Thoracolumbar Burst Fractures: A Systematic Review of Management

KALLIOPI ALPANTAKI, MD; ARTAN BANO, MD; DRITAN PASKU, MD; ANDREAS F. MAVROGENIS, MD; PANAYIOTIS J. PAPAGELOPOULOS, MD, DSc; GEORGE S. SAPKAS, MD; DEMETRIOS S. KORRES, MD; PAVLOS KATONIS, MD

abstract

The management of thoracolumbar burst fractures remains challenging. Ideally, it should effectively correct the deformity, induce neurological recovery, allow early mobilization and return to work, and be associated with minimal risk of complication. This article reviews the related studies reporting their clinical data for the management of thoracolumbar burst fractures, discusses the most suitable approach in cases such as these, highlights specific treatment recommendations, and proposes a treatment algorithm. Using PubMed and Scopus databases to search the term thoracolumbar burst fractures, abstracts and original articles in English investigating the treatment of thoracolumbar burst fractures were searched and analyzed.

Almost 90% percent of all spinal injuries involve the thoracolumbar region; 10% to 20% of such injuries are burst fractures.[1-4] Thoracolumbar burst fractures result from vertical compression to the slightly flexed spine.[5] In some instances, a rotational or shear component[6] or some extension force[7] may be necessary to cause the characteristic burst fracture pattern. The 3-column theory, as presented by Denis[2] describes both the mechanism of injury and the concept of spinal stability; burst fractures can be 2 or 3 column injuries.[8,9]

According to Denis,[2] a spinal fracture is described as burst if there is compression of the anterior column, fracture of the middle column, and retropulsion of bone fragments into the spinal canal. In severe burst fractures the pedicles spread and an associated fracture of the posterior rim usually involving the lamina may occur. The combination of a concomitant lamina fracture with a burst fracture can be linked with a dural tear and entrapped nerve roots.[8,9]

The management of thoracolumbar burst fractures remains challenging. Ideally, it should effectively correct the deformity, induce neurological recovery, allow early mobilization and return to work, and be associated with minimal risk of complication. This article reviews the related studies reporting their clinical data for the management of thoracolumbar burst fractures, discusses the most suitable approach, highlights specific treatment recommendations, and proposes a treatment algorithm. Using PubMed and Scopus databases to search the term thoracolumbar burst fractures, abstracts and original articles in English investigating the treatment of thoracolumbar burst fractures were searched and analyzed.

POSTTRAUMATIC SPINAL INSTABILITY

In 1949, Nicoll[10] introduced the concept of posttraumatic spinal instability and defined unstable spinal injuries based on the presence of subluxation or dislocation, disruption of interspinal ligaments, or laminar fractures at L4 or L5. This concept has been used as an instrument for treatment decisions over the past 50 years. Panjabi et al[11] and White et al[12] defined clinical instability of the spine as the loss of the ability of the spine under physiologic loads to maintain relationships between vertebrae in such a way that there is nei-

Drs Alpantaki, Bano, Pasku, and Katonis are from the Department of Orthopedics, University Hospital of Heraklion, Crete, and Drs Mavrogenis, Papagelopoulos, and Sapkis are from the First Department of Orthopedics and Dr Korres is from the Third Department of Orthopedics, Athens University Medical School, Attikon University General Hospital, Athens, Greece.

Drs Alpantaki, Bano, Pasku, Mavrogenis, Papagelopoulos, Sakas, Korres, and Katonis have no relevant financial relationships to disclose.

Correspondence should be addressed to: Panayiotis J. Papagelopoulos, MD, DSc, First Department of Orthopedics, Athens University Medical School, 4 Christovassili St, 15451, Neo Psychikon, Athens, Greece (pjp@hol.gr; pjportho@otenet.gr).

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ther damage nor subsequent irritation to the spinal cord or nerve roots and development of incapacitating deformity or pain. This definition considers both mechanical and neurological instability. Moreover, it includes acute as well as chronic instability; practically, fractures that are associated with neurological injury are considered as unstable, since the spinal column has already failed as a protective structure.

According to Denis,[2] there are 3 types of instability in the thoracolumbar spine; the mechanical instability that refers to the potential of spinal collapse with subsequent deformity, the neurological instability that refers to the potential of further neurological injury, and the combined mechanical and neurologic instability. The 3-column model is useful for the assessment of spinal instability; any thoracolumbar burst fracture can be unstable, while middle[2,13] or 2-column[14,15] failures are absolute criteria for instability.

