Bicortical Laminar Screws for Posterior Fixation of Subaxial Cervical Spine: A Radiologic Analysis With Computed Tomography Images

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Abstract

Study Design: Retrospective radiological analysis.

Objectives: Translaminar screw (TLS) placement is one of the fixation techniques in the subaxial cervical spine. However, it can be difficult to use in small diameter of the lamina. This study proposed a novel bicortical laminar screw (BLS) and analyzed the related parameters using computed tomography (CT).

Methods: Cervical CT images taken at our institution from January 2013 to March 2017 were used for measurement. On the axial images, the maximum screw length (MSL) and trajectory angle (TA) of BLS and TLS were measured, together with the distance from the midline (DM) to the BLS entry point and the lamina width (LW). On the parasagittal images, the height of the lamina (LH) was measured.

Results: MSL of BLS and TLS were 21.00 and 20.97 mm, 19.02 and 20.91 mm, 18.45 and 21.01 mm, and 20.00 and 21.01 mm in C3, C4, C5, and C6, respectively. TA of the BLS and TLS were 21.24° and 34.90°, 19.05° and 34.22°, 18.65° and 33.61°, and 18.30° and 34.51° at C3, C4, C5, and C6, respectively. DM were 6.44, 5.77, 5.68, and 6.03 at C3, C4, C5, and C6, respectively. LW and LH were 3.52 and 12.44 mm, 2.87 and 12.49 mm, 2.76 and 12.42 mm, and 3.18 and 13.30 mm at C3, C4, C5, and C6, respectively.

Conclusion: We suggest that BLS fixation is a feasible alternative option for posterior fixation to the lamina of the subaxial cervical spine. It may be especially useful when pedicle screw, lateral mass screw, and TLS are not appropriate.

Keywords

subaxial cervical spine, bicortical laminar screw, posterior instrumentation

Introduction

Translaminar screw (TLS) placement is a method of fixation to the lamina of the cervical vertebra.1 Growing use of TLS in the cervical spine has been reported recently, primarily adopted for fixing C2 or C7.2,3 It was introduced to overcome the disadvantages of other posterior fixation methods such as the small dimension of the pedicle and the risk of vertebral artery or nerve root injury.4 According to the method reported by Wright,2 the ideal entry point of TLS is where the cervical spinous process meets the cervical laminae and, with this technique, the screw is inserted in the parallel into the contralateral laminae. However, in the morphometric analysis of C3 to C7, the thickness of the lamina for screw insertion is found to be insufficient to facilitate an intraosseous placement of the TLS using a common 3.5-mm-diameter screw.5 Thus, the feasibility of TLS 3.5-mm-diameter screws is questionable due to the relatively small laminar width and height.6,7

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As such, we propose a novel technique: bicortical laminar screw (BLS) placement. With this method, the screw trajectory is such that it enters the ipsilateral cortical bone at the junction of the lamina and spinous process, similar to as seen with TLS; however, BLS distally targets the dorsal cortex of the contralateral lamina. Our hypothesis is that BLS is more feasible, safe, and stable than TLS for fixation in the subaxial cervical spine. It may reduce the risk of ventral breach of the lamina among smaller lamina and improve stability due to the bicortical purchase of the bilateral lamina. The purpose of this study was to analyze the trajectory and dimensions related to BLS by assessing axial and parasagittal computed tomography (CT) images of the subaxial cervical spine and comparing the findings with those of TLS.

**Material and Methods**

This study was a retrospective chart review and was approved by the institution review board (IRB) of our hospital (IRB no. 2017-04-027-004). The cervical CT images of 200 patients, including 100 males and 100 females, taken at our institution from January 2013 to March 2017 were randomly selected. The mean age of the subjects was 55.1 years (male, 53.3 years and female, 57.0 years), ranging overall from 19 to 84 years. The exclusion criterion was a fracture on the lamina of the subaxial cervical spine. A picture archiving communication system (PACS) (INFINITT PACS; INFINITT Healthcare) was used to measure the radiologic parameters.

