leading to lifelong disability and a loss of economically productive years. Around 70% of these fractures initially occur without immediate neurological damage, and ultimately, 55% of patients maintain their neurological integrity. Among the remaining 45% who do develop neurological symptoms, 26% experience incomplete injuries, while 19% suffer from complete injuries. Notably, up to 75% of spine fractures manifest in the T10-L2 region. [1,10,11]

In an epidemiological investigation conducted by Hu et al. within the Canadian population, the annual incidence of spinal injuries was recorded at 64 per 100,000 individuals. In North America as a whole, the annual occurrence of spinal injuries exceeds 160,000 cases. Among thoracolumbar injuries, approximately 50-60% impacted the transitional zone (T11-L2), while 25-40% affected the thoracic spine, and 10-14% involved the lower lumbar spine and sacrum. These fractures occur more frequently in males, with the highest incidence observed between the ages of 20 and 40. Neurological complications were observed in 20-36% of thoracolumbar junction fractures in various studies. The likelihood and extent of neurological deficits are contingent upon the specific fracture type. According to a multcenter study, the incidence of neurological deficits varied from 22% to 51% depending on the fracture type, with rates of 22% in type A, 28% in type B, and 51% in type C fractures, as per the AO classification. [2,12-17]

Evaluation:

Most thoracolumbar junction fractures stem from severe traumatic events, such as motor vehicle collisions and falls. A comprehensive patient history is invaluable in understanding the nature of the injury's cause, particularly in patients who are neurologically stable. In cases of low-energy mechanisms like falls from ground level, neurological injury is typically absent. However, patients may exhibit neurological injury symptoms, which become evident during the neurological examination. [1]

Patients experiencing neurological injury often report sensations of weakness, tingling (paresthesia), or numbness below the level of the injury, as well as urinary retention. It's essential to conduct a thorough examination of the spine, including a careful log roll maneuver, to identify any signs such as skin abrasions, tenderness, localized kyphosis, or the presence of a noticeable gap between the spinous processes. [2]

Elderly individuals, those with osteoporosis, or those at risk of developing osteoporosis, who present with acute back pain following minor incidents like ground-level falls or low-impact traumas should undergo a CT scan to assess the possibility of compression fractures. A diagnosis of osteoporosis can be established based on the presence of a vertebral body fracture alone or through a DEXA scan yielding a value less than -2.5. When it comes to evaluating vertebral column fractures, imaging serves as the definitive diagnostic approach. [4]

Given that the spinal cord terminates at the L1-L2 level and the cauda equina occupies the lower canal, a range of neurological injury patterns can emerge in cases of thoracolumbar fractures. Injuries above the L1 level have the potential to harm the spinal cord, resulting in a typical upper motor neuron injury. In contrast, injuries occurring well below the L1-L2 level primarily affect the cauda equina roots, implicating a lower motor neuron injury with involvement of one or more nerve roots. An intriguing feature associated with T12-L1 injury is Conus medullaris syndrome, which is characterized by exclusive damage to the sacral nerve innervations controlling bowel and bladder function while leaving lumbar nerve roots intact. [2]

Lateral spine radiographs, in particular, prove invaluable for diagnosing both osteoporosis and vertebral column fractures. By measuring the adjacent vertebral bodies and comparing them to the affected segment, valuable insights can be gleaned. However, for a comprehensive assessment of spinal fractures, CT scans are regarded as the superior imaging modality. CT imaging allows healthcare professionals to evaluate the spine in three dimensions, facilitating an accurate grading of the extent of pathology. Furthermore, CT scans can be instrumental in guiding patients toward DEXA scans for osteoporosis assessment. Moreover, While CT scans excel in providing a structural view of the spine, MRIs offer a more holistic perspective by depicting the relationships between bony structures and soft tissues while capturing the acuity of the condition. On the other hand, dual-energy X-ray absorptiometry (DEXA scans) stand as the gold standard for diagnosing osteoporosis, with a T score of less than -2.5.

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indicative of the condition. However, it's important to note that DEXA scans are not suitable for diagnosing compression fractures. [4, 18]

A CT scan offers significantly enhanced diagnostic capabilities compared to plain radiographs, particularly when assessing the extent of bony injuries. Moreover, it excels in evaluating the degree of canal compromise, a crucial aspect in spinal injury assessment. Research conducted by James et al. in 2005 emphasized that plain radiographs often fail to detect laminar and articular process fractures, which are optimally visualized through axial CT scans. [19] Nevertheless, obtaining anteroposterior (AP) and lateral plain radiographs in cases of suspected injury remains valuable for both preoperative planning and postoperative follow-ups. Additionally, they can reveal subtle soft tissue changes and variations in the posterior elements, serving as red flags that warrant further examination. CT scans, especially when employing sagittal and coronal reconstructions, prove effective in visualizing kyphotic and translation injuries. It is essential to meticulously assess vertebral body height, disc spaces, inter-pedicular distances, and inter-spinous process intervals, comparing them between the injured and non-injured levels. Nonetheless, it is crucial to acknowledge that CT scans have limitations in capturing soft-tissue injuries, including disc herniations, epidural or subdural hematomas, ligamentous injuries, and spinal cord parenchymal damage. [5]

Management:

The primary objective in addressing thoracolumbar fractures is the restoration of the spine’s anatomical integrity and structural stability, thereby creating an optimal biological and biomechanical environment to promote functional recovery. Historically, conservative methods were the standard for treating these fractures. However, significant progress in spine biomechanics, imaging technologies, and surgical techniques has prompted a shift in treatment approaches from conservative measures to surgical interventions in recent decades. It's important to note that neurological deterioration is a rare occurrence in patients managed conservatively for thoracolumbar fractures. Yet, when we consider evidence-based medicine, there remains a shortage of high-quality comparative studies directly comparing the outcomes of conservative versus operative treatments. [9] With that being said, Conservative management is discouraged for spinal fracture-dislocations due to the presence of not only fractures but also varying degrees of ligament and disc damage. [10]

