



RESEARCH ARTICLE

INDIRECT LONG SEGMENT STABILISATION BY POSTERIOR APPROACH FOR UNSTABLE BURST COMPRESSION FRACTURES OF THORACOLUMBAR SPINE IN ADULTS

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ABSTRACT

Thoracolumbar spine fractures are common injuries that can result in significant disability, deformity and neurological deficit. Controversies exist regarding the appropriate radiological investigations, the indications for surgical management and the timing, approach and type of surgery. This study provides an overview of the epidemiology, biomechanical principles, radiological and clinical evaluation, classification and management principles for burst fractures in thoracolumbar spine operated by posterior approach. Biomechanically the thoracolumbar spine is predisposed to a higher incidence of spinal injuries. Computed tomography provides adequate bony detail for assessing spinal stability while magnetic resonance imaging shows injuries to soft tissues (posterior ligamentous complex [PLC]) and neurological structures. Different classification systems exist and the most recent is the AO spine knowledge forum classification of thoracolumbar trauma. Treatment includes both nonoperative and operative methods and selected based on the degree of bony injury, neurological involvement, presence of associated injuries and the integrity of the PLC. Significant advances in imaging have helped in the better understanding of thoracolumbar fractures, including information on canal morphology and injury to soft tissue structures. The ideal classification that is simple, comprehensive and guides management is still elusive. Involvement of three columns, progressive neurological deficit, significant kyphosis and canal compromise with neurological deficit are accepted indications for surgical stabilization through anterior, posterior or combined approaches.

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INTRODUCTION

Fractures of the thoracic and lumbar region constitute a spectrum of injuries ranging from the simple undisplaced fractures to complex fracture dislocations.<sup>1</sup> Anatomically and functionally, the thoracic and lumbar spine can be divided into three regions – thoracic spine (T1-T10), thoracolumbar junction (T10-L2) and the lumbar spine (L3-L5). The thoracic spine is functionally rigid due to coronally oriented facet joints, thin intervertebral discs and the ribcage. Thus, it requires huge amounts of energy to produce fractures and dislocations. The narrow spinal canal in this region predisposes to spinal cord damage resulting in a high incidence of neurological deficit. The lumbar spine, on the other hand, is relatively flexible due to the thicker intervertebral discs, sagittal orientation of facet joints and the absence of the rib cage.

The relatively lesser incidence of neurological injury in lumbar fractures can be attributed to the large size of the neural canal and the greater resilience of the cauda equina nerve roots. The thoracolumbar junction (T10-L2) is uniquely positioned in between the rigid thoracic spine and the mobile lumbar spine. This transition from the less mobile thoracic spine with its associated ribs and sternum to the more dynamic lumbar spine subjects the thoracolumbar region to significant biomechanical stress.<sup>1,2</sup> Hence, fractures of the thoracolumbar region are the most common injuries of the vertebral column. Though fractures of the thoracolumbar spine are common injuries, 50% of these are unstable and can result in significant disability, deformity and neurological deficit. There are standard classification systems that have been described based on fracture morphology, injury mechanism, neurological deficit and injury to posterior ligamentous complex (PLC). Radiographs are the basic investigation while computed tomography (CT) scan provides information on the extent on bony injury and magnetic resonance imaging (MRI) scan shows injury to the spinal cord and soft tissue structures.

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However, despite extensive studies on this common injury, controversies still exist regarding the appropriate radiological investigations, the type of Nonoperative treatment, the indications for surgical management, the timing of surgery, approach and type of surgery, need for fusion and the role of spinal canal decompression. This review provides an overview of the epidemiology, biomechanical principles, radiological and clinical evaluation, and evolution of classification system and management principles

