Surgical Neurology International

SNI: Spine, a supplement to Surgical Neurology International

OPEN ACCESS

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Editor: Nancy E. Epstein, MD Winthrop University Hospital, Mineola, NY, USA

CT-based morphometric analysis of C1 laminar dimensions: C1 translaminar screw fixation is a feasible technique for salvage of atlantoaxial fusions

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Received: 20 October 14 Accepted: 20 December 14 Published: 07 May 15

This article may be cited as:
Yew A, Lu D, Lu DC. CT-based morphometric analysis of C1 laminar dimensions: C1 translaminar screw fixation is a feasible technique for salvage of atlantoaxial fusions. Surg Neurol Int 2015;6:S236-9.

Available FREE in open access from: http://www.surgicalneurologyint.com/text.asp?2015/6/5/236/156603

Abstract

Background: Translaminar screw fixation has become an alternative in the fixation of the axial and subaxial cervical spine. We report utilization of this approach in the atlas as a salvage technique for atlantoaxial stabilization when C1 lateral mass screws are precluded. To assess the feasibility of translaminar fixation at the atlas, we have characterized the dimensions of the C1 lamina in the general adult population using computed tomography (CT)-based morphometry.

Methods: A 46-year-old male with symptomatic atlantoaxial instability secondary to os odontoideum underwent bilateral C1 and C2 translaminar screw/rod fixation as C1 lateral mass fixation was precluded by an anomalous vertebral artery. The follow-up evaluation 2½ years postoperatively revealed an asymptomatic patient without recurrent neck/shoulder pain or clinical signs of instability. To better assess the feasibility of utilizing this approach in the general population, we retrospectively analyzed 502 consecutive cervical CT scans performed over a 3-month period in patients aged over 18 years at a single institution. Measurements of C1 bicortical diameter, bilateral laminar length, height, and angulation were performed. Laminar and screw dimensions were compared to assess instrumentation feasibility.

Results: Review of CT imaging found that 75.9% of C1 lamina had a sufficient bicortical diameter, and 63.7% of C1 lamina had sufficient height to accept bilateral translaminar screw placement.

Conclusions: CT-based measurement of atlas morphology in the general population revealed that a majority of C1 lamina had sufficient dimensions to accept translaminar screw placement. Although these screws appear to be a feasible alternative when lateral mass screws are precluded, further research is required to determine if they provide comparable fixation strength versus traditional instrumentation methods.

Key Words: Atlantoaxial fusion, translaminar fixation, C1-C2 fusion

Access this article online

Website: www.surgicalneurologyint.com

DOI: 10.4103/2152-7806.156603

Quick Response Code:

INTRODUCTION

Previous literature has focused on the utilization of C2 translaminar screws.[2,7,11,17] Here, we present a single case of bilateral C1 translaminar screw fixation utilized to salvage a C1/2 fusion. We also assessed the feasibility of applying this technique to the general adult population by undertaking a morphometric computed tomography (CT)-based study focused on documenting the average bilateral C1 laminar dimensions.

MATERIALS AND METHODS

Case report

After a motor vehicle accident, a 46-year-old male presented with upper cervical midline tenderness and symptoms of a whiplash injury, but without myelopathy or radiculopathy. Plain and dynamic X-rays demonstrated an os odontoideum with 8 mm of C1/2 subluxation [Figure 1a and b]. The patient was scheduled for a C1-2 fixation with C1 lateral mass screws and C2 translaminar screws. However, when exposure of the C1 lateral mass revealed an anomalous vertebral artery, C1 fixation was achieved utilizing an alternative translaminar approach. Postoperatively, 2½ years later, he remains asymptomatic and cervical plain films were negative for signs of hardware migration or pseudoarthrosis [Figure 2].

CT based morphometric study

At UCLA Ronald Reagan Medical Center, 532 consecutive noncontrast CT scans of the cervical spine performed for any indication in patients aged >18 years were reviewed; 30 patients were excluded due to congenital C1 deformity, history of C1 fracture or laminectomy, or inadequate image quality. On axial CT images, bilateral C1 minimum bicortical diameters, laminar lengths, laminar angulation from the midline, and C1 laminar heights were measured (e.g., from mid-sagittal CT images). Laminar length measurements were directed from the midline along the axis of the lamina toward the lateral mass/laminar junction. Laminar angulation was defined as the angle between midline and the long axis of the lamina utilized in the length measurement. Lamina was deemed acceptable for translaminar screw placement if they possessed a minimum bicortical diameter of 4.5 mm, laminar height of 9 mm, and length of 20 mm. The difference in rate of screw acceptance by gender was analyzed using Fisher's exact test.

RESULTS

The 502 patients ranged from age 18 to 99 years with a mean age of 52.8 years, and included 303 males and 199 females. The average bicortical diameters, laminar lengths, laminar heights, and angulation from the midline are shown in Table 1. The number of measured lamina that could accept a translaminar screw based on bicortical diameter, length, and height are shown in Table 2. Of note, 75.9% of C1 lamina demonstrated sufficient bicortical diameter (diameter ≥4.5 mm) to accept bilateral screw placement. A total of 63.7% of C1

Table 1: Morphometric data

	Left BCD	Right BCD	Left length	Right length
Average±SD	5.62±1.18	5.58±1.19	24.39±2.76	24.21±2.85
	Left trajectory	Right trajectory	Left height	Right height
Average±SD	64.6±4.49	66.19±4.62	10.03±1.72	10.01±1.74

BCD: Bicortical diameter, SD: Standard deviation. Trajectory measurements in degrees. Otherwise, parameters are in millimeters

