Single Reference Point for Lumbar Pedicle Screw Insertion in Degenerative Spine: A Technique and Case Series Analysis

ABSTRACT

Aim: To describe a single reference entry point technique for lumbar pedicle screw fixation in degenerative spine and to assess its accuracy in a retrospective case series.

Materials and methods: We describe a simple technique for lumbar pedicle screw insertion which is based only on a single reference point, the superior half of transverse process. We retrospectively evaluated the computed tomography (CT) images for any pedicle wall violation with screw of all the patients who were treated by this technique who also had undergone a postoperative CT scan during the study period. A team of three evaluators of different experience and training, including one spine consultant, one spine fellow, and a musculoskeletal radiologist independently studied the CT pictures and pedicle wall violations graded using a previously described grading system, and the data were analyzed by simple percentages.

Results: A total of 240 patients had undergone lumbar pedicle screw fixation with this new technique during the study period, of which 36 had undergone a CT scan. A total of 164 lumbar pedicle screws were assessed. Pedicle wall violations were recorded in 9.7, 8.5, and 12.2% of the screws respectively, by consultant spine surgeon, radiologist, and spine fellow. Most of the breaches were of grade I severity as per all the three observers. There were no grade IV breaches.

Conclusion: The single reference point entry for pedicle screws in the lumbar spine described was as accurate as other well-established techniques with comparable pedicle malposition rates.

Keywords: Degenerative spine, Lumbar pedicle screw insertion, Pedicle wall violation, Single reference entry point, Transverse process.


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Conflict of interest: None

INTRODUCTION

Pedicle, being the meeting point of the posterior and anterior components of the vertebra, is the force nucleus. Fixation through the pedicle gives the strongest fixation on a vertebra. However, the structure of the pedicle is really complex. It is inclined in all the three planes (sagittal, coronal, and axial) and, it has craniocaudal, transverse, and least diameters.\(^1,2\) In a coronal section, the craniocaudal measurement of the pedicle cross-section is much more than the mediolateral one, with a narrow isthmus comparable to a dumb-bell.\(^2,3\)

Since the 1940s, vertebral screw and pedicle screw fixation have evolved and become increasingly popular among spine surgeons. Toumey in 1943 and King in 1948 provided the first descriptions of use of bone screws. King described the placement of screws parallel to the inferior border of the lamina and perpendicular to the facet joint. In 1949, Thompson and Ralston reported a pseudoarthrosis rate of 55% using similar technique. Boucher in 1959 and Pennel in 1964 described a method using longer stainless steel screws placed through the facet joint into the pedicle and vertebral body. Boucher was the first to use pedicle screws.\(^4\) In 1970, Buck first described the use of screw fixation in the direct repair of isthmic lytic defects in 16 patients with spondylolisthesis.

In 1970, Roy-Camille guided by Judet described the use of posterior plates with screws positioned sagittally through the pedicles and articular process. Louis and Maresca subsequently modified their techniques which were later modified by several authors. Transpedicular screws quickly were modified to be used in several other situations.

A variety of different techniques, such as freehand, fluoroscopy-guided, and stereotactic navigation-guided pedicle screw insertion are used for the placement of lumbar pedicle screws. The most common technique remains the conventional use of posterior anatomic landmarks (freehand) with or without fluoroscopic assistance. Traditionally, two reference lines (vertical and horizontal craniocaudal and mediolateral) have been used to identify the pedicle entry point. The vertical reference line varies in different studies from Roy-Camille et al,\(^5\) Magerl,\(^6\) and Weinstein et al\(^7\) or Su et al.\(^1\) All these reference lines will...
be affected by degenerative spine conditions where there may be changes in the facet orientation and there will be facet hypertrophy. Traditionally, the horizontal reference line is the center of the transverse process. Study by Su et al\(^1\) had noted that the center of the pedicle corresponds to a little above the mid-transverse process. Many studies have reported complications following transpedicular instrumentation.\(^8-11\) Inferior and medial penetration compromises the nerve roots, whereas superior and lateral aspects of the pedicles are relatively safe. Inserting the pedicle screw is more difficult in degenerative spine with facet hypertrophy, since most of the techniques for freehand pedicle screw fixation has lateral border of the facet joint as an important reference point. It is important to note that the base of the facet and the transverse process are little affected by the degenerative process as the facet capsule is attached to the lateral ridge of the superior articular process. On evaluating the coronal sections of the lumbar spine CT scans, it was found that the superior half of the base of the transverse process had a more safe relation with the pedicle, as far as screw entry point is considered. The study by Robertson and Stewart,\(^12\) as early as year 2000, also showed that the midline of the transverse process has a more caudal relationship with the pedicle (it does not correspond to the midpoint of the pedicle in the sagittal plane). A technique was gradually evolved by the corresponding author based on these facts and could be used safely even in cases where the facet is severely hypertrophied.