The significance of the integrity of the posterior ligamentous complex,[5] and the potential of posterior column failure in patients with burst fractures[16-22] has been also emphasized. Radiographic findings of 50% of anterior vertebra body height loss, interspinous process widening and kyphosis of more than 30° to 35° were suggestive of posterior ligamentous complex disruption.[16,17] However, less than 50% to 60% anterior vertebra body height loss, absence of neurological deficits and kyphosis less than 30° to 35° were defined as stable injuries.[18,19]

Magnetic resonance imaging (MRI) studies showed that burst fractures should be considered unstable if there is associated posterior longitudinal ligament injury.[20-22] This is necessary to distinguish unstable (3-column) from the relatively stable (2-column) burst fractures.[20-22] The AO/Magerl classification enables a more exact definition of stable and unstable spinal fractures.[23] Using pathomorphological criteria, 3 mechanisms of injury, of which the effect is shown on radiographs and computed tomography (CT) scans have been described; A=compression, B=distraction, and C=rotation type fractures.[23]

SPINAL CANAL COMPROMISE AND NEUROLOGICAL INJURY

The relationship between spinal canal compromise as measured using CT and neurologic injury has been widely investigated. Some surgeons operate on patients with thoracolumbar burst fractures when CT scan shows canal narrowing more than 40% to 50%; however, this criterion has been based on anecdotal evidence rather than controlled clinical studies.[24] However, there is clinical and laboratory evidence that paralysis occurs at the moment of injury and it is not related to the position of bone fragments on subsequent imaging.[25,26] In addition, high-speed video tests have shown that at higher levels of occlusion the final position of the bone fragments was inadequately correlated with the maximum level of impingement; any neurological injury is likely to occur at the point of maximum canal occlusion, which also corresponds with the maximum pressure generated to the spinal cord.[27]

Furthermore, there is no consensus on the optimal method for measurement of spinal canal compromise and spinal canal remodelling.[28,29] A series of 115 patients with thoracolumbar burst fractures treated with posterior distraction instrumentation showed a spinal canal clearance ranging from 49% to 72% of normal immediately postoperatively.[28] At final follow-up, the mean canal measurement was 87% of normal. Interestingly, fractures with greater amounts of initial compromise demonstrated greater amount of canal remodeling. In addition, the same series showed no statistically significant difference between patients who underwent early or late surgery, and concluded that direct decompression might not be important in neurologically intact patients with different degrees of canal compromise.[28]

Neurological recovery from thoracolumbar burst fractures cannot be predicted by the amount of initial canal encroachment and kyphotic deformity.[29-35] According to Shuman et al,[31] the degree of spinal canal narrowing reflects the final resting position of the vertebral body fragments after trauma. In their series of 12 patients who were treated surgically there was no correlation between reduction of the retropulsed fragments and subsequent neurologic improvement.[31] Nevertheless, others have shown that although the canal remodeling was not considerably different for patients who showed neurological improvement compared to those who did not, the degree of canal compromise was greater in patients with neurological deficits (52%) compared to those who were neurologically intact.[32] A more significant feature of predicting neurologic recovery it seems to be the integrity of the posterior ligamentous complex (61% vs 25% for patients with or without neurologic deficit, respectively).[33]

Following burst fractures, the spinal canal can undergo resorption of intracanal bony fragments and canal clearance.[29] Thus, "natural clearance" and remodeling of the canal occurs regardless operative or nonoperative treatment, and "surgical clearance" partially affects the neurological outcome.[36,37]

NONOPERATIVE TREATMENT

Despite the confusion regarding the exact definition of spinal instability and canal compromise, the recognition of an unstable injury is crucial for the appropriate treatment and prevention of further injury. The clinical challenge in decision making for the management of patients with thoracolumbar burst fractures is the selection based on the fracture pattern of the patients that could be successfully and safely treated nonoperatively. In this subject, clear indications do not exist.[38-55]

Deterioration of neurological status is a widely accepted absolute indication for early surgical intervention.[38-40] Early studies suggested that surgical treatment provides for superior outcome for patients with thoracolumbar burst fractures[41]; De-

nis et al[42] reported late neurological deterioration in 17% of conservatively treated patients. However, subsequent studies found no neurological deterioration in initially neurologically intact patients who were treated nonoperatively,[43-45] and concluded that conservatively treatment is safe and acceptable in treating neurologically intact patients.[46,47] Tezer et al[48] and others[16,17,49] suggested that nonoperative treatment is appropriate only for patients with normal neurological status and sufficient posterior ligament complex, as shown by anterior vertebral body height >50% of the posterior height and kyphotic angulation <25°.[16,17,49]

