Rationale and proposed advantages of MIS

The treatment goals of minimally invasive spine surgery (MIS) are the same as traditional open surgery across all types of spine pathologies. Looking specifically at spine trauma, the aim of management is to (1) obtain and maintain spinal stability, (2) optimize neurological outcome, and (3) obtain a satisfactory clinical outcome that will allow the patient to return to as optimal a quality of life as possible. Treatment should provide the best outcome with the least amount of associated morbidity. According to a systematic review assessing 138 papers on the surgical management of thoracolumbar trauma by Verlaan et al. [1], the average infection rates reported ranged from 0.7% for anterior procedures to 3.1% for posterior procedures. Median blood loss was greater than 1 l for posterior, anterior, or anterior–posterior procedures. Thus, conventional techniques can be associated with significant morbidity. Can these complications be minimized by adjusting techniques?

According to Kim [2], MIS is predicated on several basic principles: (1) avoid muscle crush injury by self-retaining retractors, (2) avoid disruption of tendon attachment sites of key muscles, (3) use known anatomic neurovascular and muscle plains, and (4) minimize collateral soft tissue injury by limiting the width of the surgical corridor. The primary goal of MIS is to reduce approach-related morbidity thus reducing complications and improving outcomes both in the short and long term. Ideally, postoperative pain and recovery time will be reduced, which ideally will allow the patient to return to work earlier. Equally important is (a) the avoidance of misplaced screws, (b) constructs that are equally biomechanically stable to what can be achieved with traditional open approaches, (c) adequate decompression in patients with neurological compression, and (d) the achievement of fusion when indicated. The question is whether MIS surgery can improve outcomes and minimize complications over traditional open surgery.

Indications and application of MIS in thoracolumbar trauma

The appropriate management of thoracolumbar injuries is fraught with controversy as to operative indications and what procedure is best for different fracture patterns. This is particularly noticeable when comparing different regions of the world. In discussing MIS for spine trauma, three basic options meet criteria either as stand-alone or in some combination: (1) anterior endoscopic decompression and stabilization, (2) “mini-open” anterolateral approaches, and (3) posterior percutaneous segmental pedicle screw fixation (Fig. 1).

Anterior endoscopic approach

Anterior endoscopic decompression and stabilization has been used as a stand-alone or with supplemental posterior stabilization for various injuries, but the most common indication is in burst type injuries. The largest series to date is by Khoo et al. [3], who published their findings on 371 consecutive patients treated with thoracoscopic-assisted treatment. Interestingly, 65% also had supplemental posterior pedicle-screw instrumentation. The severe complication rate was low (1.3%), with one case each of aortic injury, splenic contusion, neurological deterioration, cerebrospinal fluid leak,
Changes in practice patterns. In a large academic level 1 trauma center, the advent of minimally invasive spine surgery for trauma indications in ankylosing fracture has not led to a decline in the number of conventional open procedures, but has brought about an increase of overall surgical cases. The causes for this development are unclear, but may include changing patient demographics, with more elderly patients sustaining significant fractures, such as seen in ankylosing spinal disorders, or may result from changing treatment preferences as well. (Adapted from [11])

There was an increased chance for survival for elderly patients treated with percutaneous fracture fixation for ankylosing thoracolumbar fractures compared to conventional open fracture care. Perhaps a statistically significantly greater operative blood loss, increased infection rate, or longer hospital stay has a role in this observation. (Adapted from [11])
and severe wound infection. They emphasized a steep learning curve, which is a recurring theme in thoracoscopic-assisted surgery throughout the literature, but concluded that the functional and cosmetic benefits to the patient warranted the difficult training process. Because of a variety of technical challenges, increased initial operative time, limited instrumentation, and experience, endoscopic procedures as a whole have not gained much popularity worldwide. No long-term difference in outcome has been reported with this technique compared with classic "open" techniques.

**Mini-open anterolateral approaches**

"Mini-open" anterolateral approaches for decompression and stabilization are another possible application of MIS to spine trauma. Most surgeons would argue that in the face of an anterolateral approach, they only open enough to safely carry out the indicated procedure; therefore, what is the threshold to change nomenclature from classic open to mini-open? In a recent study of 80 patients (in which trauma was the operative indication in 57), Baaj et al. [4] reported a total complication rate of 12.5%. Their definition of mini-open was an incision measuring 5–7 cm in length. They did not look at outcomes and concluded that this technique is technically demanding and requires proficiency. Smith et al. [5] looked at 52 patients treated for traumatic injuries and followed them up for 2 years; they found a 13.5% complication rate and no need for re-operation and no neurological deterioration. They concluded that this technique is safe and effective. No comparative studies on this subject are available at this point in the literature. Most studies have demonstrated reduced blood loss, reduced perioperative pain, and reduced hospital stay; however, no differences in long-term outcomes have been shown in the studies to date.

