Although minimally invasive techniques for spinal fixation have grown tremendously in popularity over the last several years, these techniques were originally described nearly 40 years ago. Magerl and Dick described the percutaneous placement of a spinal internal fixator in 1977 in nontraumatic cases. Since that time, there have been several retrospective case series published on minimally invasive fixation techniques for spinal trauma, most notably the use of percutaneous pedicle screw fixation without fusion. While mini-open approaches allow access for arthrodesis, purely percutaneous nonfusion fixation techniques do not allow for bone graft placement. Purely percutaneous posterior screw/rod fixation for trauma has unclear long-term efficacy as the screw-bone interface may loosen in the absence of fusion.

Object. Minimally invasive spinal (MIS) surgery techniques have been used sporadically in thoracolumbar junction trauma cases in the past 5 years. A review of the literature on the treatment of thoracolumbar trauma treated with MIS surgery revealed no unifying algorithm to assist with treatment planning. Therefore, the authors formulated a treatment algorithm.

Methods. The authors reviewed the current literature on MIS treatment of thoracolumbar trauma. Based on the literature review, they then created an algorithm for the treatment of thoracolumbar trauma utilizing MIS techniques. This MIS trauma treatment algorithm incorporates concepts form the Thoracolumbar Injury Classification System (TLICS).

Results. The authors provide representative cases of patients with thoracolumbar trauma who underwent MIS surgery utilizing the MIS trauma treatment algorithm. The cases involve the use of mini-open lateral approaches and/or minimally invasive posterior decompression with or without fusion.

Conclusions. Cases involving thoracolumbar trauma can safely be treated with MIS surgery in select cases of burst fractures. The role of percutaneous nonfusion techniques remains very limited (primarily to treat thoracolumbar trauma in patients with a propensity for autofusion [for example, those with ankylosing spondylitis]).

Key Words • minimally invasive • spinal trauma • spinal cord injury • spinal fracture

Lumbar and Thoracolumbar Injury Classification

Historically, there have been multiple classification systems described for thoracolumbar spinal injury. In 2005, the Spine Trauma Study Group described a novel classification system that has proven to be quite useful clinically and is known as the Thoracolumbar Injury Classification System (TLICS). The TLICS is notable because it takes into account neurological injury in addition to radiographic findings. In addition, this system generates a score that can then be directly used to determine surgical versus nonsurgical management. The TLICS system leaves the specifics of the surgical management up to the surgeon, including the surgical approach and type of fixation. The surgical management of thoracolumbar fractures has grown significantly more diverse in the last several years with the advent of minimally invasive surgical techniques.

We reviewed the current literature on minimally invasive techniques for the treatment of thoracolumbar trauma and propose an algorithm to be used in conjunc-
tion with TLICS to help determine which patients may be candidates for treatment with minimally invasive techniques.

Methods

We reviewed the literature and found that minimally invasive spinal (MIS) surgery for trauma can be divided into nonfusion and fusion methods. Nonfusion MIS surgery techniques involve the use of percutaneous placement of pedicle screws (which may or may not be removed at a later date) without placement of bone graft or other attempts at inducing arthrodesis. Minimally invasive fusion techniques, on the other hand, have generally involved mini-open approaches that allow for disectomy and/or corpectomy and cage reconstruction via a lateral or posterior approach.