The right lamina was assessed during all measurements. On the axial CT images, relative to TLS fixation, the entry point of the BLS was assumed to be located more laterally and the trajectory angle was lower to achieve bicortical purchase without disrupting the ventral cortex (Figure 1). The measurements were performed assuming that the BLS achieved purchase in both the ipsilateral cortical bone of the lamina and the contralateral cortical bone of the dorsal lamina. We measured the following parameters of BLS: maximal screw length (MSL), trajectory angle (TA), distance from the midline to the entry point (DM), and lamina width (LW) on the axial images (Figure 2). To measure the MSL, the trajectory line of BLS followed 2 principles: (1) the line was at least 2 mm dorsal to the ventral cortical bone of the lamina at the midline and (2) the line passed the dorsal cortical bone of the contralateral lamina as laterally as possible to the junction of lamina and lateral mass without passing it. MSL was defined as the length of this trajectory line within the bony structure of the cervical spine. TA was the angle between the trajectory of the BLS and the line traversing the centers of bilateral foramen transversarium. The DM, defined as the distance between the midline of the cervical vertebrae, was measured to identify and evaluate the appropriate entry point of the BLS. The midline of the cervical vertebrae was defined as the point at which the ventral cortices

**Figure 1.** Demonstration of TLS and BLS on the axial image. (a) TLS and pedicle screws on the right C3, C4, C5, and C6. (b) BLS and pedicle screws on the right C3, C4, C5, and C6. Note the partial breach of the dorsal surface of the contralateral lamina. (c) Drawing of the TLS and BLS. The solid line represents the BLS and the dotted line represents the TLS. TLS, translaminar screw; BLS, bicortical laminar screw.

**Figure 2.** Measurements on the axial CT image. (a) Solid line with arrows on both ends. The maximal screw length of BLS. (b) Solid line with large dots on both ends. The distance between the midline and entry point of BLS. (c) Angle between the transverse axis and the BLS trajectory. The trajectory angle of BLS. (d) The dotted line with large dots on both ends represents the narrowest lamina width. CT, computed tomography; BLS, bicortical laminar screw.
of the bilateral lamina meet the base of the spinous process. Finally, the LW was defined as the shortest width between the anterior and posterior cortical ends of the lamina. On the first parasagittal CT image from the midline that did not involve the spinous process, the lamina height (LH), defined as the distance between the upper and lower cortical ends of the lamina (Figure 3), was measured.

Statistical analysis was performed using the Statistical Package for the Social Sciences version 20.0 software program (IBM Corporation). All values are presented as means ± standard deviations. The Student t-test and Mann-Whitney U test were used to compare the difference between the parameters of BLS and TLS. A P value less than .05 was considered to be statistically significant.

Results

The mean values of all parameters related to BLS are shown in Table 1. The overall mean LW was 3.08 ± 0.03 mm, appearing the largest at C3 (3.62 ± 0.36 mm) and the smallest at C5 (2.76 ± 0.05 mm). The overall mean LH was 12.61 ± 0.06 mm, with the measurements of all levels exceeding 12 mm. The overall mean MSL of BLS was 19.62 ± 0.14 mm, with C5 presenting the smallest measurement at 18.45 ± 0.28 mm. The overall mean DM of BLS was 5.98 ± 0.08 mm away from the midline. The overall mean TA was 19.31 ± 0.17°, with the largest measurement recorded at C3 (21.24° ± 0.35°).

The comparison between BLS and TLS with regard to MSL and TA are summarized in Table 2. The MSL of C3 was the only parameter that did not show a significant difference.
between the 2 methods. MSL and TA of all other levels were longer and larger, respectively, in TLS in relation to BLS.

Discussion
The posterior fixation methods available for treatment of the subaxial cervical spine include interspinous wiring, facet wiring, interlaminar clap, lateral mass screw and plate, lateral mass screw and rod, and cervical pedicle screw. Currently, lateral mass screws are widely used as a multisegment fixation method in the subaxial cervical spine. Although pedicle screw fixation is known to be the most stable fixation method currently available, it is technically challenging to perform and caution should be taken against causing injury to the vertebral artery when conducted in the cervical region. In addition, vertebral arteries may exhibit anatomical anomalies or asymmetry in some cases, requiring thorough preoperative evaluation in individual cases. The use of TLS in the cervical spine can reduce the possibility of vertebral artery injury and thus may be useful in cases showing the inadequacy of achieving a good fixation with the lateral mass screw due to facet fracture, tumor, or infection. TLS placement in C2 has been reported to exhibit mechanical strength comparable to that of a pedicle screw.

Regarding TLS in the subaxial cervical spine, there are a few reports available on the limitations of TLS due to the width and vertical height of the cervical lamina. Shin et al. evaluated the feasibility of TLS fixation in the subaxial cervical region through computer simulation using three-dimensional CT images. In C3 to C6, these authors reported that the feasibility of laminar screw fixation was lower than that in C7. Especially, in C4 and C5, a low level of feasibility of less than 10% was observed; thus, it was suggested that the use of laminar screws in these levels is not recommended. Ji et al. analyzed the morphometry of the subaxial cervical spine in the Korean population to evaluate the feasibility of TLS. These authors also reported
that the feasibility of TLS insertion was significantly lower in C4 and C5. Previous studies of cervical laminar screws were conducted based on the assumption that the trajectory of the screw insertion is parallel to the lamina, which means that only the ipsilateral outer cortical bone is purchased and the screw tip remains in the cancellous portion of the lamina. Considering the wide use of conventional 3.5-mm-diameter screws in the cervical spine, the width of the cervical lamina may not be large enough for interosseous placement using such screws. Therefore, previous reports have suggested that the feasibility of laminar screw fixation in the subaxial cervical spine is not high.7

