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Original Article

Posterior Transpedicular Screw Fixation of Subaxial Vertebrae: Accuracy Rates and Safety of Mini-laminotomy Technique

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Abstract

Background and Aim: Posterior cervical transpedicular screw fixation has the strongest resistance to pullout forces compared with other posterior fixation systems. Here, we present a case on the use of this technique combined with a mini-laminotomy technique, which serves as a guide for accurate insertion of posterior cervical transpedicular screws. **Materials and Methods:** We retrospectively analyzed data from 40 patients who underwent this procedure in our clinic between January 2014 and March 2017. **Results:** The study population comprised 27 males (67.5%) and 13 females (32.5%) aged 15–80 years (median, 51.5 years). Surgical indications included trauma (n = 18, 45%), degenerative disease (n = 19, 47.5%), spinal infection (n = 2, 5%), and basilar invagination due to systemic rheumatoid disease (n = 1, 2.5%). In the 18 trauma patients, 14 short-segment (1–2 levels) and 4 long-segment (≥3 levels) posterior cervical instrumentation and fusion procedures were performed. The mini-laminotomy technique was used in all patients to insert, direct, and achieve exact screw fixation in the pedicles. Pedicle perforations were classified as medial or lateral and were also graded. Among the 227 cervical pedicle fixations performed, 48 were at the C3 level, 49 at C4, 60 at C5, 50 at C6, and 20 at C7. Axial computed tomography scan measurements showed that 205 of 227 (90.3%, Grade 0 and 1) screws were accurately placed, whereas 22 (9.69%, Grade 2 and 3) were misplaced. However, no additional neurological injury due to misplacement was observed. **Conclusion:** As negligible complications were observed when performed by experienced surgeons, the mini-laminotomy technique can be safely used for posterior transpedicular screw fixation in the subaxial vertebrae for single-staged fusion.

Keywords: *Mini-laminotomy technique, posterior cervical transpedicular screw fixation, subaxial vertebrae*

Introduction

Biomechanical studies have demonstrated the superior strength of the posterior cervical transpedicular screw fixation compared with the standard posterior fixation techniques, such as facet screw fixation, lateral mass screw plate, or posterior wiring, particularly for multilevel fixation.[1,2] Several reports have suggested that pedicle screws can be safely used in the surgical treatment of degenerative, tumoral, infectious, and traumatic malalignment of the cervical spine.[3-6] Technical challenges encountered during transpedicular screw fixation involve great individual variation in pedicle location, dimension, and angulation between cervical levels or even at the same level.[7-9] Several techniques have been proposed to approach the exact pedicle location without any injury to vital structures such as the vertebral artery and/or nerve roots.[3,4,10] These include bony landmarks, funnel technique, mini-laminotomy technique, and certain selected entrance points defined at the quadrants of the articular mass with measured medial angulation of 25°–45°.[1,2,8,10-12] Currently, computer-assisted navigation systems are being increasingly used to minimize fixation failure in the operating theater.[13]

The posterior cervical transpedicular screw technique provides the strongest resistance to pull-out forces compared with other posterior cervical fixation systems. Since its first use by Abumi in 1994,[7] many surgeons have practiced it, developed procedural improvements, and compared results.[5,10,14] A cervical pedicle screw has not only ensured shorter instrumentation with sagittal correction but also simultaneously achieved posterior decompression and reconstruction,[9,15] which has led to the use of anatomical landmarks, funnel technique with palpation of the medial, superior

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pedicle walls, or direct visualization using laminotomies and computed tomography (CT)-assisted navigation systems.[1,2,10,11,14,16] Reported accuracy rates for cervical pedicle screw fixation range between 16.8% and 97%,[2,8,11] and neurovascular injury remains a major concern in the use of this technique.[3,5,6,17]

Thus, the purpose of this study was to eliminate risk factors that prevent accurate screw positioning using the mini-laminotomy technique and to assess its feasibility in clinical settings with a wide range of pathologies, including traumatic Hangman's fractures and rheumatoid basilar invaginations.

Materials and Methods

We retrospectively evaluated 40 patients who underwent the mini-laminotomy technique with posterior cervical transpedicular screw fixation in our clinic between January 2014 and March 2017. The study population comprised 27 males (67.5%) and 13 females (32.5%) aged 15–80 years (median, 51.5 years), in whom 227 cervical pedicle fixations were performed [Supplementary Table 1]. Informed consent was obtained from the patients for enrollment and use of their data for analysis and publishing, along with requisite institutional approval for the study and its publication.