## EPIDEMIOLOGY

In an epidemiological study by Hu et al. in the Canadian population, the incidence of spinal injuries was 64/100,000 population/year.<sup>3</sup> In North America, the incidence of spinal injuries is more than 160,000 every year.<sup>2</sup> Among the thoracolumbar injuries, 50-60% affected the transitional zone (T11-L2), 25-40% affected the thoracic spine and 10-14% involved the lower lumbar spine and sacrum.<sup>4</sup> Thoracolumbar fractures are more frequent in men, and the peak incidence is observed between 20 and 40 years.<sup>4,5</sup> Neurological injury complicates 20-36% of fractures at the thoracolumbar junction in different studies.<sup>6,7</sup> The chances and extent of neurological deficit depend on the type of fracture. In a multicenter study, the incidence of neurological deficit ranged from 22% to 51% depending on the fracture type (22% in type A, 28% in type B and 51% in type C fractures, according to the AO classification).<sup>8</sup>

Injuries to the thoracolumbar spine are usually the result of high-energy blunt trauma. Sixty-five percent of thoracolumbar fractures occur due to motor vehicle injuries and falls from a height, with the remainder contributed by sports injuries and violence. Since these are high-velocity injuries, thoracolumbar fractures are commonly associated with other injuries like rib fractures, pneumo-hemothorax, and rarely great vessel injuries, hemopericardium and diaphragmatic rupture<sup>9,10</sup> [Figure 1]. Seat-belt (chance) fractures and flexion distraction injuries are often associated with intraabdominal visceral injuries. Long bone fractures and head injuries are also common and can often lead to missed injuries of the spine.<sup>8</sup> Due to such associated “distracting” injuries, the incidence of missed injuries of the thoracolumbar spine has been reported to be as high as 20%, especially in those with high-energy blunt trauma and altered mental status.<sup>11</sup> In a review of 508 consecutive spinal injury patients, Saboe et al. identified associated injuries in 47%. Most frequent injuries were head injuries (26%), chest injuries (24%) and long bone injuries (23%).<sup>12</sup>

## DIAGNOSIS

### Clinical evaluation

Needless to say, any suspected spinal trauma patient in the emergency room should be evaluated following the basic principles of trauma assessment including primary and secondary survey. Once life-threatening injuries are prioritized, a careful history about the injury mechanism and information pertaining to any back or neck pain and neurological symptoms are acquired. Patients typically present with a history of trauma following a road traffic accident, fall from height, a direct blow to the spine or rarely gunshot injuries. Axial, nonradiating back pain of stabbing or aching quality is the most common symptom. Patients with neurological injury complain of weakness, paresthesia or anesthesia below the

injury level and urinary retention. Thorough inspection of the spine should be performed after a careful log roll maneuver to look for abrasions, tenderness, local kyphosis and a palpable gap in between spinous processes. Neurological assessment should follow the standard American Spinal Injury Association (ASIA) guidelines<sup>13</sup> [Figure 2]. As the spinal cord ends at the L1-L2 level, and the cauda equina fills the distal canal, varied neurological injury patterns can be observed with thoracolumbar fractures. Neurological injuries above L1 can damage the spinal cord producing a typical upper motor neuron injury. Injuries much below L1-L2 affect only the cauda equina roots involving few or multiple nerve roots resulting in lower motor neuron type injury. Conus medullaris syndrome characterized by exclusive damage to sacral innervations to the bowel and bladder, with intact lumbar nerve roots, is a unique feature of T12-L1 injury

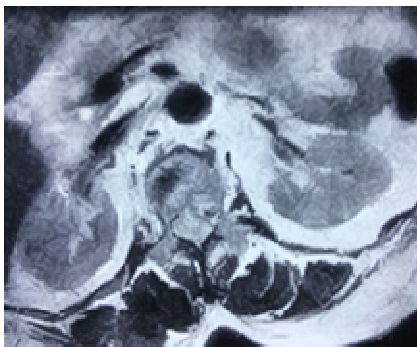
The form is titled 'INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY ISCS'. It includes fields for Patient Name, Examiner Name, and Date/Time of Exam. The main section is a grid for testing Motor (M) and Sensory (S) functions at various spinal levels (C2, C3, C4, C5, C6, C7, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, L1, L2, L3, L4, L5, S1, S2, S3, S4-S5). The grid is divided into 'MOTOR' and 'SENSORY' columns. Below the grid are sections for 'NEUROLOGICAL LEVEL', 'SENSORY LEVEL', 'MOTOR LEVEL', and 'ASIA IMPAIRMENT SCALE (AIS)'. There are also checkboxes for 'COMPLETE OR INCOMPLETE?' and 'ZONE OF PARTIAL PRESERVATION'. The form includes a small anatomical diagram of the human body with key sensory points marked.

