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Thoracolumbar Junction (TLJ) Fracture: Principle of Management

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Abstract

The thoracolumbar junction (TLJ) is the most common site of traumatic spinal injury. Its management is a highly controversial area. There are no specific guidelines for management of these injuries. The primary goal of treatment of TLJ fractures involves protecting the spinal cord from further neural damage, obtaining the stability by reconstructing anatomical alignment of spinal column, and returning patients to workplace through early mobilization and rehabilitation. There is a great variation in evaluation of stability of these fractures, which is one of the crucial factors in deciding the treatment. Controversy also exists regarding conservative versus operative treatment, timing of intervention, anterior versus posterior approach, short versus long segment fixation, and bracing versus no bracing. This article had reviewed the conflicting results and recommendations for management of TLJ fractures of previously published reports in PubMed, PubMed Central, and Medline databases. We analyzed these related articles which addresses issues regarding evaluation of stability, indications for operative and conservative treatment, timing of surgery, surgical approach, and fusion length.

Keywords
- thoracolumbar junction
- fracture
- instability
- conservative
- operative
- fusion length

Introduction

The thoracolumbar junction (TLJ) (T10–L2) is the transition zone between the less mobile thoracic spine and the more dynamic lumbar spine, which leads this region to significant biomechanical stress. Hence, TLJ fractures are the most common spinal injuries of the vertebral column.

As much as 50% of these injuries are unstable and can result in significant disability, deformity and neurological deficit.[1]

A high-incidence of neurological deficits is associated with TLJ fractures. Kyphotic deformity, late neurological deterioration, and chronic pain are long-term consequences, which can hamper the quality of life.[2] Various authors classify these fractures by using different parameters to guide the management of TLJ fractures and define the indications for surgery.[3] These classifications have also not been validated by randomized clinical trials. There is a conflict of evidence in trials comparing conservative and surgical management in burst fractures with intact neurology.[4]

The primary goal of treatment of TLJ fracture involves protecting the spinal cord from the further neural damage, obtaining the stability by reconstructing anatomical alignment of spinal column, and returning patients to workplace through early mobilization and rehabilitation. These fundamental principles have not been changed for decades. Different authors had taken different parameters to decide the treatment plan. Some large, multicenter studies of TLJ fractures have been conducted,[5] but there is still lack of consensus for optimal management of these injuries.

This article had reviewed the conflicting results and recommendations for management principles of TLJ fractures from previously published reports. Specifically, it addresses issues regarding evaluation of stability, indications for operative and conservative treatment, timing of surgery, surgical approach, and fusion length. We hope this information will

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help surgeons to a better understanding of treatment strategies for TLJ fractures.

Material and Methods

Literature Search

A systematic literature search was performed in the PubMed Central, PubMed, and Medline databases. We screened the title and abstract by combining the term "thoracolumbar (all fields) AND junction (all fields) AND ("fractures, bone" [MeSH Terms]) OR ("fractures" [all fields]) AND ("bone" [all fields]) OR ("bone fractures" [all fields]) OR ("fracture" [all fields]) AND "management" (all fields). The search was performed to include articles published between 2001 to 2018. A total of 181 articles (original articles = 142, review articles = 31, case report = 4 and randomized control trial = 4) were found and analyzed.

Selection Criteria

Inclusion criteria: The inclusion criteria for selection of articles include the following:

1. Article published in English language.
2. Articles having, at least, the keyword "thoracolumbar fracture."
3. Article published between 2001 to 2018.
4. Articles describing only posttraumatic thoracolumbar junction fracture.

Exclusion criteria: The following exclusion criteria were used to select the final articles:

1. Osteoporotic thoracolumbar fracture.
2. Thoracolumbar fracture associated with malignancy.
3. Thoracolumbar fracture associated with ankylosing spondylitis.
4. Articles published before 2001

Data Extraction

Data concerning study population, classification of fractures, intervention, indication for treatment, and results of the included studies were summarized. The studies were heterogeneous with respect to population, interventions, and outcomes. Therefore, data were not statistically pooled, but the most important results are described in detail.