More than 50% spinal canal compromise, initially considered a surgical indication, has been debated in patients with intact the posterior elements.[40] Mumford et al[50] showed that approximately 65% of intraspinal fragments are resorbed and most are completely remodeled within 1 year after the injury. De Klerk et al also showed reduction of canal compromise by 50% within the first year after nonoperative treatment, even in patients with neurological injury.[50,51]

The development of posttraumatic deformity and secondary mechanical pain from soft tissue fatigue or alterations of the biomechanics of the spine has also been considered an indication for surgical treatment of patients with thoracolumbar burst fractures.[52] Some authors advise surgical treatment for neurologically intact patients with kyphosis >35°.[19] However, it has been well established that posttraumatic kyphosis is progressive regardless of the type of treatment,[50] and an increase in Cobb angle related to the initial angle of kyphotic deformity has not been documented.[45]

In the long term, some progression of deformity and back pain is expected in neurologically intact patients despite adequate bracing; therefore, follow-up radiographs should be obtained at regular intervals of the angle of kyphosis and vertebra height loss.[45,53,55,56] Moreover, posttraumatic kyphosis has not been correlated with the degree of pain or function[55]; most of these patients report excellent or good clinical results, low visual analog scale score, and complete return to pre-injury activity level.[53,55-60]

Operative Treatment

The indications for operative treatment and type of procedure for stabilization of a thoracolumbar burst fracture remain controversial, especially for neurologically intact patients. However, for patients with neurological deficits, especially incomplete neurological injury, it is generally accepted that surgical treatment has significant advantages in mobilization, pain relief, and pulmonary function.[60,61] The main goal of surgical treatment is to decompress the spinal canal and nerve roots, realign the spine, correct and/or prevent the development of posttraumatic kyphotic deformity, and provide long-term stability of the injured spinal segments.[62]

Progressive neurological deterioration is generally accepted an absolute indication for early surgical intervention.[38,40] Other strong surgical indications include incomplete neurological injury, >50% spinal canal compromise, >50% anterior vertebral body height loss, more than 25° to 35° angle of kyphotic deformity, and multiple noncontiguous spinal injuries. Relative indications include associated nonspinal injuries and patients nursing or comorbidities such as obesity that prevent nonoperative treatment.[17,19]

Recently, the Spine Trauma Study Group proposed a treatment algorithm for patients with thoracolumbar fractures based on a novel classification. Although not yet fully validated by prospective randomized studies, The Thoracolumbar Injury Classification and Severity Score (TLICSS) considers 3 primary criteria to determine stability and to propose operative or nonoperative treatment. These criteria include fracture morphology (compression: 1 point; translational/rotational: 3 points; distraction: 4 points), neurological injury (intact: 0 points; nerve root injury: 2 points; cord or conus medularis incomplete injury: 2 points; cord or conus medularis complete injury: 3 points; cauda equina syndrome: 3 points), and the integrity status of posterior ligamentous complex (intact: 0 points; injury suspected/indeterminate: 2 points; injured: 3 points). Total score can measure from 1 to 10 points. According to this classification and treatment algorithm, operative treatment is recommended for a score ⩾5 points, and nonoperative treatment for a score ⩽3 points.[63,64]

The type of surgical procedure can be decided based on the fracture pattern, the severity of neurological injury, and the surgeon's experience. Accepted methods for operative decompression and stabilization of thoracolumbar burst fractures include posterior reduction and instrumented fusion without decompression (ligamentotaxis),[17,65] posterolateral decompression and posterior instrumented fusion,[66] anterior decompression and instrumented fusion,[67,68] and combined anterior and posterior approach.[69-71] Laminectomy alone does not restore neurological function and is associated with significant complications including deterioration of spinal instability and secondary kyphosis, mechanical pain, and neurological injury.[2]

Anterior Surgical Approaches

The main indication for anterior decompression is incomplete neurological injury with radiographically demonstrated neural compression by bone or disk fragments. Since the compressive tissues following a thoracolumbar burst fracture are invariably located in the anterior spinal canal, better results can be obtained with direct removal of the retropulsed bone and soft tissue fragments from the spinal canal to relieve the pressure from the spinal cord and the cauda equina, and anterior spinal reconstruction and fusion.[67,68]