**Posterior percutaneous segmental pedicle screw fixation**

The largest amount of literature in MIS and traumatic thoracolumbar injuries involves posterior percutaneous segmental pedicle screw fixation. There are numerous case series assessing the efficacy and safety of percutaneous fixation for various injuries. Interestingly, many of these studies focus on burst injuries in neurologically intact patients that one could argue do not merit operative intervention at all. Blondel et al. [6] reported on 29 neurologically intact patients with A3 fractures treated with balloon kyphoplasty and posterior percutaneous screws. They concluded that this is a safe technique but that rigorous patient selection is necessary and the time to learn the procedure must be taken into account. Ni et al. [7] looked at 36 neurologically intact patients with A3 fractures and also concluded that percutaneous fixation is an alternative for the management of these injuries. Palmisani et al. [8] examined 51 neurologically intact patients with 64 fractures (57 of which were AO type A fractures) and also concluded that percutaneous pedicular screw fixation is an adequate and safe procedure in specific fracture types. None of these articles had a comparative arm including traditional open screw placement, and one could also argue, as mentioned previously, that many of these patients could be treated conservatively. There is certainly an increasing trend in North America to manage neurologically intact "burst" or AO A type fractures nonoperatively.

The only article comparing traditional open screw placement with percutaneous screw placement is a study by Wild et al. [9] on 21 neurologically intact, consecutive patients with thoracolumbar AO A-type (mainly A3) fractures in which 11 patients were treated with conventional open surgery and 10 were treated with percutaneous fixation (Fig. 2). Interestingly exclusion criteria for this study included patients with rupture of the posterior longitudinal ligament, fractures of the vertebral joint of the vertebral arch, and patients with neurological deficits—the very patients for which operative indications are generally agreed upon. These patients were followed up for 5 years. The authors found no difference in long-term outcome looking at Hannover Spine Scores and SF-36, but noted decreased blood loss with percutaneous techniques (Fig. 3).
Several articles touting the use of percutaneous pedicle screw instrumentation acknowledge that many of these injuries could be treated nonoperatively and claim that “conservative treatment is a highly demanding procedure for the patient,” thus justifying the use of MIS techniques [10]. Conventional open surgery traditionally utilized a formal bone fusion technique that is clearly more difficult to achieve, if even attempted, with a percutaneous technique. The ramifications of bypassing a formal arthrodesis have yet to be fully explored. Unfortunately, there is a paucity of literature looking at the use of percutaneous screw fixation in patients in whom operative indications are regularly agreed upon such as flexion-distraction injuries or AO type B injuries, patients with neurological deficits, fracture dislocations, or AO type C injuries, and patients with ankylosed spines and extension injuries. Much of the literature has focused on the safety side of percutaneous screw placement and intraoperative benefits and little on long-term outcomes. More specific research efforts, such as applying posterior MIS techniques to patients with specific disorders (e.g., patients with spine fractures in ankylosing spondylitis) are just beginning to emerge ([11], Fig. 4).

**Conclusion**

Despite several advances toward safe and successful MIS for thoracolumbar spine trauma, considerable work remains to be done. Much work to date has focused on safety and intraoperative advantages, but little has been done to show any differences in the intermediate and long-term range with respect to benefits and outcomes. There are no randomized, prospective studies to date demonstrating the equivalence or superiority of MIS techniques over traditional open techniques. There are certainly even more unanswered questions about the economics of spine trauma care using nonoperative, conventional surgical or minimally invasive surgical care techniques. Apart from the economics, it stands to reason that management principles of spine trauma should be adhered to regardless of choice of technique, and at present the specific clinical indications for MIS techniques are still being defined. Thus, although the theoretical benefits of improved outcomes with MIS techniques in the setting of trauma may seem appealing, insufficient clinical data exist from which one can draw any specific conclusions and there is certainly insufficient data to make treatment recommendations in favor of MIS in trauma. In the end, hopefully the best interest for patient care will prevail and not the appeal of technical possibilities.

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**Conflict of interest.** On behalf of all authors, the corresponding author states that there are no conflicts of interest.
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