Mechanism and Morphology of Injury

A. Compression fracture:
   As much as 50% of TLJ fractures are compression fractures.[6] Compression fractures are caused by axial compression and flexion forces. It shows wedge deformities of vertebral body on radiologic examination. In compression fracture, there is only anterior column failure, but middle and posterior column are preserved. Most of the compression fractures are not associated with neurological deficit.
B. Burst fracture:
   Burst fractures account for up to 17% of all major spinal fractures. The thoracolumbar region (T11 to L2) is the most common site of burst fractures. It results from compression failure of both the anterior and middle columns under substantial axial loads.[6] The sudden application of a supraphysiological axial load results in vertebral end plate failure, as adjacent disc tissue is driven into the vertebral body. The neurologic injury had been reported in 30% of patients with burst fractures.[7] It is due to retropulsed bony fragment from the posterior superior end plate of vertebral body, leading to some degree of canal compromise.
C. Flexion distraction injury:
   The flexion-distraction injury, or the so-called Chance fracture, primarily occurs via distractive forces on the spine. The axis of rotation is located within or in front of anterior vertebral body. Thus, the distractive forces are loaded on the posterior and middle columns, and compressive forces are loaded on the anterior column. This injury generally occurs in high-energy motor vehicle accidents when one only wears the lap belt and not the shoulder belt along with it. This injury accounts for 1 to 16% of all TLJ fractures and occurs most commonly at the TLJ. Neurological injury occurs in 25% of patients, and in 30% of cases, it is associated with abdominal injuries.[8]
D. Fracture dislocation injury:
   The fracture dislocation injury is caused by a varied combination of shear, torsion, distraction, flexion and extension forces, and it is a very unstable injury, because all three columns are damaged. This is a high-energy injury and 75% of it is accompanied with neurological injury. It would be diagnosed if there is unilateral or bilateral facet fracture, subluxation or dislocation.

Evaluation of Stability

A. Compression fracture:
   a. Stable compression fracture:
      Compression fractures are stable when they are not associated with posterior ligament complex (PLC) injuries.
   b. Unstable compression fracture:
      Compression fractures are considered unstable when they are associated with any of the following:[9]
      1. Associated with PLC injury.
      2. Kyphotic deformity > 30 degree.
      3. Loss of vertebral body height > 50%.
      4. If the injury had occurred in three contiguous vertebral bodies.
B. Burst fracture:
   a. Stable burst fracture:
      For stable burst fracture, it should be mechanically and neurologically stable.
      1. Burst fracture should be considered mechanically stable when[10]
         i. Loss in the vertebral body height is < 50%.
         ii. Traumatic kyphosis < 30 degree.
         iii. Intact PLC.
      2. Burst fractures are neurologically stable when it is not associated with neurological deficit.

b. Unstable burst fracture:
   1. Burst fracture should be considered mechanically unstable when it is associated with any of the following:[10]
      i. Decrease in the vertebral body height > 50%.
      ii. Traumatic kyphosis > 30 degree.
      iii. Ruptured PLC.
   2. Burst fractures are neurologically unstable when it is associated with neurological deficit.

C. Flexion distraction injury:
Flexion distraction injuries are usually unstable, as it is associated with PLC injury.[10]

D. Fracture dislocation injury:
Fracture dislocation injuries are always unstable, as it is usually associated with PLC injury.[10]

Discussion

Despite tremendous improvements in spinal imaging and management techniques, it is sometimes difficult to determine whether a fracture is stable or unstable. However, this distinction is important when making treatment decisions. Denis classified unstable TLJ fractures into three degrees of instability: mechanical instability (first degree), neurological instability (second degree), and mechanical and neurological instability (third degree).[6] Among these, the most severe degrees of instability occur with fracture dislocation injuries, flexion distraction injury and burst fractures with ruptured PLC.

