SURGICAL TECHNIQUE

Isthmus-guided Cortical Bone Trajectory for Pedicle Screw Insertion

Koichi Iwatsuki, MD, PhD, Toshiki Yoshimine, MD, PhD, Yu-ichiro Ohnishi, MD, PhD, Kosi Ninomiya, MD, Toshika Ohkawa, MD, PhD

Department of Neurosurgery, Osaka University Medical School, Osaka, Japan

Herein is described cortical bone trajectory (CBT), a new path for pedicle screw insertion for lumbar vertebral fusion. Because the points of insertion are under the end of the inferior articular process, and because the screws are inserted toward the lateral side, there is less soft tissue development than with the conventional technique; the CBT technique therefore enables less invasive surgery than the conventional technique. However, it has some drawbacks. For example, in the original CBT approach, the points of insertion are in the vicinity of the end of the inferior articular process. Because this joint has been destroyed in many patients who have indications for intervertebral fusion surgery, it is sometimes difficult to use it as a reference point for screw insertion location. With severe lateral slippage, the screw insertion site can become significantly dislocated sideways, with possible resultant damaging to the spinal canal and/or nerve root. The CBT technique here involved inserting the screws while keeping clear of the intervertebral foramen with the assistance of side view X-ray fluoroscopy and using the end of the inferior articular process and the isthmus as points of reference for screw location.

Key words: Cortical bone trajectory; Isthmus guide; Lumbar fusion

Introduction

Recently, pedicle screws have been increasingly used in management of a number of lumbar disorders. However, implant fixation in patients with osteoporosis and poor bone mineral density currently poses a major challenge¹. In patients with particularly poor bone quality, screw loosening can result from purchase reduction^{2,3}. In a study of pedicle screw insertion, Sterba *et al.* found that inserting screws perpendicular to the pedicle achieved greater pull-out strength than with the conventional standard technique, in which the screws are inserted toward the medial side⁴. More recently, cortical bone trajectory (CBT), in which pedicle screws are inserted slightly laterally, was reported by Santoni *et al.* With the CBT technique, the largest screw is inserted in a region of theoretically high bone density, enabling implant fixation without being reliant on the bone mineral density of the trabeculae, as with the conventional technique⁵. With the CBT technique, fixation to the bone cortex is achieved at four sites: the dorsal, postero-medial, and anterolateral sides of the pedicle, and the marginal

region of the vertebral body. The CBT technique is considered superior to the conventional technique, which involves fixation with trabeculae (Fig. 1). It has been shown that the resultant fixation strength is comparable to that achieved with the conventional technique, even when shorter and/or thinner screws than are used with the conventional technique have been used⁶.

However, the CBT technique has some drawbacks. For example, in the original CBT form of this technique, the insertion points are in the vicinity of the end of the inferior articular process. This joint has been destroyed in many patients in whom intervertebral fusion surgery is indicated; it is therefore sometimes difficult to use it as a reference point for screw insertion location. With severe lateral slippage, the screw insertion site can become significantly dislocated sideways, with possible resultant damage to the spinal canal and/or nerve root.

We have increased the safety of the CBT technique by inserting the screws while keeping clear of the intervertebral foramen with the assistance of lateral fluoroscopy, using the

Address for correspondence Koichi Iwatsuki, MD, PhD, Department of Neurosurgery, Osaka University, Medical School, 2-2 Yamadaoka, Suita, Osaka 565-0871, Japan Tel: 0081-6-68793652; Fax: 0081-6-68793659; Email: kiwatsuki@nsurg.med.osaka-u.ac.jp, rockmoon@mbn.nifty.com

Disclosure: The authors have no conflicts of interest to declare.

Received 10 May 2014; accepted 27 May 2014

Fig. 1 Arrow a: direction of screw insertion with the conventional technique. Arrow b: direction of screw insertion with the CBT technique. In both cases, the screw pass through many trabeculae.

isthmus as a reference point for screw location. We here propose isthmus-guided CBT for lumbar screw insertion.

Technique

To overcome the above drawbacks, we propose using the lateral margin of the isthmus and the superior margin of the intervertebral foramen as reference points for screw insertion points (modified CBT method, Fig. 2). With this approach to screw insertion, nerve root damage and screw deviations into the spinal canal are theoretically avoided, even in patients with severe intervertebral joint degeneration. This is achieved by exposing the lateral margin of the isthmus (unlikely to be influenced by any

degeneration) and inserting the screw at a point 3 mm medial to the lateral margin of the isthmus, with the superior margin of the intervertebral foramen as imaged by lateral fluoroscopy serving as the reference point for insertion on the craniocaudal axis and projecting 5-o'clock orientation in the left pedicle and 7-o'clock orientation in the right pedicle (Video S1).

We performed lumbar vertebral fusion surgery on four patients using the original CBT technique in January and February 2013 then, in March and April, we performed the same surgery on another four patients using the modified CBT technique. All eight patients had lumbar degenerative spondylolisthesis (Meyerding I) with spinal canal stenosis. All screws used were 4.5 mm in diameter and 25 mm in length (Zodiac, Alphatec Pacific, Tokyo, Japan). The number of screws used was 32 and 24, respectively. The screws did not cause dura mater damage, nerve root disorders, bone fractures, or any other unwanted phenomena. Each patient was examined for screw misplacements in which screws had not been appropriately inserted into the pedicle. The number of such deviations was 4/32 screws in the four patients treated by the original CBT technique (12.5%), and 1/24 screws in the four treated by the modified CBT technique (4.2%); confirming improved accuracy of screw insertion with the latter approach.

