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Accuracy of C2 pedicle screw placement using the anatomic freehand technique

Mohamad Bydon[a,b,1], Dimitrios Mathios[a,b,1], Mohamed Macki[a,b], Rafael De la Garza-Ramos[a,b], Nafi Aygun[c], Daniel M. Sciubba[a], Timothy F. Witham[a], Ziya L. Gokaslan[a,b], Ali Bydon[a,b,*], Jean-Paul Wolinksy[a]

[a] Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, USA
[b] Johns Hopkins Spinal Biomechanics and Surgical Outcomes Laboratory, Baltimore, USA
[c] Department of Neuroradiology, Johns Hopkins University School of Medicine, Baltimore, USA

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ABSTRACT

Objective: The objective of this study is to evaluate the incidence and prognostic factors of breach rates following the placement of C2 pedicle screws using the anatomic, freehand technique.
Methods: We retrospectively reviewed the medical records of all patients who underwent C2 transpedicular instrumentation over six years at a single institution. All intraoperative, image-guided techniques were excluded. Breaches were ascertained from immediate postoperative CT images. All images were analyzed by three independent reviewers. The screw length was correlated with (1) the breach rate and (2) the breach severity. Severity of the breached screws reflects the screw circumference (0–360°) perforating the pedicle wall (Grade 1–Grade 4).
Results: Of the 341 C2 pedicle screws inserted in 181 patients, the average screw length was 22.93 ± 3.7 mm. The average distance from the foramen transversarium to the screw insertion point was 13.17 ± 2.63 mm. The distance from the medial rim of the pedicle to the dura of spinal cord was 3.53 ± 1.57 mm. Of the 341 screws, the overall breach rate was 17.3% ($n = 59$). Of the 59 breaches, 89.83% of screws ($n = 53$) breaching the spinal canal was statistically significantly higher than the 10.17% of screws ($n = 6$) breaching the foramen transversarium ($p < 0.001$). Moreover, 27 (45.8%) were Grade 1, 16 (27.1%) Grade 2, 6 (10.2%) Grade 3, and 10 (16.9%) Grade 4. None of the C2 breaches resulted in neurological sequela. No association was found between breach rate and gender, race or age. While the average screw length was 22.93 ± 3.7 mm [12–34 mm], screw length did not predict a cortical violation ($p = 0.4$) or severity of the breach ($p = 0.42$) in a multiple regression model.
Conclusions: In this cohort study on the anatomic freehand placement of C2 pedicle screws, the breach rate was 17.3%. Lateral breaches were more common than medial breaches. Screw length was not statistically correlated with cortical violation or severity of breach. Therefore, screw length is not a prognostic factor for C2 pedicle screw misplacement.

1. Introduction

Instrumented fusion of the C2 spinal level is technically challenging, owing to the anatomical complexity of the upper cervical spine. In 1992, Jeanneret and Magerl described the transarticular screw fixation of the atlantoaxial joint [1,2]. In 1994, Goel et al. first described the posterior plate and screw fusion technique in the atlantoaxial fusion [3]. In 2001, Harms and Melcher popularized the placement of minipolyaxial screws into the C2 pedicle [4]. In the Harms technique, the C2 pedicle screws caudally communicated with the C1 lateral mass screws rostrally via a rod-cantilever construct. Today, C2 pedicle screws have become an important adjunct to the arthrodesis of the atlantoaxial joint. Although the safety profile of C2 pedicle screws has been well established in the literature [5], freehand placement of these pedicle screws is not without its risk of intraoperative complications.

* Corresponding author at: Corresponding author at: Johns Hopkins School of Medicine, Department of Neurosurgery, 600 N Wolfe St. Meyer 7-109 Baltimore, MD 21205, USA. Tel.: +1 443 287 4934; fax: +1 410 502 3399.
E-mail addresses: mbydon1@jhmi.edu (M. Bydon), abydon1@jhmi.edu (A. Bydon).
[1] These authors contributed equally to this manuscript.