Although spinal canal naturally remodeling occur with time after spinal trauma,[29,36,37] the goal of anterior approach is

to provide an optimum environment for the recovery of incomplete neurological injury by complete decompression of the neural tissue and spinal reconstruction. The degree of neurological recovery, rate of spinal fusion, saggital spine alignment, and return to pre-injury activities after anterior spinal decompression of thoracolumbar fractures appears more favorable compared to techniques that do not decompress the spinal canal.[67,68,72-78] Anterior spinal reconstruction using tricortical iliac crest strut graft can be used to improve kyphosis and vertebral collapse. The use of anterior vertebral plates, dual rod and screw systems, titanium mesh cages and expanding cages has greatly improved postoperative spinal stability and reduced donor-site morbidity from major bone graft harvesting techniques.[72-78]

In a study of 150 patients with thoracolumbar burst fracture and associated neurological injury treated with a single stage anterior decompression, instrumentation and fusion, the fusion rate was 93% and improvement of at least 1 Frankel grade was observed in 142 patients.[73] Fifty-six (72%) of the 78 patients with preoperative paralysis or dysfunction of the bladder recovered completely. One hundred twenty-five (96%) of the 130 patients who were employed before the injury returned to work after the operation, and 112 (86%) returned to their previous job without restrictions.[73] Mean improvement of 2 Frankel grades has been shown in patients who underwent anterior decompression within 48 hours.[74] Other studies have shown neurological recovery even when anterior decompression was performed within 7 weeks following the injury.[75]

Posterior Surgical Approaches

Posterior stabilization is the most widely accepted treatment option for thoracolumbar spine instability.[79-81] Numerous types of posterior spinal instrumentation have been used for the treatment of burst fractures such as rod and hook constructs, posterior plates and pedicle screws for three-column support,[65] and multiple hook-rod configurations that typically involve stabilization of a greater number of motion segments and furthermore the hooks may be applied purely in distraction or distraction–compression mode.[80,81]

The posterior approach is complicated by poor initial fixation or secondary loosening in patients with osteoporotic spine.[82] To prevent this complication, longer constructs, augmentation of the instrumentation with calcium phosphate bone cement, and use of cementable cannulated screws, screws thread engagement in the pedicle, penetration of the screws through the anterior cortex, and use of larger diameter screws may significantly increase the stability of the construct and the screw pullout strength.[83-85]

Short-segment pedicle screw fixation allows for spinal stabilization while simultaneously preserving as many motion segments as possible.[49,86-95] When short-segment fixation was compared to long-segment fixation, although the radiographic parameters were more favorable for the long-segment fixation, the clinical outcome was the same between the 2 methods.[90] However, a retrospective study of 22 patients with thoracolumbar burst fractures treated with short-segment posterior fixation reported a higher rate of failure of the single-level cephalad extension of the instrumentation compared to the 2-level cephalad extension.[92] In order to prevent instrumentation failure and improve the biomechanical stability of the construct, some authors have proposed the use of pedicle screws at the level of the fracture for additional fixation points that may aid in fracture reduction and kyphosis correction.[93] In addition, achievement of solid fusion results in a lower risk of implant failure.[94,95]

However, the loss of fracture reduction and deformity correction after posterior approaches may be greater due to re-collapse of the anterior column. A study showed that during fracture reduction through the posterior approach, the central endplate remains under pressure by the intervertebral disk and could not be reduced to an anatomical position by distraction alone.[96] In this setting, the combination of the short-segment posterior fixation with kyphoplasty reinforces the anterior column and prevents anterior vertebral body height loss.[97-102] These techniques have been proven safe and effective, with high rates of fusion and better clinical outcomes, although cement leakage outside the borders of the vertebral body may occur.[98] Calcium phosphate bone cement is preferable over methylmethacrylate because of its in vivo histological properties.[99,100]

The use of transpedicular bone grafting techniques using bone cement, hydroxyapatite or titanium blocks for reconstruction of the anterior column in addition to short segmental fixation has been based on the hypothesis that augmentation of the anterior and middle columns could diminish the correction loss and bending forces that may lead to failure of the posterior instrumentation; results of this method were favorable regarding neurological improvement, anterior column restoration, kyphotic correction, implant failure prevention, and pain control.[103-107]

A significant disadvantage of the posterior approaches to the spine include the fusion disease. Fusion disease includes denervation of paraspinal muscles and facet capsules, damage to the proximal facet joint, and weakening of other supportive structures, resulting in prolonged postoperative pain and disability.[108] Recently, to reduce the posterior-approach related complications, minimally invasive techniques such as percutaneous CT-guided pedicle screw fixation of thoracolumbar burst fractures have become popular with improved clinical and functional results, shorter time of recovery, and lower complication rate.[109-111]