Discussion

The CBT technique is superior or equivalent to the conventional technique in the following four regards. First, the screws are inserted from the medial to the lateral side and from the caudal to the cranial side, and hence are directed away from the dura mater and nerve root. This reduces the incidence of nerve root disorders and postoperative neuritis. Second, because the starting point of insertion is positioned more medially than with the conventional technique, less soft tissue dissection and traction and a shorter skin incision are required. Particularly in the case of lower lumbar vertebrae, the requirement for extensive soft tissue dissection makes the

Fig. 2 Screw insertion points (red dots) in the modified CBT technique (our proposal). A screw is inserted in the vicinity of the inferior articular process from the dorsal side at a point 3 mm medial to the lateral margin of the isthmus. In side views, the superior margin of the intervertebral foramen serves as the reference point.

Fig. 3 Plain radiographs of a patient in whom pedicle screws have been inserted using the original CBT technique. The screw on the right side of the fifth lumbar vertebra was inserted medially (black arrows).

conventional technique much more invasive than the CBT technique. Third, because the medial branch nerve, which originates from the dorsal branch of the nerve root, runs in the vicinity of the mammillary process, this nerve is likely to be

injured in the conventional approach, in which that is the location of the insertion point⁷. This can be avoided in the CBT method. Fourth, with the conventional technique, screw fixation strength is basically dependent on pedicle trabeculae.

Fig. 4 CT images of the patient shown in Figure 3. The insertion point for the screw on the right side of the fifth lumbar vertebra is 6 mm medial to the lateral margin of the isthmus. The screw has been misplaced in the spinal canal.

(A) Axial CT. (B) Coronal CT. (C) Sagittal CT.

Fig. 5 Plain radiographs of a patient in whom screws have been inserted using the modified CBT technique.

Fig. 6 CT images of the patient in Figure 5. The screws have been appropriately inserted. Compared with the case shown in Figure 4, the insertion point for the screw is more lateral and the angle is appropriate in this case. (A) Axial CT. (B) Coronal CT. (C) Sagittal CT.

From the viewpoint of trabeculae, the CBT technique is comparable to the conventional technique; screws pass through almost the same amount of trabeculae, and equivalent fixation forces can be expected (Fig. 1).

On the other hand, the CBT technique has some risks. With the original CBT technique, screw insertion at inappropriate angles could cause nerve root disorders because the insertion points are positioned just above the nerve root. If the screw diameter is too large for the pedicle, bone fractures are likely to result. Furthermore, pedicle screws are sometimes inserted at inappropriate points in patients with severe degeneration, as shown in Figures 3 and 4. In the indicated case, the insertion point for the screw on the right side of the fifth lumbar vertebra was 6 mm medial to the lateral margin of the isthmus. This screw was misplaced in the spinal canal. On the other hand, with the modified CBT technique, almost all screws are inserted appropriately (Figs 5 and 6). The only deviation detected was of a screw that escaped lateral to the ventral side of the pedicle.

The modified CBT technique is not superior to the original CBT method in the following aspects; because the screws used are shorter and their insertion points closer to the cranial side than with the original CBT technique, there is less bone cortex in contact with the screws. Although this would seem to influence fixation strength, to date we have encountered no problems with regard to postoperative fixation; however, the duration of follow-up is short.

In recent years, screws have been increasingly used in vertebral fusion surgery. Techniques for safe screw insertion are required. We consider the isthmus-guided CBT described here to be a safe technique.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Video S1. Isthmus-guided cortical bone trajectory for pedicle screw insertion

References

1. Wittenberg RH, Shea M, Swartz DE, Lee KS, White AA 3rd, Hayes WC. Importance of bone mineral density in instrumented spine fusions. *Spine (Phila Pa 1976)*, 1991, 16: 647–652.
2. Okuyama K, Sato K, Abe E, Inaba H, Shimada Y, Murai H. Stability of transpedicle screwing for the osteoporotic spine. An *in vitro* study of the mechanical stability. *Spine (Phila Pa 1976)*, 1993, 18: 2240–2245.
3. Cho W, Cho SK, Wu C. The biomechanics of pedicle screw-based instrumentation. *J Bone Joint Surg Br*, 2010, 92: 1061–1065.
4. Sterba W, Kim DG, Fyhrie DP, Yeni YN, Vaidya R. Biomechanical analysis of differing pedicle screw insertion angles. *Clin Biomech (Bristol, Avon)*, 2007, 22: 385–391.
5. Santoni BG, Hynes RA, McGilvray KC, et al. Cortical bone trajectory for lumbar pedicle screws. *Spine J*, 2009, 9: 366–373.
6. Matsukawa K, Yato Y, Kato T, Imabayashi H, Asazuma T, Nemoto K. *In vivo* analysis of insertional torque during pedicle screwing using cortical bone trajectory technique. *Spine (Phila Pa 1976)*, 2014, 39: E240–E245.
7. Bogduk N, Long DM. The anatomy of the so-called “articular nerves” and their relationship to facet denervation in the treatment of low-back pain. *J Neurosurg*, 1979, 51: 172–177.