Review Article

Minimally invasive spinal surgery for trauma: a narrative review

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Abstract: Over the past decade there has been a revolution in availability for minimally invasive techniques for the fixation of spinal fractures. In this narrative review we aimed to take a comprehensive look at these developments and their results from the Atlas to the Sacrum establishing the current evidence base for percutaneous fixation at each level of the spine.

Keywords: Percutaneous; minimally invasive spine; trauma

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Introduction

The initial forays into minimally invasive spine surgery may be ascribed to Wittmoser in 1973 (1) when he performed the first endoscopic sympathectomy. By convention percutaneous spinal fixation is thought to have started with Magerl's use of external fixators to treat spinal fractures (2).

Over the past decade there has been a revolution in available for minimally invasive techniques for the fixation of spinal fractures. In this narrative review we aimed to take a comprehensive look at these developments and their results from the Atlas to the Sacrum establishing the current evidence base for percutaneous fixation at each level of the spine.

Materials and methods

Pubmed and the Cochrane database were searched using the terms "minimally invasive" and "spine". This yielded a total of 3,516 results. We examined the period 1998 to 2016 inclusively. Non English language studies were excluded. All studies which involved vertebral augmentation alone (vertebroplasty or kyphoplasty) were eliminated. Only papers dealing with spinal fractures were included. All papers dealing with degenerative spinal conditions, tumors and deformity correction were removed. This left a total of 27 papers during this period. All the papers were independently reviewed by two of the authors (D Bhagawati and DD Bhagawati).

Cervical spine

A number of studies examined have the use of minimally invasive and percutaneous techniques of the cervical spine.

Wang *et al.* (3) focused on C2 peg fractures, performing a study to compare percutaneous to open techniques for anterior surgery. They examined Anderson and D'Alonzo type II and "shallow or rostral" type III fractures (3). The technique of screw fixation for these fractures has been well established since the early 1980s (4). In Wang *et al.*'s technique the patient was placed supine and on traction, 1 cm anterior incision made along the medial border of Sternocleidomastoid. Blunt dissection was used to pass through the platysma and sternocleidomastoid fascia. A guide tube with a blunt tip was used to get to the mid cervical level and the tube was passed up from there to C2. A sharp tipped guide wire was then passed up to the C2 disc material. This was followed by a standard percutaneous

technique of serial dilation using specifically designed dilators that fit around the guide tube. These allow for the accessible area to be progressively increased. Finally a cannulated screw is passed over the guide wire to the appropriate depth as judged on image intensifier images.

In their study there was no significant difference in radiation exposure between the two groups. Both intra-operative time and blood loss were significantly lower in the open group. In terms of complications there was neither significant neurological or airway complications nor any major vessel injuries. Two patients in the open group suffered from dysphagia and one patient in the percutaneous group had a non-anatomic fusion. Their conclusion was that the safety profiles of these two techniques were equivocal.

Chi *et al.* (5) examined treatment of a similar fracture type. Their technique again involved placing the patient in traction. They then used an injection of normal saline in the prevertebral fascia to separate the neurovascular bundle from the trachea and esophagus. Otherwise the rest of their technique was similar to Wang *et al.* They again found no major complications and satisfactory fusion on CT of 90%. There was unfortunately no comparative group.

In their small series of six patients, Holly *et al.* (6) described their experience of using a posterior C1/2 fixation for Anderson-D'Alonzo type II fractures. Here they used fluoroscopic localization of the C2 pedicle and serial dilation for exposure. They then used to the technique of Harms *et al.* (7) to site a C1 lateral mass and C2 pedicle screw. Again there were no significant complications with solid fusion in all cases on both CT and dynamic screening.

Wu *et al.* (8) described a percutaneous technique for treating Hangman's fractures. In this study they described first attempting to determine the trajectory of screw placement based on pre-operative CT scanning. Again a posterior stab incision was made and a guide wire inserted to CT pedicle under fluoroscopic guidance. Serial dilation was then used prior to the insertion of the screw for osteosynthesis. Like other series this small series found no neurological or vascular complications. CT scanning revealed 85% satisfactory screw placement, 10% breaching the medial wall and 100% fusion. Sagittal balance was maintained on the lateral X-rays although how this was assessed was not stated.

Posterior lumbar pedicle screw fixation

The basic principles of posterior lumbar pedicle screw fixation in modern practice were illustrated by Khoo *et al.* in 2002 (9). They performed a two-part study; firstly the anatomical aspects then the clinical aspects of modern percutaneous techniques as applied to posterior interbody fusion. In their anatomical study they found the average inter-pedicular distance was 10.1 mm with L5-S1 being the broadest. The average height was 14.4 mm with L2–3 being the tallest. With regard to cannulated pedicles the average height and width were 10 and 10.1 mm, respectively. The lordosis increased at from the higher levels (2.1 degrees at L2–3) to the lower levels (11.2 degrees at L5-S1). There was only one breach for the pedicle—superiorly at L4 otherwise all other screws were firmly inside the pedicles.

