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Correlation between computed tomography measurements and direct anatomic measurements of the axis for consideration of C2 laminar screw placement

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Abstract

BACKGROUND: C2 laminar screws are becoming an increasingly used method of fixation. They allow for avoidance of fixation through the C2 pedicle, eliminating the risk of vertebral artery injury. Recent studies have described the anatomic considerations of this technique in a large cadaveric population. In clinical practice, however, direct measurement is impractical and preoperative imaging must be relied upon to determine whether or not this technique can be safely used.

PURPOSE: To evaluate the ability of computed tomography (CT) to accurately assess critical dimensions of the C2 vertebrae with regard to intralaminar screw placement.

STUDY DESIGN/SETTING: Cadaveric analysis.

METHODS: The C2 vertebrae of 84 adult spines were randomly selected from a large cadaveric collection. Direct measurements were performed to determine laminar thickness, estimated screw length, and spinolaminar angle. Fine cut axial CT scans were then performed on all specimens and all measurements were repeated from these images. Correlation coefficients were calculated to determine the ability of CT scan to accurately determine these measurements.

RESULTS: CT scan measurements were found to be highly correlated with direct measurements for both left and right mean laminar thickness (0.975 and 0.947, respectively). Screw lengths using CT scan were found to be significantly longer than previously reported direct measurements (24.8 vs. 28.8 mm; $p<.01$). The mean CT spinolaminar angle was 42.45°, whereas it was 48.47° on direct measurement. Correlation coefficient for spinolaminar angle measurements was low (0.23); however, this is likely because of measurement variability.

CONCLUSIONS: Given the high degree of correlation between CT measurements and direct anatomic measurements, we conclude that CT scan can accurately determine laminar thickness, a measurement critical to safe placement of intralaminar screws. It appears that longer screw lengths that were previously reported may be safely used while remaining intra-osseous. We continue to advocate preoperative planning using CT to identify patients whose lamina may be unable to accommodate safe screw placement using this technique.

Keywords: CT scan; C2 vertebrae; Arthrodesis; Axis; Atlantoaxial; Laminar screw

Introduction

A variety of fixation techniques for the upper cervical spine have been described. Although numerous wiring techniques have been used successfully, these techniques often require rigid postoperative brace immobilization and

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have been shown to be biomechanically inferior to screw fixation [1–7]. A myriad of screw techniques have also been described. Recent constructs have evolved in an attempt to improve fusion rates without requiring the use of rigid external immobilization. The transarticular C1–C2 screw technique, and the Harms C1–C2 polyaxial screw and rod construct are two popular methods of atlantoaxial fixation [8,9]. Although these techniques provide solid fixation and are biomechanically superior to traditional wiring constructs, they also carry an increased risk of vertebral artery injury. Recently, Wright described fixation of the axis with intralaminar screws [10]. This has been shown to be biomechanically equivalent to other screw fixation techniques while decreasing the risk of inadvertent damage to the vertebral artery [11].

We previously reported guidelines for placement of C2 intralaminar screws using a large number of cadaveric specimens [12]. Although these data are useful in establishing safe parameters for this technique, direct measurement is impractical and does not allow for routine presurgical planning. Preoperative computed tomography (CT) scan has been recommended to determine the feasibility of this technique on an individual patient basis. To our knowledge, correlation between direct anatomic measurements and CT scan measurements has not been evaluated. The purpose of this study was to examine the relationship between CT scan measurements and gross anatomic measurements of the axis as they pertain to the critical parameters required for safe placement of C2 laminar screws.

Materials and methods

A total of 84 intact human cadaveric C2 vertebrae were randomly selected from the Hamann-Todd Osteologic Collection at the Cleveland Museum of Natural History. Demographic information was available on each skeletal specimen, including age at death, gender, and race. Height and weight measurements recorded at the time of death were also available for each specimen.

Direct measurements were performed on each vertebrae based on clinical application to the technique described by Wright [10] and were consistent with our previous cadaveric description [12]. Laminar thickness was measured bilaterally on all specimens, for a total of 168 measurements, using high precision digital calipers (Mitutoyo, Kanagawa, Japan). This measurement was taken at the thinnest part of the lamina in the axial plane. Digital photographs of each specimen were then taken in the axial plane of the caudal aspect of each specimen. A 1-cm marker was placed alongside each specimen as a reference marker, allowing for magnification correction for each specimen image. Image J software (NIH.com) was used for subsequent measurements of both the specimen and the reference marker. The angle formed by the C2 spinous process and a line parallel to the longitudinal axis of the lamina was measured (Fig. 1). This represents the trajectory needed to place a screw along the long axis of the C2 lamina using the spinous process as an anatomic landmark. A length measurement was also taken from the contralateral spinolaminar junction to the lamina/lateral mass junction to estimate screw length. The length of the screw was divided by the length of the 1-cm reference marker in each photograph to give a true length measurement for each specimen. Both the angle and the length of each specimen were taken randomly from either the left or right lamina (84 angle and length measurements).

CT imaging was then obtained for all 84 specimens. Spinolaminar angle, laminar length, and laminar thickness were then remeasured on the same CT scan image, which correlated with the thinnest part of the lamina in the axial plane. All CT scan measurements were performed in a blinded fashion. For laminar length, the measurement was taken from the contralateral spinolaminar junction to

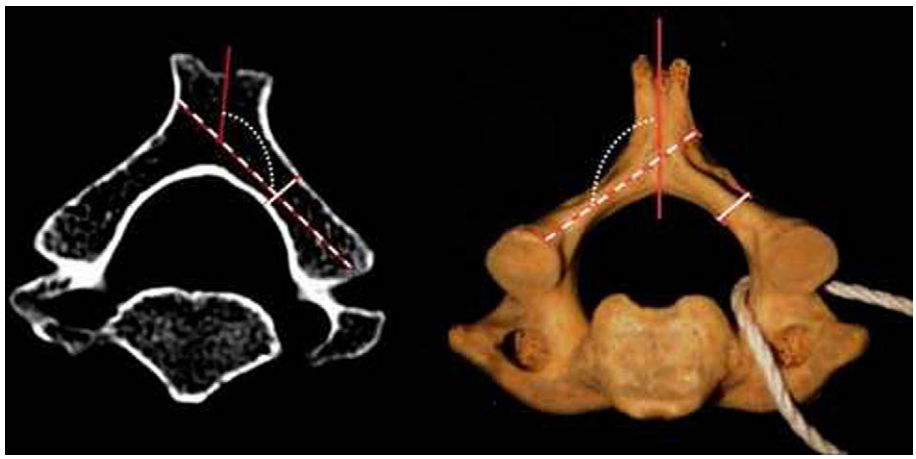

Fig. 1. Axial CT scan and photograph of C2 specimens. The dotted arc represents the spinous process laminar angle. The dashed line represents the laminar length or the potential length for an intra-osseous laminar screw. The solid white line represents the laminar thickness. The CT scan allows for a longer estimate for potential screw length.