SURGICAL TECHNIQUE

Transpedicle Osteotomy Positioning in Pedicle-lengthening Laminoplasty

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Pedicle-lengthening laminoplasty is a new minimally invasive technique for surgical treatment of lumbar spinal stenosis. The procedure is performed with the assistance of fluoroscopy and involves creating a pedicle passage, transpedicle osteotomy from inside the pedicle passage and lengthening it by using an implant bilaterally to enlarge the spinal canal and neural foramen. A critical component of the procedure is the precise determination of the osteotomy site on the pedicle. The objective of this study was to examine *in vitro* whether fluoroscopic positioning could be used to guide the osteotomy and to define the cutting site in the pedicle-lengthening laminoplasty in relation to the posterior vertebral line. It was found that the osteotomy site was from 2.0 to 3.5 mm posterior to the posterior vertebral line. The maximum difference between the measured value and that theoretically simulated on 3-dimensional (3D) computed tomography reconstruction was 0.3 mm. The spinal canal cross-sectional area was significantly enlarged after pedicle-lengthening. Accurate placement of the osteotomy is critical in pedicle-lengthening laminoplasty. Guiding the positioning of the osteotomy based on the posterior vertebral line images provides satisfactory accuracy, suggesting a possible clinical application for our technique; however, further verification *in vivo* is needed.

Key words: Laminoplasty; Lumbar; Pedicle-lengthening; Stenosis

Introduction

Pedicle-lengthening laminoplasty is a new minimally invasive technique for surgical treatment of lumbar spinal stenosis. The procedure is performed with the assistance of fluoroscopy and involves creating a pedicle passage, transpedicle osteotomy from inside the pedicle passage and lengthening it using an implant bilaterally to enlarge the spinal canal and neural foramen (Fig. 1)¹⁻⁴. Because it largely preserves the normal anatomical structures, the procedure reduces major bleeding, complications, perineural scarring and postoperative instability. A critical component of the procedure is the precise determination of the osteotomy site; a technique for achieving this has not been previously been described¹⁻⁴. The purpose of this study was to assess whether a fluoroscopic positioning method could be used to guide the osteotomy and to define the cutting site.

Materials and Methods

The experiment was performed on cadaveric vertebrae (L₃, L₄ and L₅, *n* = 6, average age 61 years). The procedure included creation of pedicle passages, transpedicle osteotomy, and pedicle-lengthening and fixation. Under lateral C-arm fluoroscopy, a guide pin was driven through one of the pedicles into the vertebral body to create a 5 mm diameter passage to near the front of the vertebral cortex.

A specially designed bone saw was then deployed into the passage to perform the transpedicle osteotomy from the inside out (Fig. 2). A targeting transecting site 2 mm posterior to the posterior vertebral body line was chosen⁵. A one-line sign technique was used to determine the posterior vertebral body line radiographically⁶. With the aid of fluoroscopic guidance and tactile feedback, the surgeon manually operated and controlled the saw until the pedicle had been cut

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Fig. 1 Decompression and enlargement of the spinal canal by pedicle-lengthening laminoplasty.

circumferentially. After completion of the first pedicle transection, the procedure was repeated on the contralateral pedicle.

After the pedicles had been transected, pedicle-lengthening implants (Fig. 3) were screwed into the pedicle passages. The implants lengthened a total of 3 mm, leading to expansion of the gap at the osteotomy site and an increase in the area of the spinal canal (Video S1). Three-dimensional (3D) computed tomography (CT) reconstruction was used to simulate the osteotomy and calculate the enlargement of the spinal canal required.

Fig. 2 The manual bone saw used in the osteotomy. (a) Retracted position. (b) Partially deployed position. (c) Fully deployed position.

Fig. 3 The screw implant used in pedicle-lengthening.

The results are presented as mean and standard deviation. Analysis of variance was used to analyze differences between the tested groups ($P < 0.05$).

Results

Each osteotomy site was determined using the posterior vertebral line as a guide (Fig. 4). The distance between the osteotomy site and the posterior vertebral line ranged from 2.0 to 3.5 mm; this did not differ significantly between L₃, L₄ and L₅ or between the left and right pedicles (Fig. 5).

The actual measured values were in agreement with the values theoretically simulated on the 3D CT reconstruction models. The maximal difference between measured and simulated values was 0.3 mm.