Surgical indications observed were trauma in 18 patients (45%), degenerative disease (cervical spondylotic myelopathy) in 19 (47.5%), spinal infection in 2 (5%), and basilar invagination due to systemic rheumatoid disease in 1 (2.5%). In the 18 trauma patients, 14 short-segment (1–2 levels), and 4 long-segment (≥3 levels) posterior cervical instrumentation and fusion procedures were performed. In one trauma patient, with a Grade 4 flexion–distraction type of injury, anterior cervical discectomy and anterior plate–screw fixation procedure were also simultaneously considered to enable a 360° fusion. In two other multiple trauma patients, additional T12 and L1 burst fractures were managed during the same surgical session. The mini-laminotomy technique was used in all patients to insert, direct, and exactly position the screw at the pedicle, and the perforations were classified as medial or lateral and graded.

Preoperative assessment and surgical technique

All patients underwent preoperative CT and magnetic resonance imaging of the entire spinal column to identify additional anterior or posterior multilevel/compartment instability and/or injuries. The CT scans were used to estimate pedicle length, width, diameter, sagittal/axial trajectory angles, and bone qualities (compact or cancellous bone) for surgical planning. Required screw lengths were measured using CT such that they could reach the anterior one-third of the vertebral body when completely tightened.

For surgery, the patients were placed in the prone position with the head fixed. A standard median skin incision was made, and the posterior paravertebral muscles were widely and laterally dissected to fully expose the facet joints. Pedicle entrance points were made such that they were 1–2 mm lateral to the midpoint of the superior articular process [Figure 1]. Before screw insertion, mini-laminotomies were opened toward the superomedial edge of the lamina, which then proceeded to the inferior articular process. The superomedial edge of the lamina was preferred for this procedure because of its relatively safe distance from neurovascular structures. The inferior border of the superior lamina and the superior border of the inferior lamina were excised using a 1–2-mm Kerrison rongeur. The medial and superior borders of the pedicle were identified using a blunt-/ball-tipped microhook, and the type of bone tissue within the pedicle, as determined in the preoperative CT, was used to guide the surgeon's approach to establishing the screw's trajectory. In sclerotic bone, the cortex was perforated using a 1-mm high-speed diamond burr, tapped with the free hand, and drilled with a 1-mm drill groover at a medial angulation of 25°–45°. However, a blunt pedicle probe was preferred for cancellous bone, and the trajectory was kept as close as possible to the medial wall of the pedicle as it is the strongest. Screw diameter was decided on the basis of preoperative CT scans (mean, 3.5 mm). The sagittal trajectory was guided using biplanar fluoroscopy during the procedure. Axial angles were medially directed according to the direction of the pedicle felt by mini-laminotomy. To avoid iatrogenic neural injury before posterior decompression, proper rods were placed and attached to the screws. Neural tissue was protected by inserting hemostatic materials at the planned surgical site of screw insertion. Otogenic bone grafts obtained from the patients' spinous processes and laminae were used for fusion, but allogenic bone grafts were used when no decompression was performed.

Postoperative radiographic analysis

Postoperative cervical three-dimensional (3D)-CT scans were performed for all patients to evaluate pedicle

Figure 1: Pedicle entrance points, 1–2-mm lateral to the midpoint of superior articular process

screw positions. Perforations were graded as Grades 0–3 [Figure 2], wherein Grade 0 was defined as the screw positioned within the walls of the pedicle with cortical perforations [Figure 2a], Grade 1 as <25% of the screw penetrating the pedicular cortex and no neurovascular contact [Figure 2b], Grade 2 as >25% of the screw penetrating the pedicular cortex but no neurovascular contact [Figure 2c], and Grade 3 as Grade 2 perforation but with neurovascular contact, that is, >50% perforation [Figure 2d].

Results

Cervical transpedicular fixation was performed using 227 screws in 40 patients. Among these, 48 screws were at the C3 level, 49 at C4, 60 at C5, 50 at C6, and 20 at C7, and 205 (90.3%) of the 227 screws were graded as being properly positioned [Grade 0 and Grade 1; Table 1]. However, 22 screws (9.69%) were improperly positioned [Grade 2 and Grade 3; Table 2] and 43 (18.09%) had perforated the pedicle [Table 3].