TLS is usually performed by a freehand technique using a pedicle probe after drilling the entry point with a burr. If the operator is not assisted by navigation, there is a risk of making a cortical breach during TLS insertion. We have experienced an unexpected breach of the ventral cortex of the lamina after performing TLS (Figure 4). Fortunately, the patient did not show postoperative neurologic abnormalities. However, since the adverse event, we have considered a modification of TLS involving a safer trajectory with the distal screw targeting the dorsal cortex of the lamina. There are reports of subaxial screw fixation mimicking BLS. Rhee et al14 reported a case of bicortical fixation of the C2 lamina by adjusting the direction of one TLS in a patient with C2 lateral mass fracture. In our practice, we recently experienced a case requiring BLS. A 50-year-old woman underwent posterior instrumentation using lateral mass screws on C6 to C7. However, the fluoroscopic view after screw fixation with the freehand technique showed improper placement that might endanger the nerve root. Since the adjustment of the entry point and further drilling would compromise the lateral mass, we switched the lateral mass screws to two 3.5 × 22 mm BLS. Postoperative CT showed proper placement (Figure 5). Due to the trajectories, screw heads may cause impingement to each other when performing BLS on one side and lateral mass screw on the other. However, when performed in a saw bone, by inclining the screw heads of BLS to the spinous process as much as possible, impingement of the screw heads is significantly reduced. Therefore, the adverse event provides an opportunity for further modifications to improve the safety and feasibility of BLS.
heads was avoided, and rods were able to be connected unforcefully.

The trajectory of BLS intersects the long axis of the lamina on the axial view rather than appearing parallel (Figure 2). BLS insertion may be possible to attempt even in cases with a smaller width of the cervical lamina. We assume that the indication of posterior fixation on the lamina can be expanded by using BLS. Considering that the mean LH of all subaxial cervical spines in this study was greater than 12 mm, technically, bilateral fixation of 3.5- or 4-mm screws is possible. Although the difference was less than 3 mm, the MSL of BLS was significantly smaller than that of TLS. However, the MSL of BLS can be lengthened since mild breaching of the dorsal cortex of the lamina, although it should be minimized, is possible. Furthermore, the bicortical purchase achieved by BLS can theoretically yield improved stability relative to that of TLS.

Still, there are some limitations to this study that should be noted. First of all, this was a radiological analysis lacking clinical application. A future clinical study with larger cases is required to evaluate the usefulness and feasibility in considering BLS as an alternative to TLS. Second, biomechanical studies using bone models for the assessment of stability were not included. Although BLS can achieve bicortical purchase, since the MSL of BLS was shorter than that of TLS, it is necessary to prove that the stability of BLS is, at minimum, comparable to that of TLS. Third, a larger area of dorsal cortex breach may lead to compromised lamina bone, which may be related to decreased stability. Fourth, the distal end of BLS may impinge on the overlying soft tissues, provoking or exacerbating clinical symptoms. Anatomically, for example, it may irritate the multifidus muscle of the posterior cervical musculature. Fifteenth, the actual incidence of cortical bone breach during TLS was unable to analyze due to small number of cases. Finally, errors of dimensions between the actual cervical vertebra and the images assessed through PACS is of concern due to the slice thickness of CT.

To the best of our knowledge, this study is the first large radiological analysis focused on BLS fixation in the subaxial cervical spine. The recommended values for MSL, TA, and DM were 20 mm, 20°, and 6 mm, respectively, although such parameters should be individualized for each patient using CT images. Among patients with anatomical variations or intraoperative situations that make the use of other posterior fixation methods, including pedicle screw, lateral mass screw, or TLS, impossible, BLS may be a safe and effective alternative treatment option for posterior fixation in the subaxial cervical spine.

Conclusion

CT analysis showed that BLS could be a feasible alternative technique for posterior fixation in the subaxial cervical spine. The consideration of technical aspects is necessary to prevent possible complications by setting an appropriate entry point and trajectory. BLS may be especially useful when pedicle screw, lateral mass screw, and TLS are not appropriate. Further biomechanical studies and clinical reports are necessary to conclude the clinical usefulness.

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Declaration of Conflicting Interests

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