The spinal canal cross-sectional area at the level of the middle vertebrae was significantly enlarged after pedicle-lengthening (Fig. 6). The area increases were 16.4% at L₃ ($P < 0.05$), 15.6% at L₄ ($P < 0.05$) and 12.7% at L₅ ($P > 0.05$).

Fig. 4 A lateral image of the osteotomy site showing its relationship to the posterior vertebral line.

Discussion

This study has demonstrated that, under intra-operative fluoroscopy, the correct osteotomy site can be determined as 2 mm from the posterior vertebral line. This site allows circumferential osteotomy of the pedicle with an accuracy of 0.3 mm. Correspondingly, the spinal canals were enlarged by 16.4% at L₃, 15.6% at L₄ and 12.7% at L₅, respectively.

Lumbar spinal stenosis causes back and/or leg pain, limiting affected patients' ability to stand and ambulate. The most frequent cause is degenerative changes, including narrowing and bulging of the intervertebral disc, hypertrophy of the facet joints, thickening and buckling of the ligamentum flavum and/or degenerative spondylolisthesis. Conservative treatments are usually effective in patients with mild stenosis^{7,8}. However, in severe cases, surgical decompression may be necessary in to achieve better clinical outcomes⁹. However, traditional open decompression surgery with or without lumbar fusion has the risks of significant blood loss, wound infection, iatrogenic instability, perineural scarring, medical complications and prolonged recovery¹⁰. In addition, the pain relief achieved by open decompression may diminish over time, requiring further, more complex revision surgery¹¹.

Pedicle-lengthening laminoplasty provides a novel surgical strategy for enlarging the spinal canal and neural foramen with a minimally invasive approach. In theory, the advantages of this procedure over traditional open lumbar decompression include the lack of removal of normal anatomical structures and the reduced risk of major bleeding, infection and medical complications^{12,13}. The procedure also minimizes disruption of neurologic and ligamentous structures, leading to reduced perineural scarring and preserved postoperative stability. Provided bone healing occurs at the osteotomy site, the canal remains permanently enlarged. Pedicle-lengthening laminoplasty may therefore be indicated in patients with significant medical comorbidities who are poor candidates for open surgery.

Although pedicle-lengthening osteotomy is still in its early stage, a few studies have demonstrated promising outcomes. Previous *in vitro* studies have shown significant increases in spinal canal cross-sectional area and the aperture

Fig. 5 Distance of osteotomy site from posterior vertebral line.

Fig. 6 Enlargement of the spinal canal by pedicle-lengthening laminoplasty.

of neural foramina^{1,2}. For example, lengthening of 4 mm can enlarge the spinal canal area of L₄ by 22% and the neural foramina of L₄/L₅ by 71%. Kinematic measurements have indicated that the overall and segmental kinematics are not significantly altered because the signatures of the intact and lengthened states are similar for all motion pairs³. Clinical outcomes on 19 pilot patients have shown encouraging 12 month results⁴. No operative complications occurred; however, there were four adverse events during follow-up. Significant improvement was found in scores on the following outcome scales: Oswestry Disability Index, Zurich Claudication Questionnaire, 12-Item Short-Form Health Survey and Visual Analog Scale. On imaging, no evidence of device subsidence, migration, breakage or heterotopic ossification was found. According to thin-slice CT, healing of the osteotomy site had occurred in all patients by 6-month post-operatively. The average increase in the area of the spinal canal was 15%.

The drawbacks of this technique should also be discussed. First, intraoperative fluoroscopy involves radiation exposure for the patient and operative staff. Methods of limiting intraoperative fluoroscopy usage, improving protection from radiation, or using computer-assisted image guidance should be further developed. Second, the procedure is technically demanding. Manual control of the bone saw requires experience, tactile feedback and caution. Intraoperative neuromonitoring may be necessary to prevent neurological injury.

In conclusion, accurate placement of the osteotomy is critical in pedicle-lengthening laminoplasty. The study describes a technique for guiding osteotomy positioning based on posterior vertebral line images. This technique provides satisfactory accuracy, suggesting a possible clinical application; however, further verification *in vivo* is needed.

Supporting Information

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

Video S1 Transpedicle osteotomy positioning in pedicle-lengthening laminoplasty.

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