For the clinical part of their study Khoo *et al.* (9) examined three cases of percutaneous posterior lumbar interbody fusion (PLIF). These early cases had long operative times averaging over 5 hours. There was steep learning curve with duration of the procedures decreasing from 6 hours 15 mins for the first case to 4 hours 30 mins for the third. Blood loss likewise decreased from 280 to 110 mL. There were no intra-operative complications and no change on the nerve monitoring. Follow-up CT demonstrated good screw placement. One screw (L5) did penetrated the anterior cortex but clinical sequelae resulted.

In the earlier studies no adverse effects other than screw mal-position were apparent. These studies were relatively small. Larger studies have subsequently been performed. Heintel *et al.* (10) examined a total of 502 pedicle screws in 111 patients studied as a cohort over 2 years. The fused segments were between T6 and L5. The trajectory of the screws was pre-planned using multi-planer CT scanning. Again a Jamshidi needle technique followed by serial dilation was used. Accuracy of screw placement was determined using the technique of Zdichavsky *et al.* (11). In this system 2b and 3b grouping equated to medial wall breaches. The Zdichavsky classification assesses in the axial plane only and thus does not assess superior or inferior pedicle breaches. Of the 111 patients 40 underwent percutaneous fixation alone, 53 had an additional balloon kyphoplasty and 18 had a minimally invasive ventral procedure. Twenty-four screws breached the anterior cortex but these did not require revision. They defined optimal screw length at >85% of the anterior-posterior dimension and 85% of the screws fulfilled these criteria. Using the Zdichavsky system (12) 98% (494 of 502) were judged to be good or excellent. One screw in a patient with ankylosing spondylitis required revision for a medial wall breach and resulted in Frankel/ American Spinal Injury Association (ASIA) C incomplete

spinal cord injury. This was a non-fusion study and thus all the screws were removed. The operative times were not published.

Some units have advocated the use of vertebral cement augmentation in addition to percutaneous screw fixation in the treatment of osteoporotic vertebral compression fracture. However, Teyssédou *et al.* (13) found little difference in terms of deformity correction or pain score between vertebral augmentation with percutaneous fixation and vertebral augmentation alone.

Direct comparative data on percutaneous *vs.* open posterior lumbar fusions has been somewhat limited. Grossbach *et al.* [2013] (14) reviewed their 10-year experience comparing open to percutaneous techniques. Their series of 38 patients examined a young population (average age 32). Open posterior lateral fusions in 27 patients were compared to 11 patients who underwent percutaneous non-fusion fixation. Pre-operatively the open patients were noted to be younger (average 27 *vs.* 40 years old). The intra-operative time was less in the minimally invasive surgery (MIS) group (195 *vs.* 257 mins) with significantly less blood loss (93 *vs.* 498 mL). Average hospital stay was also shorter (7.6 *vs.* 11 days). However the kyphotic corrections seemed to be more consistently maintained in the open group possibly related to a greater number of levels fused.

The loss of kyphosis correction and vertebral height after initial fixation has been a consistent finding (15). This may be a result of the use of non-fusion techniques or lack of anterior support. However this appears to have had no significant effect of global sagittal balance (16). The operative time has varied significantly ranging from 61 (15) to 195 mins (14). This may well reflect an underlying learning curve (17). Screw malposition has been a relatively rare complication occurring in less than 5% of cases although screws into L5 appear to have been a particular problem (13). Loosening of the locking nut has also been noted as a rare complication (17).

Raley *et al.* (18) used strict criteria to assess screw malposition on axial CT scanning. In their single surgeon series they found a screw malposition rate of 9.7%. Although almost three quarters of these (26 out of 33) were lateral rather than medial malpositions. In 0.9% of their cases there was a breach of the anterior vertebral cortex by the K-wire used during the procedure. These comprised four cases in total. One had a small volume retro-peritoneal bleed that was treated non-operatively. The rest made un-eventful recoveries. Consistent with other studies they showed a learning curve with operative time decreasing from 238 mins for the first five cases to 147 for the last five. Likewise the mean fluoroscopic time decreased from 1.71 to 0.79 mins which equated to a radiation exposure of 44.9 mGy.

One major concern with percutaneous techniques has been superior facet violation. In a study by Jones-Quaidoo *et al.* (19) they found that violations were twice more as common in percutaneous techniques than open methods (13% *vs.* 6%). The long term consequence of this difference has yet to be determined.

Anterior thoracic

Although video-assisted thoracoscopic surgery has been used for degenerative disc disease (20) we failed to find any widespread use of it in spinal trauma.

Anterior lumbar

Olinger *et al.* (21) described a lumboscopic technique to achieve anterior fusion after posterior stabilization. Here the retro-peritoneal space was accessed from the lateral decubitus position and expanded using carbon dioxide. An anterior fusion was performed using iliac crest graft. In their series of 12 patients there was relatively little blood loss (<200 mL) but again a learning curve was present with the operative time decreasing from 5.8 to 4.3 hours across the series. One patient suffered a pneumothorax, one a deep vein thrombosis in the contra-lateral leg, one an infection the iliac graft donor site and two suffered femoral nerve weakness. The rates of fusion and clinical outcome were not reported.