Enishi T, et al. reported a case study where they presented two cases of significant thoracolumbar spine fracture-dislocation without neurological deficits. Preservation of neurological function was attributed to specific factors, including bilateral pedicle fractures maintaining spinal canal relationships in one case and rotational displacement and vertebrae collapse decompressing the dura and expanding the spinal canal in the other. To prevent neurological deterioration, late deformity, and pain, the authors recommend spinal reconstruction. Moreover, for cases without neurological deficits, surgical intervention, specifically anterior subtotal corpectomy, and reconstruction combined with posterior decompression, was proposed to restore spinal alignment and stability, making it the preferred treatment choice for such patients. [20]

In another case reported by Nakao Y, Kajino T. (2013) a 47-year-old Asian man involved in a heavy equipment accident presented with complaints of low back pain, numbness, and weakness in both lower extremities. Radiographic and CT imaging indicated laterolisthesis at the L1-2 and L4-5 levels, along with fractures involving several vertebral processes. Urgent surgery was performed, involving open reduction of the fracture-dislocations, placement of pedicle screws, laminectomy, and bone grafting. Following surgery, the patient demonstrated improved neurological function and began rehabilitation. While he experienced marked improvements in muscle strength, some residual deficits persisted, particularly in the right leg. Sensation remained compromised in specific distributions. Notably, the patient regained voluntary bowel and bladder function. At the one-year follow-up, radiographs showed an anatomically aligned spine with intact instrumentation and presumed solid spinal fusion. [21]

Traditional techniques of spinal instrumentation, including screw-plate, hook-rod, and screw-rod systems, have been effectively utilized. While many of these unstable injuries have been addressed using these methods without necessitating further anterior spinal surgeries, recent observations suggest that long-term outcomes may not always preserve reduction, height, or sagittal balance. In the context of thoracolumbar burst fractures that are unstable, some experts argue for the need for anterior decompression and rebuilding of the anterior column to prevent later imbalances in the coronal and sagittal planes. Yet, most studies recommend a posterior method for addressing fracture dislocations. [22]

Various research has investigated the treatment of thoracolumbar fractures. Some randomized controlled trials have contrasted surgical and non-surgical treatments for thoracolumbar burst fractures,
finding no notable benefits from surgery. [23-26] non-surgical treatment methods encompass the use of thoracolumbar braces, plaster casts, Jewett braces, and plastic body casts for around 12 weeks. Most compression fractures are deemed stable and can be managed either through close monitoring or by using an orthosis. [1]

**Surgical Intervention methods:**

Surgical interventions for lumbar spine fractures and dislocations are diverse and have been refined over the years to enhance safety and efficacy. Here’s a detailed examination of the primary surgical techniques:

1. **Posterior Instrumentation:** This is often a preferred method for lumbar spine fractures. By utilizing pedicle screws connected by rods, this technique offers direct stabilization of the fractured or dislocated segments of the lumbar spine. The widespread adoption of this method stems from its potential to offer immediate stability, aiding in faster patient recovery and rehabilitation [27].

2. **Anterior Lumbar Interbody Fusion (ALIF):** ALIF is a notable technique in spine surgery. This approach accesses the lumbar spine from the front. Once the surgeon reaches the affected vertebrae, an implant, typically filled with bone graft material, is placed between them to encourage fusion. The direct visualization of the lumbar spine that ALIF allows facilitates accurate placement of grafts and implants [28].

3. **Transforaminal Lumbar Interbody Fusion (TLIF) and Posterior Lumbar Interbody Fusion (PLIF):** These are posterior techniques targeting the lumbar spine. Their primary objective is to remove a segment of the intervertebral disc and promote the fusion of the vertebrae using grafts and/or cages. Opting for a posterior approach has the advantage of bypassing the major blood vessels in front of the spine, potentially reducing vascular complications. Both TLIF and PLIF can address a spectrum of lumbar issues, from fractures to degenerative disc diseases [29].

4. **Combined Posterior Anterior Approach:** Some patients with thoracolumbar burst fractures might see improved outcomes from combined surgical methods. This approach is particularly relevant for those with pronounced kyphosis, significant canal compromise, and neurological issues due to spinal cord compression. The benefits of using combined surgical techniques include enhanced sagittal alignment, comprehensive spinal canal and neural relief, and stabilization of the disrupted posterior ligament complex. In a study involving 20 patients with a specific type of unstable thoracolumbar burst fracture, they were treated with posterior fixation followed by a procedure involving removal of the vertebra and placement of a titanium cage. Out of these, 12 patients with initial neurological impairments showed notable recovery. Two years after the operation, the average back pain score was relatively low, and there were no instances of instrumentation failure. When looking at outcomes over an average of 6 years, combined surgery had outcomes that were on par with posterior-only procedures in terms of clinical results, neurological improvement, fusion success, and kyphotic angle. Nevertheless, the posterior-only approach had a greater likelihood of loss of reduction and instrumentation issues. [2,30,31]

The selection of a surgical technique often depends on the unique characteristics and location of the patient's injury, potential surgical challenges, the surgeon's experience with a particular method, and the resources available at the healthcare facility.

4. **Conclusion**

Lumbar spine fractures and dislocations present a significant clinical challenge. While conservative management remains an option for specific injuries, the advent of advanced surgical techniques offers the potential for enhanced functional recovery and anatomical restoration. Selecting the appropriate management strategy should be tailored to individual patient factors, nature of the injury, and available expertise and resources.

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