## Radiological evaluation

Standard radiographic evaluation includes antero-posterior and lateral radiographs. Radiographic evaluation should include spinal alignment, presence of any rotation or translation, assessment of the kyphosis, loss of vertebral height, and widened inter-pedicular or inter-spinous distance.<sup>11,14,15</sup> CT scan of the injured area characterizes the fracture further and provides the degree of canal compromise. Approximately, 25% of burst fractures are misdiagnosed as compression fractures if radiographs alone are evaluated<sup>16</sup> [Figure 4]. MRI scan provides information on spinal cord or root injury, presence and extent of cord edema and hemorrhage, and epidural hematoma.<sup>17</sup> Other advantages of MRI are its ability to evaluate injury to the intervertebral discs and PLC, and identify the presence of noncontiguous injuries through screening of the whole spine [Figure 5]. The incidence of noncontiguous spinal fractures is 1.6-23.8%.<sup>18,19</sup> The incidence of a delayed diagnosis of the second lesion ranges from 23.1% to 83.3%.<sup>18,19</sup> Thorough clinical examination of the entire spine to look for bruise and tenderness, radiographs of the other regions of the spine and sagittal MRI screening of the whole spine can potentially avoid missing other injuries

## CLASSIFICATION

Biomechanics of the load bearing and supporting structures of the vertebral column form the basis of understanding the spinal injuries and their classification systems. The classification of thoracolumbar fractures has evolved over the years as the understanding of the spinal biomechanics, mechanism of injury and identification of vertebral stability improved.



Early classification systems described by Boehler (1929) and Jones were descriptive systems, based only on radiographs.<sup>20</sup> Holdsworth revolutionized the thoracolumbar injury classification with the introduction of the “two column concept.”<sup>21</sup> Denis believed that the middle column is the key to the stability of the fracture and proposed the “three column concept.”<sup>22</sup> Based on the three column concept described by Denis and the possible mechanisms of failure of the columns, McAfee described a simplified system of classifying injuries<sup>23</sup> [Table 1]. This system is simple and includes most injuries observed in clinical practice. In 1994, Magerl analyzed 1445 cases of thoracolumbar injuries and presented a comprehensive AO classification of thoracolumbar fractures based on the mechanism of injury and morphological pattern of the fracture.<sup>6</sup>

Despite being a comprehensive classification system, this system was cumbersome with poor inter-observer reliability. McCormack et al. introduced a classification (load sharing classification) to predict the risk of implant failure after posterior short segment fixation for thoracolumbar fractures. This classification intends only to identify fractures that would require supplemental anterior fixation following a posterior surgery.<sup>24</sup> The Thoracolumbar Injury Classification System (TLICS) created by “The Spine Trauma Study Group,” is based on three major injury characteristics – mechanism of injury, integrity of the PLC and neurological status. Based on the severity scores within these three categories, a total score is calculated that can be used to guide treatment.<sup>25</sup> Among these classification systems, the Denis/McAfee classification, AO classification and the TLICS classification are commonly used in clinical practice. Blauth et al. have reported that the inter-observer reliability of the AO classification was low (fair agreement,  $\kappa = 0.33$ ), and when the injury was classified into subgroups, the inter-observer reliability decreased further.<sup>26</sup> Oner et al.<sup>27</sup> and Wood et al.<sup>28</sup> also reported that the Denis classification system ( $\kappa = 0.60$  and  $0.606$ ) showed higher inter-observer reliability than the AO classification system ( $\kappa = 0.35$  and  $0.475$ ). Lenarz et al. compared the reliability of Denis, AO, and TLICS systems in 97 thoracolumbar fractures and observed that in all the three systems, variation in reliability was present, with the highest reliability occurring in the senior resident group and attending spine surgeon group.<sup>29</sup> The lowest reliabilities were in the nonspine attending orthopedists and junior residents. In each group, the neurologic status had the highest inter observer and intraobserver reliability. They concluded that the TLICS is an acceptably reliable system when compared with the Denis and AO systems.