The mechanical stability of TLJ spine is evaluated by whether PLC is damaged.[11] On plain radiograph, 50% decrease in vertebral body height, increase in interspinous distance, and greater than 30 degrees of kyphotic deformity are suggestive of PLC injury.[12] CT is the most appropriate examination for assessing diastasis of facet joint related to PLC injury.[13] MRI is regarded as a significant examination in determining the treatment plan because it can evaluate PLC injury directly.[14] Many studies reported that MRI has a high-sensitivity and specificity for detecting PLC injury.[15]

Conservative versus Operative Management

On reviewing the literature, it is clear that operative intervention is indicated for fracture dislocation, flexion distraction injury, unstable burst and unstable compression fracture. Stable burst and stable compression fractures are managed with conservative treatment. There are different arguments for operative versus conservative treatment with regard to stable burst fracture, but most literature are in favor that conservative treatment is better than operative treatment[10]

The study done by Denis[6] stands out as it is the only study in the literature reporting a neurological deterioration with conservative treatment of burst fractures. He reported neurological deterioration in 6 out of 29 patients with burst fractures. His results were not supported in the subsequent literature. Shen et al[16] in 2001 believed that since surgeons are reluctant to publish iatrogenic injuries, reports of neurological deterioration after surgery are few. However, he speculated that the risk of neurologic injury actually may be higher with surgical management, based on his experience. Weinstein et al[17] had successfully treated 42 patients conservatively, and no case with early or late neurological deterioration were reported. Chow et al.[18] also reported successful conservative management in 26 patients with hyperextension bracing or casting with no neurological deterioration. Wood et al,[19] Celebi et al,[20] and Yi et al[21] had similar findings.

Surgeons in Favor of Surgical Management Have Few Arguments

(a) Immediate stabilization of the spine will decrease the chance of neurological deterioration.
It is established that the neurological injury primarily occurs at the time of injury due to the mechanical damage to the cord. There are studies which proved that the geometry of canal is not an indicator of the extent of neurological dysfunction and that surgical decompression does not alter its outcome. In fact, the neurological status itself is an indicator that the canal is not compromised enough to cause neurological compromise. Therefore, the need for surgical decompression of the canal is not present.[22,23]

(b) Surgery will correct kyphosis, thereby decreasing pain and perhaps future degenerative changes.
The amount of correction obtained after surgical intervention is impressive initially, but studies showed that much of it would lost subsequently.[24] The kyphosis increases even when the hardware remains intact through mechanisms such as motion at screw-plate junction, motion of screw within the bone and fatigue bending. Extension of the fusion segments may preserve the correction but at the cost of loss of motion segments.[25] An increase in kyphosis by up to 12°was reported following posterior surgery.[26] McNamara et al[27] reported a postoperative kyphosis progression of 8.7°with only 69% return to routine activity in his 13 surgical patients. No significant difference in kyphotic progression was noted between conservative and surgical groups in the randomized study by Wood et al [19] In contrast, Siebenga et al[28] in his prospective trial found significantly less kyphotic deformity during follow-up in the surgically managed group.

(c) Surgery allows early mobilization, thereby decreasing the complication and costs related to prolonged bed rest. Bed rest followed by mobilization in a cast or TL orthosis for up to 8 to12 weeks was recommended at one point, but it was demonstrated that bed rest did little to prevent further kyphotic progression of the injury. Hence, such neurologically intact patients should be mobilized as soon as possible.[29]

(d) Surgical decompression allows the removal of retropulsed fragments from the canal and decreases the chances of neurological deterioration.
Several studies have shown that the retropulsed fragments reabsorb gradually with the remodeling of the canal.[30] Shen and Shen noted a reabsorption of approximately half of the retropulsed fragment within a year.[25] Interestingly, Celebi et al[20] found that the

remodeling is better with a higher amount of initial canal compromise. Yazici et al[31] and Dai [32] found no significant difference in the amount of canal remodeling between conservatively and surgically managed patients. Mohanty and Venkatram[33] demonstrated that there are no correlation between the initial neurological deficit and subsequent recovery with the degree of canal compromise in their study on TLJ burst fractures treated conservatively.