Anterior Vs Posterior Approaches

Relatively few studies compare anterior to posterior approaches for thoracolumbar

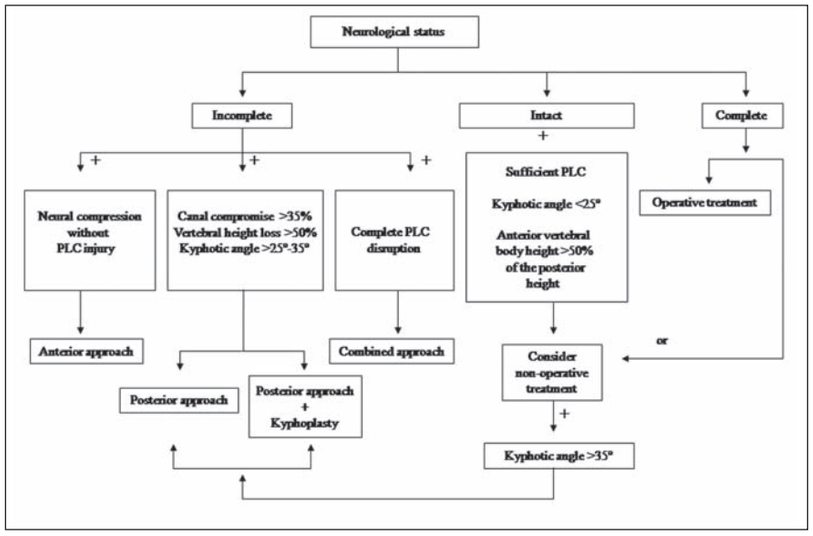

Figure: Treatment algorithm for patients with thoracolumbar spine burst fractures. Abbreviation: PLC, posterior ligamentous complex of the spine.

burst fractures, and most of them show an advantage of the anterior approach.[112-115] In his series, Gertzbein[112] reported that bladder function significantly improved following anterior compared to posterior procedures. Hitchon et al[113] showed that angular deformity was more successfully corrected and maintained when the anterior approach was used. Others also showed that although both approaches are associated with a statistically significant initial improvement in sagittal alignment, the posterior approach was associated with increased loss of sagittal correction (8.1°) compared to the anterior approach (1.8°) at follow-up.[114] In general, although clinical outcome may be similar, the anterior approach for thoracolumbar burst fractures may present fewer complications and need for additional surgery compared to the posterior approaches.[115]

Combined Surgical Approaches

Select patients with thoracolumbar burst fractures may benefit from combined surgical approaches. Indications include complete posterior ligamentous complex disruption and partial neurological injury, and rigid posttraumatic kyphotic deformity as seen in more than 2-week-old injuries.[116-118]

The advantages of combined surgical approaches are improved sagittal alignment, thorough spinal canal and neural decompression for optimum recovery of neural function, and stabilization of the disrupted posterior ligamentous complex.[116] In a series of 20 consecutive patients with a single-level unstable thoracolumbar burst fracture treated by bisegmental posterior fixation followed by anterior corpectomy and titanium cage implantation 7 to 10 days later, 12 patients with initial neurological deficits recovered an average of 1.5 grades on the ASIA scale. Two years postoperatively, the mean visual analog scale score for back pain was 1.6 points and the mean pain at the anterior approach site was 1.2 points. At the latest examination, 2 years after treatment, instrumentation failure did not occur; the mean loss of kyphosis correction was 3°.[117] 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.[118]

Recommendation

After decades of treating spinal fractures with different methods and approaches, the questions raised by this article remain challenging. Based on the results of the search of the related literature for the purpose of this article, we present an algorithm for the treatment of thoracolumbar burst fractures (Figure). Treatment decisions in these patients require complete evaluation of the neurological status and identification of the presence of spinal instability. Most thoracolumbar and lumbar burst fractures can be treated conservatively in select neurologically intact patients. The presence of neurological deficits and spinal instability require surgical treatment through the appropriate surgical approach. In severely injured and polytrauma patients with complete neurological injury, nonoperative treatment may be recommended. If sufficient posterior ligamentous complex, canal compromise >35%, anterior vertebral body height loss >50% and kyphotic deformity more than 25° to 35°, surgical treatment through the posterior-only approach or posterior approach combined with kyphoplasty is indicated.

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