The AO spine knowledge forum has proposed a recent comprehensive modified AO classification including morphology of the fracture, neurological status, and description of relevant patient-specific modifiers.<sup>30</sup> The fracture morphology is assessed based on 3 main injury patterns: Type A (compression-injury to the vertebral body without PLC involvement), type B (tension band disruption - the failure of posterior (PLC) or anterior (anterior longitudinal ligament) constraints), and type C (displacement/translation) injuries. Neurologic status is classified as follows: No neurologic injury (N1), radicular symptoms or deficits (N2), incomplete spinal cord injury (SCI) or any kind of cauda equina injury (N3), complete SCI (N4) and unknown neurologic status (NX). Forty cases with a broad range of injuries were classified independently twice by group members and the reliability in the identification of a morphologic injury type was substantial ( $\kappa = 0.72$ ). The classification appears much simpler and equally comprehensive when compared with the previous AO classification and includes important information about neurology and posterior ligamentous structures. Based on this classification, type A4, B1, B2, B3 and C injuries will need surgical stabilization. The inter/intraobserver reliability of this classification is yet to be studied, apart from the originators.

## MANAGEMENT

### Medical management

Throughout resuscitation in the emergency room and subsequent care, all efforts must be taken to immobilize spinal injury patients safely and intermittently log roll to prevent

pressure sore formation. Stabilization of unstable injured motion segments plays an important role in preventing further injury. In a patient with SCI, injury to neural structures occurs both at the time of injury (primary – nonmodifiable) and in the subsequent period due to vascular dysfunction, edema, ischemia, electrolyte shifts, free radical production, inflammation and delayed apoptotic cell death (secondary – potentially modifiable).<sup>31</sup> Numerous pharmacological agents thought to mitigate the secondary injury have been extensively studied. These include the steroids (antiinflammatory), gangliosides, naloxone (opiate receptor antagonist), calcium channel blockers, free radical scavengers and neurotropic agents.

Steroids were extensively employed in the clinical treatment of SCI beginning in the mid-1960s. In rat SCI models, steroids have been shown to improve neurological recovery.<sup>32</sup> After encouraging “positive” results with the use of high dose steroids in North American Spinal Cord Injury Study (NASCIS) 1 and 2 trials, the NASCIS 3 trial studied the effect of methyl prednisolone within 3-8 h of injury and concluded that better neurological recovery is statistically observed if administered over 24-48 h.<sup>33</sup> However, a number of articles have strongly criticized the NASCIS trial design, analysis and reporting. Coleman et al. observed that the NASCIS II and III reports have used specific choices of statistical methods that have strongly shaped the reporting of results. The primary outcome analysis of the trials were negative with modest beneficial effects being proven only through post hoc analyses, inappropriately excluding >70% of the patients.<sup>34</sup> After a thorough review of the three NASCIS trials, Hurlbert concluded that evidence of the drug's efficacy and impact is weak and may only represent random events, and the use of high dose methyl prednisolone in the treatment of acute SCI is not proven as a standard of care.<sup>35</sup> A survey published in 2006 revealed that the majority of respondents continue to administer methylprednisolone, but they are motivated predominantly by fear of litigation.<sup>36</sup>

### Nonoperative management

Most thoracolumbar fractures are stable injuries amenable to nonoperative management. Simple compression or stable burst fractures without neurologic complications can typically be treated with commercially available thoracolumbar orthoses, or a hyperextension cast that permit early ambulation.<sup>37,38</sup> [Figure 6]. There is no consensus on the exact duration of treatment. The advantages of a brace or cast over unprotected ambulation have also not been studied. However, it has been shown that external support has no mechanical stabilizing effect on the lumbar spine.<sup>39</sup> In a systematic review of studies, Giele et al. concluded that there is no evidence for the effectiveness of bracing in patients with traumatic thoracolumbar fractures.<sup>40</sup> During nonoperative care, it is common to observe a certain degree of increasing fracture kyphosis in most patients, often closer to the pretreatment sagittal alignment. However kyphosis even up to 30° has not been shown to correlate with pain in several studies