**MATERIALS AND METHODS**

**Technique of Pedicle Screw Insertion**

After general anesthesia with endotracheal tube and positioning prone, standard midline exposure was used, taking care to expose the base of the transverse process, where it joins the base of the superior articular process. It is not necessary to expose the tip of the transverse processes. The posterior surface of the transverse process has a ridge running medially laterally from its base. The base of the transverse process immediately cranial to this ridge is the reference point. The starting point is on the base of the superior articular process immediately posterior to this reference point (Figs 1 to 4). A 6 mm diamond-tipped burr (Midas Rex Legend Stylus) is used to open the cortex, making a window of about 4 to 5 mm. The whole of the burr is not introduced inside, as a larger cortical defect may lead to lesser pull-out strength. A pedicle sound or awl is used to create the screw track. Curved or straight sound can be used, sometimes interchanging depending on the local anatomical variation. The main point is that the sound tip is allowed to freely

![Fig. 1: Saw bone model depicting the entry point for pedicle screw and its relation to the superior half of the transverse process. Note that the entry point is not at the junction of facet and transverse process, but a little posterior on the superior facet](Image)

![Fig. 2: Intraoperative view depicting the entry of the pedicle screw and its relation to the superior half of the transverse process](Image)

![Fig. 3: Coronal CT section with the pedicle screw and its relation to the superior half of the transverse processes](Image)
fall through the pedicle isthmus into the vertebral body by gentle rocking or twisting movement, this will ensure that the pedicle walls are not penetrated. The angle at which the screw must be entered is about 10 to 25° from the midsagittal plane, the angle is increased from the upper lumbar levels to the lower levels. Tapping is done depending on bone quality, screw length measured, and then the screw is introduced. We mostly use a polyaxial screw for easiness of the later rod insertion. Difficulties are expected at the L5 level, where the highest angulation from the midline is needed and a high iliac crest prevents that. Another difficulty is where there is excessive forward sloping of the transverse process. Sometimes, the facet overhang hides the entry point, and in that case, a little drilling out of the lateral part of the facet may be required.

Analysis

A retrospective analysis was done of all the patients who had undergone lumbar pedicle screw fixation from January 2013 to August 2015 using the new technique who also had underwent a postoperative CT scan for any pedicle wall violation with the screw. Informed consent was obtained from all the patients prior to the beginning of the study for using the data of their cases. The inclusion criteria were any patient who underwent a lumbar pedicle screw fixation during the above period with a lumbar spine CT scan done any time in the postoperative period. Any patient for whom postoperative CT was not done was excluded. Postoperative CT scans are not routinely advised for all patients as to avoid unnecessary radiation, due to cost concerns, and the difficulty to motivate a patient without any symptoms for a scan. The CT scans were taken only in those who had complaints of back pain or leg pain postoperatively or if there was any suspicion of a suboptimal fixation either during surgery or as indicated in postoperative X-ray imaging. The case records were analyzed and then the CT image analysis was done by an experienced spine surgeon, a musculoskeletal radiologist, and a spine fellow. Plain CT scans were done by using a 64-slice CT (GE light speed VCT, General Electricals, USA), taking 0.6 mm sections. The CT pictures were analyzed using Advantage Work Station Volume Share 4 (GE) and Centricity PACS–IW (GE) for any pedicle wall violation. We used multiplanar reformed image (axial, sagittal, coronal/oblique) sequences, and metal artifacts were reduced using hardware (volume rendering) with enhanced constructs.