Posterior Minimally Invasive Pedicle Screw Fixation

Grossbach et al. described a series of 11 patients who underwent posterior percutaneous pedicle screw placement for flexion-distraction injury of the thoracolumbar junction. They then compared kyphotic angulation, American Spinal Injury Association (ASIA) grade, operative time, and blood loss with a group of 27 patients treated with open fixation and fusion surgery. They found that there were no differences between the open and MIS treatment groups in regard to ASIA grade and kyphotic angulation. They did find significantly lower blood loss in the MIS surgery group and a trend toward shorter operative time in the MIS surgery group (not statistically significant). One patient in each group required hardware revision for misplaced screws. The only clinical outcome measure used by the authors was the ASIA grade; however, all patients who underwent MIS surgery were neurologically intact preoperatively and remained so after surgery. The authors provided only an average length of follow-up of 11.8 months for the MIS surgery group and a trend toward shorter operative time in the MIS surgery group (not statistically significant). One patient in each group required hardware revision for misplaced screws. The only clinical outcome measure used by the authors was the ASIA grade; however, all patients who underwent MIS surgery were neurologically intact preoperatively and remained so after surgery. The authors noted no significant differences in loss of correction and clinical outcomes between the groups. They found that operative time and blood loss were significantly lower in the percutaneous fixation group compared with the open surgery group. There was no significant difference between the 2 groups in terms of operative time or x-ray exposure. The authors did not report hospital length of stay in either group. At 5 years, the authors noted no significant differences in loss of correction and clinical outcomes. This study suggests that percutaneous fixation may be an adequate option in a limited group of patients, specifically those who are neurologically intact. However, even in this very small subset of spinal trauma patients, the benefits of percutaneous fixation appear to be only short term and there is no clear difference in the long term.

Lee et al. performed a retrospective comparative study of neurologically intact patients with thoracolumbar burst fractures, comparing 32 patients who were treated with percutaneous fixation to 27 patients who underwent open short-segment screw fixation. They achieved mid-range follow-up of approximately 30 months for the percutaneous group and 40 months for the open surgery group. At last follow-up, they reported no significant differences and loss of deformity correction or outcomes between the 2 groups. They found that operative time and blood loss were significantly lower in the percutaneous group. They reported 2 postoperative infections in the open group that required reoperation. It does not appear that hardware was routinely removed in either group. This study was of interest as it suggested that the clinical outcomes were superior in the percutaneous group in the short term, but long term there was no significant difference between the 2 groups.8

Recently, Vanek et al. reported the results of a prospective, nonrandomized observational study comparing multilevel percutaneous transpedicular screw instrumentation to open short-segment transpedicular fixation with fusion (treated with 1-level fixation above and 1-level fixation below the level of the injury). Patients with spinal cord injury were excluded. The authors noted a significant reduction in perioperative blood loss in the percutaneous group compared with the open group. They also noted significantly less postoperative pain in the percutaneous group as well as slightly shorter operative times in this group. They measured kyphotic deformity on radiographs and found no difference in kyphotic angulation at 2 years of follow-up between the 2 groups. The authors did not report surgical fusion rates. However, they did report that none of the patients required surgical revision at 2 years. The authors proposed that percutaneous transpedicular instrumentation is a potential nonfusion option for neurologically intact patients with thoracolumbar fractures.14

Posterior Minimally Invasive Corpectomy

Although corpectomy is often performed via an open anterior or lateral approach, this procedure can also be performed via a mini-open posterior transpedicular or posteroateral approach. In 2011, Chou and Lu reported a series of 8 patients, including 1 with a traumatic L-1 burst fracture, who underwent a mini-open transpedicular corpectomy. They performed a single midline posterior skin incision and placed 2 levels of pedicle

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screw fixation above and below the level of the fracture using stab incisions through the fascia. They then performed an open midline fascial opening at the level of the corpectomy, where they performed a complete laminectomy at the index fracture level as well as a partial laminectomy above and below the index level. They then created a transpedicular corpectomy through an expandable tubular retractor. The authors compared their small series to a cohort of patients, including 1 trauma patient, who underwent open surgery. They did not see a significant difference in outcomes or complications. However, it must be noted that the length of follow-up was quite short; in particular, the trauma patient underwent follow-up for only 8 months.