### Operative management

The advantages of operative treatment of thoracolumbar fractures over the nonoperative approach include avoiding an orthosis in the presence of multiple injuries, skin injuries, and obesity, immediate mobilization and earlier rehabilitation and

better restoration of sagittal alignment.<sup>4,43</sup> Surgical decompression of compressing bone fragments over the spinal cord also reliably provides a better environment for restoration of neurologic function. On the other hand, the benefits of surgical treatment must be carefully weighed against the potential surgical morbidity. Conventional open surgical techniques can be associated with morbidity because of approach-related muscle injury, increased infection rates and higher blood loss.

### Neurological recovery and surgical decompression

In general, operative treatment is indicated mainly for unstable spinal injuries such as flexion distraction injuries, unstable burst fractures and fracture dislocations. Though operative treatment reduces pain and enables early mobilization and rehabilitation, there is no difference between operative and nonoperative treatment regarding neurological recovery and long term functional outcomes.<sup>44</sup> Studies in animal models have demonstrated that neurological recovery is enhanced by early decompression.<sup>45</sup> However, this has not been proven in human studies on acute SCI. The severity of neurological injury is determined by the extent of neuronal injury incurred at the time of primary injury. But it is still worthwhile considering early surgical decompression in patients with incomplete SCI in the presence of spinal cord compression. Despite the lack of clear level I or II scientific evidence, the general accepted indications for operative treatment are given in Table 2.

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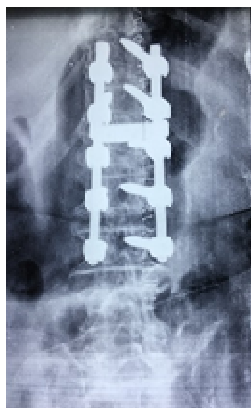
Incomplete neurological deficit  
Progressive neurological deficit  
Spinal cord compression  
Fracture dislocation  
Kyphosis >30°  
Concomitant injuries necessitating early mobilization

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### Posterior approach

Posterior short segment fixation including the proximal and distal adjacent normal vertebrae is the most commonly performed surgery for the vast majority of thoracolumbar fractures (unstable burst fractures with intact neurology, flexiondistraction injury, Chance fractures). Fracture reduction can be achieved by a combination of postural reduction, and by distraction through ligamentotaxis. Posterior pedicle screw fixation has been shown to be simple, familiar, efficient, reliable, and safe for the reduction and stabilization of most fractures and remains the most popular technique. Disadvantages include instrumentation failure, pseudarthrosis, infection, risks of SCI, inadequate neurological decompression, insufficient correction of kyphosis and the need for late instrumentation removal.<sup>48,49,50</sup> Depending on the extent of vertebral body comminution, additional anterior reconstruction may be needed to prevent implant failure. McCormack et al. retrospectively analyzed 28 patients who had been operated for thoracolumbar injuries with Steffee plates.<sup>24</sup> Three important factors in predicting posterior fixation failure were studied which included the amount of vertebral body comminuted as seen in sagittal CT images, the apposition of fracture fragments as seen in axial CT images and the amount of correction of kyphotic deformity as best measured by comparing pre and postoperative films. Each of these factors was subdivided into three grades of severity and was scored on a point system from 1 to 3, with a higher number indicating increased severity. They observed that

anterior vertebral reconstruction is essential in patients with a score  $\geq 7$  to prevent implant failure. To avoid anterior surgeries, various authors have described other techniques such as transpedicular intracorporeal bone grafting, vertebroplasty and kyphoplasty, intracorporeal filling with hydroxyapatite or calcium phosphate.<sup>51,52</sup> Other biomechanical measures to improve the strength of the construct include the use of cross-links, supplemental hook fixation at the levels of the screws and the addition of "intermediate" screw into the fractured vertebra.<sup>53,54</sup> Several biomechanical and clinical studies have shown that the addition of intermediate screws significantly increased the strength of a short segment posterior construct thus lowering the rates of loss of kyphosis after correction [Figure 7].<sup>55,56,57</sup>