Table 2: Screw acceptance rate

	Left BCD	Right BCD	Both BCD	Left length	Right length	Left height	Right height	Both height
#Accept	415	410	381	483	468	349	358	320
% Accept	82.7	81.7	75.9	96.2	93.2	69.5	71.3	63.7

BCD: Bicortical diameter

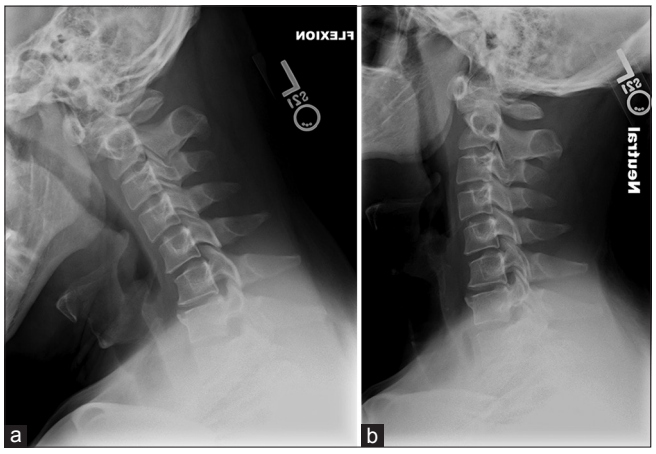

Figure 1: Preoperative cervical flexion (a) and extension (b) plain films

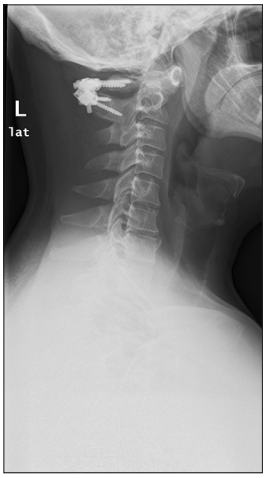

Figure 2: Two-year postoperative lateral plain films

lamina demonstrated sufficient height (distance ≥9 mm) to accept bilateral screw placement. A significant difference emerged in rates of bilateral screw acceptance with respect to sex ($P < 0.001$). Males were more likely to have sufficient bicortical diameter for both the left (odds ratio = 2.03, $P = 0.004$) and right (OR = 2.08, $P = 0.002$) C1 lamina. Males were also more likely to have sufficient laminar height for both the left (OR = 2.78, $P < 0.001$) and right (OR = 2.50, $P < 0.001$) C1 lamina.

DISCUSSION

C2 translaminar screws have been documented to be a useful method of upper cervical fixation.[23] Dorward *et al.* noted a 97.6% fusion rate in a 41-patient series operated on over a 7-year period.[7] C2 translaminar screws have been noted in multiple biomechanical studies to be comparable to C2 pedicle screws and possibly superior to C2 pars screws in terms of insertional torque, pullout strength, and resistance to flexion, extension, and axial bending.[6]

Further, C2 translaminar screws have the advantage of decreased risk of vertebral artery injury as compared with C2 pars or pedicle screws. In fact, there are reports of groups using this method specifically in patients with prior unilateral occlusion of the vertebral artery for avoidance of vascular complications.[15] To date, there are no known reports of neural or vascular injury secondary to C2 translaminar screw placement.[7] Parker *et al.* also noted that translaminar screws have a significantly smaller risk of radiographic breach as compared with C2 pedicle screws (1.3% translaminar breach vs. 7% pedicle breach).[19] Translaminar fixation has also been described in the subaxial cervical spine,[3,10,12,20] the upper thoracic spine,[13,16,18] and the lumbar spine.[1,8,19] Given the high rates of fusion, simple learning curve, technical ease of placement, and avoidance of neural and vascular complications, translaminar screw fixation has become a mainstay in the axial and subaxial cervical spine.

We believe that translaminar fixation of the atlas has similar potential, and therefore undertook to measure average laminar dimensions in the general population in order to assess the feasibility of this approach. The measurement methods utilized in this study to assess C1 morphometric parameters are similar to methods described in the literature for measurement of lamina at other levels of the cervical spine.[5,24] Our stated measurements were taken using comparable views and rounded to the nearest 0.01 mm.

Our criterion for minimum diameter necessary to place translaminar screws is comparable with previous studies. There have been varying reports in the literature regarding the minimum diameter needed to safely place translaminar screws in the cervical spine.[4,22] The largest requirement of 5 mm was suggested by Mandel *et al.*,[14] although other studies have proposed that a diameter of 4 mm is sufficient with accurate image guidance.[21] Our data demonstrated average measurements for minimum left and right bicortical diameters in our sample to be 5.62 and 5.58 mm, respectively. This suggests that a large proportion of the general population have C1 lamina that would be sufficient to accommodate translaminar screw placement. Follow up studies will be required to compare the biomechanical properties of C1 translaminar constructs relative to conventional instrumentation techniques.

CONCLUSION

C1 lateral mass screws as described by Harms *et al.*[9] have become the mainstay in rigid fixation for atlantoaxial instability. However, when C1 lateral mass screws are precluded either by tumor invasion, or aberrant vascular anatomy, C1 translaminar screws may be utilized as a salvage method for rigid constructs incorporating the atlas. Morphometric assessment by noncontrast CT imaging demonstrated that the majority of the general population, especially males, had sufficient C1 laminar dimensions to accept bilateral translaminar screw placement. These findings expand upon previous studies at the C2-7 vertebral levels by describing the anatomic characteristics of the C1 lamina. Further investigation regarding the outcomes and biomechanical properties of constructs utilizing this technique will be required to validate this approach.

ACKNOWLEDGMENT

This research was made possible with the generous support from J. Yang and Family Foundation. D.C.L. is a 1999 Paul and Daisy Soros New American Fellow.

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