(e) Bracing versus no bracing:
It has also traditionally been thought that a TL orthosis is necessary to provide some stability to these patients. This concept is also being challenged, and the interim result of a prospective randomized study of bracing versus no bracing for such burst fracture had failed to demonstrate any advantage with bracing. It is important to recognize that fracture of these patients tends to fall into some kyphosis, regardless of whether they are treated with a brace, but this radiographic phenomenon does not appear to influence clinical outcome.[34,35]

(f) Timing of surgical intervention:
With regard to the timing of surgical intervention, the absolute indication for urgent surgery is progressive neurological deterioration in the presence of significant spinal canal compromise. In addition, surgical stabilization is indicated as early as possible for patients with fracture dislocation and incomplete neurological deficit. Although early fixation of unstable spine may reduce mortality and morbidity of patients, immediate surgery is not mandatory. For poorly resuscitated and hemodynamically unstable patients, we recommend delay in surgical stabilization of TLJ fractures rather than adherence to a rigid protocol. The first priority should be given to life-threatening injuries such as unstable pelvic fractures, and brain, thoracic or abdominal injuries.[36]

Surgical Approaches

Advances in spine instrumentation techniques have greatly promoted the surgical treatment of TLJ fractures. The surgical approach of choice depends largely on the surgeons' familiarity with the surgical technique required.

Posterior Approach

Posterior pedicle screw fixation has been shown to be simple, familiar, efficient, reliable, and safe for the reduction and stabilization of most of the TLJ fractures and remains the most popular technique. It is the most commonly performed surgery for the vast majority of TLJ fractures.

The decompression can be achieved by indirect reduction using ligamentotaxis or direct decompression. The reduction using ligamentotaxis is successful if it is completed within 3 days after the injury.[37] The increase of vertebral canal after the indirect reduction is less than 20% on average but may sometimes increase up to 50%, depending on situation.[38] However, if the canal encroachment of bone fragments is greater than 67%, it is not effective because annulus is destroyed in many cases.[39] If the surgery is delayed or there is severe canal compromise, the direct reduction[40] with the transpedicular approach or direct decompression with laminectomy can be performed.[41]

Despite increasing experience, knowledge and technical advancement, pedicle screw fixation is still associated with a certain degree of complications. The most commonly reported complication is screw malpositioning, with an overall incidence of 0 to 42%.[42] Most of them are asymptomatic without any major sequelae. Serious screw-related complications such as neurological, visceral, or vascular are very rare. The overall incidence of nerve root or spinal cord injury due to screw malpositioning ranges between 0.6 and 11%.[43] 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.[44] Visceral injuries related to pedicle screw insertion are very rare. Screws can break when there is a deficient anterior column. Depending on the extent of vertebral body comminution, additional anterior reconstruction may be needed to prevent implant failure.

Anterior Approach

About 80% of the axial load of an intact spine is supported by the anterior column. When the anterior column is substantially injured, the anterior column support is reduced, leaving majority of the stress to be transmitted by the posterior implant and the bony elements. In such situations, restoration of anterior column through a tricortical bone graft or a cage is advised. Spinal canal compromise in patients presenting with neurological deficit, which cannot adequately be resolved by a posterior approach, requires anterior decompression.[45]

Although it is more invasive and technically demanding, the anterior procedure is more effective because it permits direct exposure and decompression of the neural contents and provides strong load-bearing support to the spine. The degree of neurological recovery, rate of spinal fusion, sagittal spine alignment, and return to preinjury activities after anterior decompression appears more favorable as compared with other techniques that decompress the spinal canal.[46] Kaneda et al[47] have reported a study on 150 consecutive patients who had a burst fracture of the TLJ spine with neurological deficits. The patients were managed with a single-stage anterior spinal decompression, strut grafting, and anterior spinal instrumentation. At a mean of 8 years (range: 5–12 years) after the operation, radiographs showed successful fusion of the injured spinal segment in 140 patients (93%). The neurological function improved in 95% of the patients by at least one Frankel grade, while 72% of patients recovered completely.

Anterior decompression is a superior procedure to remove the bone fragments or soft tissues which compress the neural structures. The anterior approach not only decompresses the neural contents more efficiently but also provides the superior mechanical stability. Hitchon et al.[48] reported that the anterior approach was more advantageous in the correction and the maintenance of each deformity than the posterior approach. Sasso et al[49] also reported that the average of sagittal plane correction was 8.1°with the anterior approach but it was 1.8°with the posterior approach. In some biomechanical studies, anterior approach offered superior mechanical stability than the posterior approach.[50]

To combat the higher morbidity associated with anterior approach than posterior approach, various authors have described other techniques such as transpedicular intracorporeal bone grafting, vertebroplasty and kyphoplasty, and intracorporeal filling with hydroxyapatite or calcium phosphate.[51] 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 addition of "intermediate" screw into the fractured vertebra.[52]