The improperly positioned screws did not cause any additional neurovascular injury or deficit. Postoperative cerebrospinal fluid leak in three patients was successfully managed using an external lumbar drainage.

The details of a representative case are as follows: A 36-year-old female who was involved in a motor vehicle accident approximately 3 months ago presented with intractable neck pain [Figure 3]. Neurological examination was unremarkable, but radiological workup revealed a C4–C5 dislocation that was rectified by a posterior C4–C5–C6 cervical pedicular fixation and reduction. No neurovascular injury was evident during follow-up.

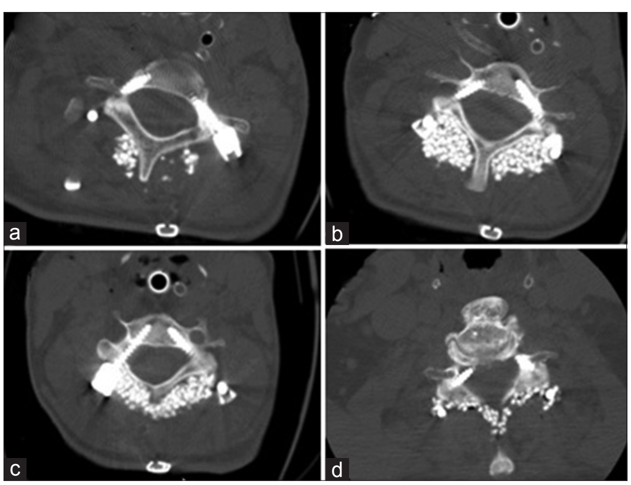

Figure 2: (a) Grade 0, screw is within the walls of the pedicle and there are cortical perforations. (b) Grade 1, <25% of the screw has penetrated the pedicular cortex and there is no neurovascular contact. (c) Grade 2, >25% of the screw has penetrated the pedicular cortex, but there is no neurovascular contact. (d) Grade 3, grade 2 perforation with additional neurovascular contacts, that is, >50% perforation

Discussion

The mini-laminotomy technique used in this study was first described by Jo *et al*.[3] It is performed under lateral fluoroscopic guidance and is based on the depth of the lateral mass whose angle is measured using preoperative CT. A 1-mm cutting burr was used to excise the outer

Table 1: Screw accuracy rates according to cervical levels

Level	Right position		Wrong position	
	Grade 0	Grade 1	Grade 2	Grade 3
C3	40	4	3	1
C4	41	4	2	2
C5	51	4	5	-
C6	37	9	1	3
C7	15	-	3	2
Total (%)	184 (81.05)	21 (9.25)	14 (6.16)	8 (3.52)
	205 (90.3)		22 (9.69)	
	Total 227 posterior cervical pedicule screws			

Table 2: Number of malpositioned screws according to cervical levels

Level	Grades 2-3 (malpositioned)	
	Right	Left
C3	1 (lateral)	3 (medial)
C4	1 (medial)	2 (medial), 1 (lateral)
C5	3 (2 lateral, 1 medial)	2 (medial)
C6	4 (1 lateral, 3 medial)	-
C7	2 (medial)	3 (medial)
Total (%)	11 (4.84)	11 (4.84)

Table 3: Number of perforated pedicles according to cervical levels

Level	Total number of cervical pedicle screws	Total number of pedicles perforated
C3	48	8
C4	49	8
C5	60	9
C6	50	13
C7	20	5
Total (%)	227	43 (18.9)

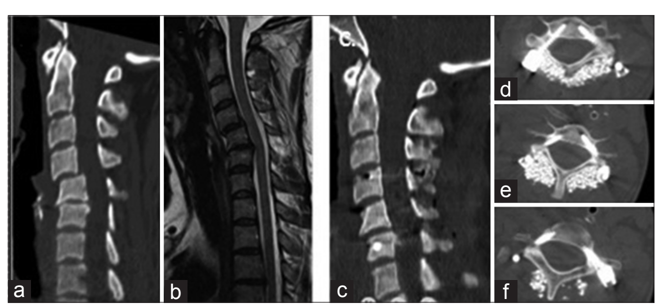

Figure 3: (a) Cervical C4–C5 dislocation on sagittal image of BT: Computed Tomography. (b) Magnetic resonance imaging; (c) Sagittal; (d-f) axial images of posterior cervical C4–C5–C6 pedicular screw fixation