Pedicle breach in the medial, lateral, superior, and inferior aspects was analyzed and graded. The pedicle wall violations were graded by accepted definitions: Grade I (0–2.0 mm), grade II (2.1–4.0 mm), grade III (4.1–6.0 mm), and grade IV (6.1–8.0 m).12,13

RESULTS

A total of 240 patients underwent lumbar spine surgery with the new technique during this period. Thirty-six patients had undergone a postoperative CT scan providing 164 lumbar pedicle screws for assessment. There were a total of 9.7, 8.5, and 12.2% pedicle breaches as per the assessment done by spine consultant, radiologist, and fellow respectively (Table 1).

In this study, there was no grade IV breach of the pedicles. Most of the breaches belong to grade I in all

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<th>Table 1: Pedicle screws position assessed by CT scan</th>
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three assessments. Grade II breaches were seen in 1.2, 0, and 1.2%, and grade III breaches were seen in 1.2, 2.4, and 0.6% as per spine consultant, radiologist, and fellow assessment respectively (Table 2).

Most of the pedicle wall violations had happened in the very early part of the study and none of the patients in the pedicle wall violation group had any clinical symptoms attributable to screw malposition. There was no neurovascular injury in any case. Although the slipping of the drill laterally led to transverse process fracture in one case, it had no clinical consequence.

DISCUSSION

A simple technique is described here for lumbar pedicle screw insertion. The screw placement accuracy was checked in patients using high-quality CT scans. The CT scan in multiple planes (combination of axial, sagittal, and coronal) is a very accurate method for assessing pedicle screws postoperatively.14,15 Concurrence of three observers of differing experience is obtained to increase the accuracy of the reporting. Our results are comparable with the available literature. Screw malpositioning rates that have been reported vary between 28.1 and 39.9% in clinical studies with postoperative CT evaluation and between 5.5 and 31.3% in cadaver studies.13,16,17 The present technique utilizes a single reference point which is unaffected by facet hypertrophy and hence, could be of particular value in degenerative spine. The facet joint is not violated, this is even more important at the cranial end of the fusion segment. The image intensifier was used only for level verification and final confirmation, and so radiation exposure was minimal. In situations where there was an obvious landmark like spondylolysis or listhesis, image was used only for final confirmation.

A recent study, Oh et al18 compared the success rates of various freehand pedicle screw fixation techniques which were found to be 93.5 to 99.1%. All these traditional methods used facet joint as important landmark which is altered in degenerative conditions of spine. In our study, we have come up with a single reference point which is useful in degenerative spine conditions where anatomy is totally altered due to facet hypertrophy.

There are a few limitations for this technique and the study. The technique requires exposure of the base of the transverse process and hence, is more time-consuming and more blood loss may be expected. Damage to the branches of the dorsal rami may cause more muscle denervation.19 On the contrary, the damage to medial branch of the dorsal rami may be advantageous in a patient with facetal arthritis and back pain, as the facet origin pain will be eliminated. The more medial angulation required can be troublesome at times, especially in the L5 pedicle, with a high iliac crest. But the more medial angulation will increase the construct strength by longer screws and the locking effect of nonparallel screws will resist lateral shifting of upper vertebra even without transverse connectors.20

The study is retrospective and the patients were apparently not randomly selected. In effect, randomization was done by submitting only the patients with symptoms for a CT study. Submitting patients without any symptoms, who are completely relieved after the surgery, for a scan has practical and ethical difficulties. Moreover, the main purpose of this article is reporting the new technique. A large prospective study using larger number of patients is on the way.

CONCLUSION

Single reference point entry for pedicle screws in the lumbar vertebrae is as good as other well-described techniques with comparable pedicle screw positioning accuracy. This technique may be very useful in the case of altered facet anatomy due to degeneration in the lumbar spine.

REFERENCES