**Figure 7.**

X-ray thoracolumbar spine lateral view showing (a) L1 flexion-distraction injury (b) treatment with posterior short segment fixation and intermediate screws (c) Lateral

radiograph performed at the end of 1-year shows good fracture healing. High velocity grossly unstable injuries like fracture dislocations usually requires multilevel spinal stabilization. Fixation of two to three segments above and below the injury is recommended for reducing the dislocation and achieving stable fixation. Similarly, unstable fractures of the thoracic spine are subjected to significant shear stresses and hence are treated with multilevel posterior fixation. For select type A and B fractures, Gotzen et al. have published their technique of posterior mono-segmental reduction and stabilization.<sup>58</sup> The injuries are usually confined to the upper-end plate alone, and pedicle screw fixation and fusion involves only the fractured and the proximal normal vertebra. In their 2 year followup of 39 patients, no implant failure was noted.

### Complications

Long segment indirect stabilisation by posterior pedicle screw fixation has become the mainstay of spinal instrumentation for fracture stabilization. Despite increasing experience, knowledge and technical advancement, pedicle screw insertion is still associated with a certain degree of complications. The most commonly reported complication is screw malpositioning, with an overall incidence of 0-42%.<sup>70,71</sup> Most of them are asymptomatic without any major sequelae, and serious screw-related complications, such as neurological, visceral, or vascular are very rare. The overall incidence of nerve root or SCI due to screw malpositioning ranges between 0.6% and 11%.<sup>72</sup> A transient self-limiting neurapraxia in the form of numbness is the usual feature and the incidence of permanent neurological deficit is rare. Vascular injuries related to misplacement of screws are potential life- and limb-threatening complications that require early recognition with prompt repair of vascular lesions and screw repositioning.<sup>73</sup> Visceral injuries related to pedicle screw insertions are very rare. The proximity of vertebral bodies to structures like lung and pleura can result in pneumothorax, effusion or an esophageal injury inadvertently. Screws can break when there is a deficient anterior column, progressive kyphosis and pseudoarthrosis. This is mainly attributable to metal fatigue due to excessive strain on the implant. The abdomen contains many vascular structures including the aorta, inferior vena cava, segmental vessels, and numerous veins, which are exposed during anterior surgeries and hence at risk for injury. Venous laceration is the most common vascular injury and usually occurs during manipulation and retraction of the great vessels.<sup>74</sup> Vascular injury can also occur while performing the corpectomy, placing the graft, and inserting the screws. Manual compression or primary repair of the tear is generally effective at treating this complication. Visceral injuries and postoperative lymphocele, or chyloretroperitoneum are uncommon events. This is usually evident intraoperatively and requires the expertise of the gastrointestinal surgeon to repair. Injuries to the peritoneum are very common but are easily repaired and do not lead to significant problems.

### Conclusion

Despite tremendous improvements in spinal imaging and management techniques in the last two decades, there is still lack of consensus in several areas in the management of thoracolumbar fractures. Principally treatment decisions in these patients require a complete evaluation of the neurological status and identification of the presence of spinal instability. CT scan provides the best information regarding the extent of

bony injury and MRI scan shows the extent and severity of cord compression and injury to PLC. The ideal classification that is simple, comprehensive and guides management are still elusive. The most recently described is the AO KF thoracolumbar classification, which appears simple and includes most information regarding the extent of vertebral body injury, neurological injury and patient modifiers. Involvement of all the three columns, progressive neurological deficit, significant kyphosis  $>30^\circ$  and canal compromise in the presence of neurological deficit are accepted indications for surgical stabilization. Compression fractures and stable burst fractures can be treated by nonoperative methods. Posterior surgery remains the most preferred technique, and anterior approach is the access of choice when decompression of the spinal cord is the priority. Minimally invasive surgeries are increasingly used to reduce surgical morbidity in the acutely traumatized patient.

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