**Lateral Minimally Invasive Corpectomy**

In recent years, mini-open lateral approaches have been described. These approaches are purported to allow for direct visualization while minimizing approach-related soft-tissue dissection. One of the larger series was reported by Smith and colleagues in 2010. These authors reported on 52 patients with thoracic and lumbar fractures (mostly T-12 and L-1), and most of these patients had a spinal cord injury. Of note, they used a transpleural approach in 9 of the patients and were able to avoid chest tube placement in all but 2 of these patients. All patients underwent supplemental internal fixation. In 75% of the cohort they used anterolateral fixation, in 46% of the cohort they used pedicle screw fixation, and in 29% of the cohort they used both anterior and posterior fixation. Complications included pleural effusion in 1 patient, intercostal neuralgia in 1 patient, and dural tears in 2 patients. None of the patients experienced neurological deterioration, and most experienced improvement in their ASIA grade. While 83% of the patients underwent follow-up at 1 year, only half of the patients had 2 years of follow-up. That said, none of the patients were reported to have complications requiring surgical revision or re-exploration.

**Anterior Thoracoscopic Treatment of Thoracolumbar Fractures**

In 2004, Kim and colleagues published a large series of patients with thoracolumbar spine fractures treated with a thoracoscopic minimally invasive approach. Of the 212 patients in this series, 91 had associated spinal cord injury with their fractures. The authors used these techniques to treat burst fractures and flexion distraction injuries, the latter of which were also treated with a posterior pedicle screw construct.

The authors’ surgical technique involved a left lateral transpleural approach using multiple portals via a thoracoscopic approach to the fractured vertebra. They then performed a thoracoscopic vertebrectomy and reconstruction with either an expandable cage or a bone graft. They noted an 85% fusion rate at 12 months. The authors also reported an overall 11% complication rate, which included aortic injury in 1 patient, conversion to open surgery in 3 patients, hardware failure in 5 patients, and neurological deterioration in 1 patient. The authors acknowledged that these thoracoscopic techniques require a significant amount of training, as the endoscopic image is 2D. It is likely that this requirement has limited the adoption of this technique in North America.

**Proposed Algorithm**

Our proposed algorithm attempts to assist the surgeon with the technical aspects of surgical planning after TLICS has provided input on an operative versus nonoperative treatment plan. In patients with a TLICS score of less than 4 (Fig. 1), external bracing is recommended. In the setting of a TLICS score of 4 (Fig. 2 upper), external bracing may be an option or the surgeon may feel that the patient requires surgical fixation. Minimally invasive options in this situation would be limited to anterior or lateral approaches for fusion and instrumented fixation, as well as posterior approaches that would result in instrumented fixation and possibly fusion. Although there is some recent literature detailing the use of percutaneous fixation without fusion for trauma, there remains a significant lack of long-term follow-up data regarding the rate of fusion. While some authors have advocated for delayed removal of hardware, since it is purported to be an “internal brace,” this instrumentation subjects the patient to a second surgery, the morbidity of which should be taken into account by the surgeon. Similarly, others have advocated that percutaneous fixation may be a more rapid and less morbid option for patients who are unstable due to multiple traumatic injuries. There remains a lack of significant evidence to support this notion, and, with
the exception of a few pioneering surgeons with a tremendous amount of experience performing percutaneous instrumentation, it is possible that this technique would take as long and perhaps longer than traditional open surgical instrumented fusion and may result in a higher incidence of hardware complications. One notable exception (Fig. 2 lower) is the treatment of fractures in patients with ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis (DISH). In these patients with a TLICS score of 4 or more, a posterior percutaneous screw-rod fixation and reduction of the fracture may be considered. These particular patients have a propensity for fusion if they are stabilized, even when a bone graft is not placed.

In the setting with a TLICS score greater than 4, it is possibly recommended that the patient undergo open or mini-open instrumented fusion (Fig. 3) via either an anterior/lateral or a posterior approach. Posterior percutaneous fixation maybe used as a supplement to anterior instrumented fusion for these cases, since the bone graft is placed in the anterior column.