Combined Anterior and Posterior Approach

Selected patients with TLJ burst fracture in whom PLC injury is accompanied with incomplete neurological injury, due to canal encroachment of fracture fragments or neurological symptoms persisting after the surgery using posterior approach or fixed kyphotic deformities occurring more than 2 weeks after the injury, may benefit from combined surgical approaches.[53] The fixation with anterior and posterior approach can provide more improved stability for all range of motion in spine compared to the fixation with anterior or posterior approach alone.[54]

In a series of 20 consecutive patients with a single-level unstable TLJ burst fracture treated by posterior fixation followed by anterior corpectomy and titanium cage implantation, 12 patients with initial neurological deficits recovered an average of 1.5 grades on the American Spinal Injury Association (ASIA) scale.[55] Two years postoperatively, the mean pain score for back pain was 1.6 points and instrumentation failure did not occur. At a mean follow-up of 6 years, a comparative retrospective study of combined versus posterior only fixation reported similar clinical outcome and neurological improvement, fusion rate and angle of kyphotic deformity in both groups. However, loss of reduction > 5°and instrumentation failure were significantly higher in the posterior only fixation.[56]

However, this approach has more bleeding risk and longer operation time, and it has not been yet proven that the clinical and radiological outcomes of this approach is more superior than the fixation with anterior or posterior approach alone.[57] Nowadays, the interbody fusion using posterior approach has been developed and used to stabilize the vertebral body, instead of the anterior–posterior approach.[58]

Short-Segment versus Long-Segment Fixation

There are certain indications, benefits and drawbacks of both short- and long-segment fixation. If anterior surgery is not feasible due to the systemic condition of the patient or inadequate technical facilities, extending posterior instrumentation and fusion may be the alternative option. Based on the 3-point fixation principle, long segment instrumented fusion, which includes two or more levels above and below the injured segment, can preserve and restore coronal and sagittal stability, prevent recurrent kyphosis, promote fusion and postreduction stability, and decrease the incidence of implant failure. Long-segment fixation and fusion are indicated for fracture dislocations with severe displacement or multiple compression or burst fractures. Long-segment fusion sacrifices motion of the fused spine.[59]

Use of short-segment fixation, which fixes the above and below segment of fracture site, has been increasing. Short-segment fixation allows sufficient stabilization, which results in adjacent levels being less affected. However, there were studies which showed that the failure rate of this short-segment fixation was 20 to 50% and the loss of reduction was 50 to 90%.[27,60] To improve the strength of short-segment fixation and avoid the motion restricting complication of long-segment fixation, there are options of intermediate screw fixation with good results. Verlaan et al described that inserting additional pedicle screws at the level of the fracture site could help in providing better kyphosis correction with saving motion segments and offer improved biomechanical stability.[61-63]

Conclusion

Treatment decision of TLJ fracture requires a complete evaluation of the neurological status and identification of the presence of spinal instability. TLJ fractures have been classified into compression fracture, burst fracture, flexion distraction injury and fracture dislocation injury, depending on injury mechanism and fracture morphology. Each injury is also subdivided into stable fracture and unstable fracture, according to the presence of neurological and mechanical stability. The PLC injury is the most important factor deciding mechanical stability. The conservative treatment is recommended for stable fractures, whereas the operative treatment is needed for unstable fractures.

Involvement of all the three columns, progressive neurological deterioration, significant kyphosis > 30°and canal compromise in the presence of neurological deficit are accepted indications for surgical intervention. Posterior approach has been shown to be simple, familiar, efficient, reliable, and safe for the reduction and stabilization of most TLJ fractures and remains the most popular technique. It is the most commonly performed surgery for the vast majority of TLJ fractures. Although anterior approach is more invasive and technically demanding, it is more effective because it permits direct exposure and decompression of the neural contents and provides strong load-bearing support to the spine. Long-segment instrumented fusion can preserve and restore coronal and sagittal stability, prevent recurrent kyphosis, and decrease the incidence of implant failure. Long-segment fusion sacrifices the motion of the fused spine. Short-segment fixation allows sufficient stabilization and the adjacent level being less affected.

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Conflict of Interest
None declared.

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