cortex of the lateral mass above the pedicle entrance, slightly lateral to the center of the facet and close to the posterior margin of the superior articular surface. The convergence angle measured was used for visualizing the entrance point of the pedicle. The insertion point itself is in the reddish cancellous bone. A mini-laminotomy was used to obtain visual and tactile reference points for the orientation of the superior and medial walls of the pedicle. The ligamentum was dissected from the inferior aspect of the superior laminar arch using a small, curved curette. Next, the inferior aspect of the superior lamina and superior aspect of the inferior lamina were excised using a 1-mm cutting burr followed by 1-mm and 2-mm Kerrison punches. The ball-tip hook was used to identify the medial and superior walls of the pedicle before screw insertion.

Abumi *et al*.[15] reported that 10 of 190 (5.3%) pedicle screws perforated the pedicle walls, whereas in a subsequent clinical series, they reported that 45 of 669 (6.7%) screws significantly perforated the pedicle.[9] Ludwig *et al*.[2] compared the reliability of three surgical techniques for pedicle screw fixation using human cadavers, and they support the use of the laminotomy technique for better visual and tactile accessibility to the cervical pedicle. In the same two-part study, they also postoperatively evaluated and categorized cortical breach as either critical or noncritical and instrumented 120 pedicles using morphometric data (Group 1), laminotomy (Group 2), or computer-assisted guidance (Group 3). In Group 1, only 12.5% of the screws were placed exactly within the pedicle, whereas there were 65.5% critical and 21.9% noncritical breaches of the pedicle. In Group 2, 45% of the screws were accurately placed within the pedicle, whereas 39.6% had critical and 15.4% had noncritical breaches. Finally, in Group 3, 76% of the screws were accurately placed, whereas 10.6% had critical and 13.4% had noncritical breaches. They also reported misplacement with critical breach in 18% of the screws while using frameless stereotactic guidance, which reduced to 12% after probing and tapping the pedicle.

Panjabi *et al*.[9] published a pioneering 3D anatomical study on pedicle height (sagittal diameter), width (transverse diameter), length, and angles for each cervical segment, which form the basis for the currently accepted values of standard screw diameter and length(s). They have specifically demonstrated that the largest pedicle dimensions are found at C2 and the smallest at C3 levels and that from C3 to C7, the transverse pedicle diameter increases from 5.1 to 6.6 mm and the sagittal diameter increases from 6.7–7.6 mm, respectively.

Abumi *et al*.[7] have described only three cortical breaches, as visualized using CT, in a clinical series of 58 patients treated with pedicle screws. They used a screw insertion point at the posterior cortex of the lateral mass that was 1-mm lateral to the center of the articular mass and close to the caudal edge of the superior articular facet with a medial angulation of 30°–40°. Axial orientation was decided based on preoperative CT scan, whereas sagittal angular orientation was achieved by intraoperative fluoroscopy.

Karaikovic *et al*.[16] placed screws according to the location of the lateral incisura at the lateral superior quadrant of the lateral mass at each cervical level, whereas An *et al*.[18] performed a cadaver study that draws attention to the unique morphology of the C7 and T1 pedicle diameters (transverse diameter, 6.9; sagittal diameter, 7.5 mm; and medial angulation 34° at C7).

Richter *et al*.[6] reported 92% of proper screw fixation in C3–C4 pedicles using image-guided drilling of 2.5-mm holes in human cadaveric specimens. The cortical and critical breaches were 3.1% in this series. Rath *et al*.[19] reported similar results in 116 pedicles. Kotil *et al*.[12] showed that screws were correctly positioned in 205 of 210 pedicles (97.6%), whereas noncritical lateral orientation was detected in three pedicles (1.4%). Among these, two screws (one each in two patients) were inappropriately positioned (0.9%, Grade 3) as they were unilaterally and directly in the vertebral foramen but did not interrupt circulation. Our results fall in the acceptable range as 90.3% of the screws were properly placed in 205 subaxial pedicles.

Conclusion

Cervical pedicle screws demonstrate the best results in single-stage posterior fusion for various pathologies of the subaxial cervical vertebrae. The mini-laminotomy technique is the treatment of choice among experienced surgeons as it has negligible risk of neurovascular injury during transpedicular screw fixation without morbidity or mortality.

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Conflicts of interest

There are no conflicts of interest.

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