**Illustrative Cases**

We have applied the TLICS scoring profile and the new MIS trauma algorithm in several cases and report these here to demonstrate our experience with it.

**Case 1**

This 69-year-old man presented with severe back pain without evidence of spinal cord injury after a motor vehicle accident. Sagittal CT scanning revealed a burst fracture with significant kyphosis and some central canal compromise, and MRI revealed significant ligamentous
Algorithm for MIS surgery in thoracolumbar spinal trauma

disruption (Fig. 4). The patient had a TLICS score of 4, and after an attempt at external bracing failed, the patient elected to undergo a minimally invasive lateral retroperitoneal approach for L-1 corpectomy and instrumented fusion (Fig. 5) and supplemental percutaneous pedicle screw fixation.

Case 2

This 58-year-old man presented 6 months after a fall that resulted in an L-1 burst fracture with a TLICS score of 4. The fracture was managed conservatively with an external brace at another institution. However, the patient developed mild myelopathy with progressive paraparesis (ASIA Grade D). Imaging revealed a stable autofusion across T12–L1; however, there was significant central stenosis with signal change within the spinal cord (Fig. 6). As this patient no longer required instrumented stabilization of his healed fracture, he underwent mini-open decompression without instrumentation (Fig. 7). This resulted in improvement of his paraparesis (ASIA Grade E).

Discussion

As discussed above, minimally invasive techniques have been described extensively in the realm of thoracolumbar spinal trauma. However, it must be noted that the efficacy of these techniques can very greatly. Mini-open

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**Fig. 4.** Case 1. Sagittal T2-weighted MR image revealing an acute T-12 burst fracture with kyphotic angulation.

**Fig. 5.** Case 1. Postoperative 36-in scoliosis radiograph demonstrating successful reconstruction with lateral minimally invasive T-12 corpectomy/cage and posterior percutaneous screw fixation.
posterior, lateral, and anterior approaches are merely an evolution of currently accepted surgical techniques that allow the surgeon to perform arthrodesis via a smaller and less morbid approach. Chou and Lu demonstrated the feasibility of mini-open posterior vertebrectomy techniques with convincing follow-up and fusion data. Similarly, Smith and colleagues have demonstrated that the minimally invasive lateral approach for vertebrectomy results in successful decompression and arthrodesis with convincing fusion data.

While several studies have been published on percutaneous pedicle screw fixation techniques, they fall into 2 categories: temporary and permanent fixation. We find the temporary fixation concept to be concerning because it may require the patient to undergo a second surgery with general anesthesia to remove the loosened hardware as there is no fusion, and there is potential morbidity associated with this. Unfortunately, the studies that described temporary fixation techniques did not delve into the rates of patient follow-up, likely because trauma patients have a low propensity to come to the clinic for follow-up.

In the studies that used percutaneous pedicle screw fixation without fusion, there is a lack of radiographic fusion data. The incidence of pseudarthrosis or long-term hardware loosening/failure is unknown. The majority of the studies that reviewed this nonfusion technique involved follow-up that was too short to reveal this problem.

In our algorithm, we suggest limiting the use of percutaneous nonfusion techniques to patients with hyperostotic disorders such as ankylosing spondylitis and DISH unless a planned hardware removal at a later date is planned after the fracture heals. We recommend that patients with TLICS scores of greater than 4 undergo instrumented fixation with a bony arthrodesis via either a conventional open or mini-open approach.

Conclusions
The advent of minimally invasive surgical techniques has expanded the treatment options for thoracolumbar trauma. We propose an algorithm for decision making that builds upon the TLICS scoring system and incorporates current minimally invasive fixation techniques.

Disclosure
Dr. Dhall receives honoraria from DePuy Spine. Dr. Wang is a consultant for and patent holder with DePuy Spine. Dr. Mummaneni receives honoraria from DePuy Spine and Globus and royalties from DePuy Spine, Thieme, and Quality Medical Publishers.

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