Conclusions

Over the last 18 years there has been an explosion on in the use of minimally invasive techniques in spine surgery (22). This has formed a body of evidence which suggests such techniques are safe and reliably achieve the goals of treating pain and preventing deformity. A significant learning curve is apparent but once mastered significant complications appear to be few. Currently the major deficit in the literature is the absence of health economics studies in this area. Specifically whether the increased cost of the equipment can be offset again the decreased hospitals stays and reduced peri-operative morbidity. However the overall trajectory is to more widespread use with apparent beneficial outcomes.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

References

1. Wittmoser R. Die Retroperitoneoskopie als neue Methode der lumbalen Sympathikotomie. Fortschr Endoskop1973;4:219-23.
2. Magerl FP. Stabilization of the lower thoracic and lumbar spine with external skeletal fixation. Clin Orthop Relat Res 1984;(189):125-41.
3. Wang J, Zhou Y, Zhang ZF, et al. Comparison of percutaneous and open anterior screw fixation in the treatment of type II and rostral type III odontoid fractures. Spine (Phila Pa 1976) 2011;36:1459-63.
4. Böhler J. Anterior stabilization for acute fractures and non-unions of the dens. J Bone Joint Surg Am 1982;64:18-27.
5. Chi YL, Wang XY, Xu HZ, et al. Management of odontoid fractures with percutaneous anterior odontoid screw fixation. Eur Spine J 2007;16:1157-64.
6. Holly LT, Isaacs RE, Frempong-Boadu AK. Minimally invasive atlantoaxial fusion. Neurosurgery 2010;66:193-7.
7. Harms J, Melcher RP. Posterior C1-C2 fusion with polyaxial screw and rod fixation. Spine (Phila Pa 1976) 2001;26:2467-71.
8. Wu YS, Lin Y, Zhang XL, et al. Management of hangman's fracture with percutaneous transpedicular screw fixation. Eur Spine J 2013;22:79-86.
9. Khoo LT, Palmer S, Laich DT, et al. Minimally invasive percutaneous posterior lumbar interbody fusion. Neurosurgery 2002;51:S166-81.
10. Heintel TM, Berglehner A, Meffert R. Accuracy of percutaneous pedicle screws for thoracic and lumbar spine fractures: a prospective trial. Eur Spine J 2013;22:495-502.
11. Zdichavsky M, Blauth M, Knop C, et al. Accuracy of pedicle screw placement in thoracic spine fractures. Part I: inter- and intra-observer reliability of the scoring system. Eur J Trauma 2004;30:234-40.
12. Zdichavsky M, Blauth M, Knop C, et al. Accuracy of pedicle screw placement in thoracic spine fractures. Part II: a retrospective analysis of 278 pedicle screws using computed tomographic scans. Eur J Trauma 2004;30:241-7.
13. Teyssédou S, Saget M, Prébet R, et al. Evaluation of percutaneous surgery in the treatment of thoracolumbar fractures. Preliminary results of a prospective study on 65 patients. Orthop Traumatol Surg Res 2012;98:39-47.
14. Grossbach AJ, Dahdaleh NS, Abel TJ, et al. Flexion-distraction injuries of the thoracolumbar spine: open fusion versus percutaneous pedicle screw fixation. Neurosurg Focus 2013;35:E2.
15. Krüger A, Rammler K, Ziring E, et al. Percutaneous minimally invasive instrumentation for traumatic thoracic and lumbar fractures: a prospective analysis. Acta Orthop Belg 2012;78:376-81.
16. Charles YP, Walter A, Schuller S, et al. Thoracolumbar fracture reduction by percutaneous in situ contouring. Eur Spine J 2012;21:2214-21.
17. Foley KT, Gupta SK. Percutaneous pedicle screw fixation of the lumbar spine: preliminary clinical results. J Neurosurg 2002;97:7-12.
18. Raley DA, Mobbs RJ. Retrospective computed tomography scan analysis of percutaneously inserted pedicle screws for posterior transpedicular stabilization of the thoracic and lumbar spine: accuracy and complication rates. Spine (Phila Pa 1976) 2012;37:1092-100.
19. Jones-Quaidoo SM, Djurasovic M, Owens RK 2nd, et al. Superior articulating facet violation: percutaneous versus open techniques. J Neurosurg Spine 2013;18:593-7.
20. Anand N, Regan JJ. Video-assisted thoracoscopic surgery for thoracic disc disease: Classification and outcome study of 100 consecutive cases with a 2-year minimum follow-up period. Spine (Phila Pa 1976) 2002;27:871-9.
21. Olinger A, Hildebrandt U, Mutschler W, et al. First clinical experience with an endoscopic retroperitoneal approach for anterior fusion of lumbar spine fractures from levels T12 to L5. Surg Endosc 1999;13:1215-9.
22. Phan K, Mobbs RJ. Systematic reviews and meta-analyses in spine surgery, neurosurgery and orthopedics: guidelines for the surgeon scientist. J Spine Surg 2015;1:19-27.

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