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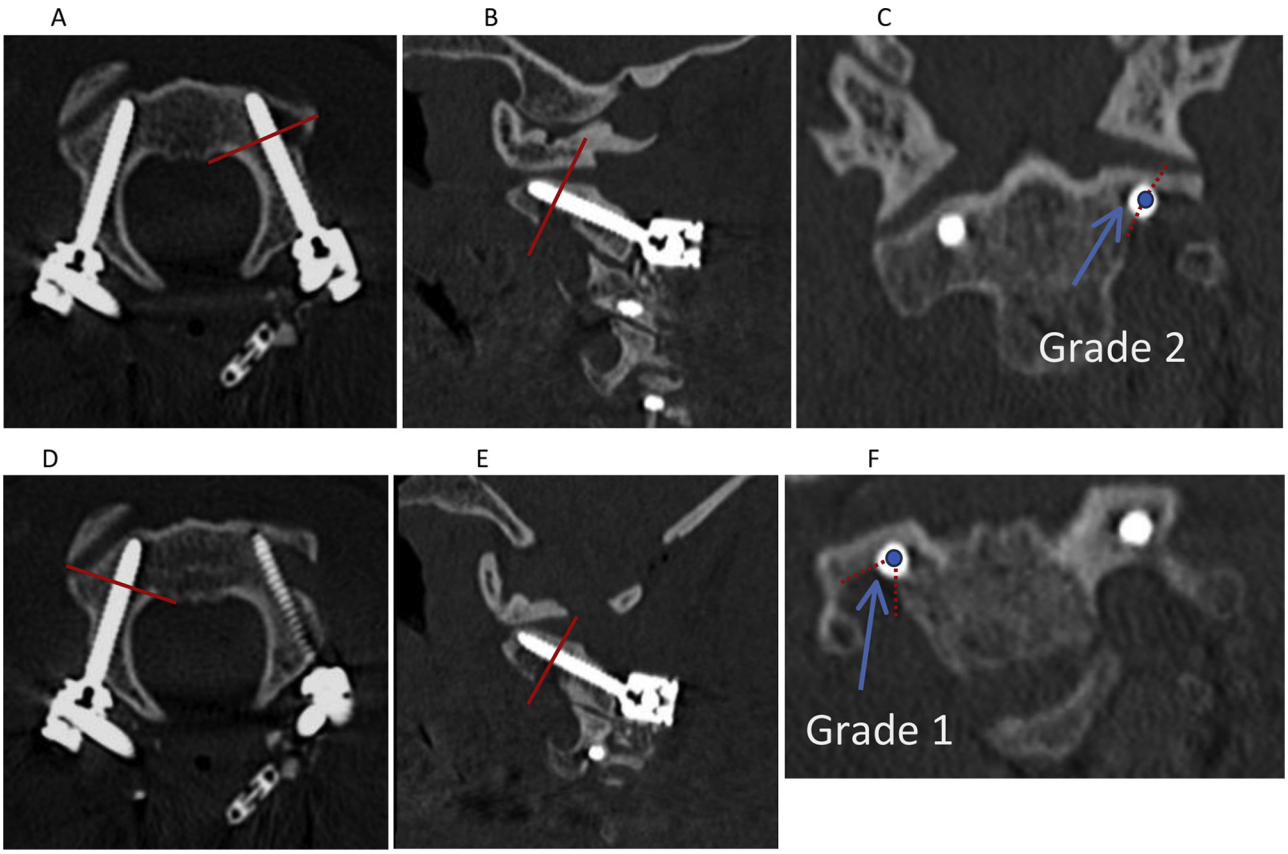

Fig. 1. (A) Axial, sagittal (B), coronal (C) CT scan cuts centered at the screw along its axis; the left screw is breaching in the FT and scored with Grade 2. (D) Axial, sagittal (E), coronal (F) CT scan cuts centered at the screw along its axis; the right screw is breaching in the FT and scored with Grade 1.

The objective of this study is to evaluate breach rates following the placement of C2 pedicle screws under the anatomic, freehand technique (i.e., without image guidance). We also sought to determine prognostic factors that may influence the C2 breach rates.

2. Methods

We retrospectively reviewed the medical records of all patients undergoing placement of C2 pedicle screws under the anatomic, freehand technique (i.e., without image guidance) at our institution from 2007 to 2012. Pedicle screw placement under image-guidance, including fluoroscopy or computerized tomography (CT), was excluded. C2 laminar and transarticular instrumentation were also excluded. Screws that were placed into the C2 foramen transversarium after vertebral artery ligation were excluded as well.

2.1. Radiographic measurements

All patients were preoperatively assessed with CT scans. The placement of the anatomic, freehand C2 pedicle screws was confirmed with immediate postoperative CT scans. Three independent reviewers confirmed the placement of the C2 pedicle screw. From these images, we ascertained C2 breaches and the trajectory of the C2 pedicle screw. The screw trajectory was assessed using the Ultra-Visual 3D reconstruction software (Madison, WI). Orthogonal views of the C2 level were resynthesized in order to create a coronal image along the C2 pedicle screw trajectory.

We measured the screw length in relation to (1) breach rate and (2) breach severity. While breach rate indicates a binary outcome, breach severity reflects the grade of the cortical violation. We measured the degree of cortical violation by measuring the circumference of the screw that was out of the bone in degrees of angle. Non-breached screws were scored as 0. Breached screws perforating the pedicle wall and exposing 0–90° of the screw circumference were scored as Grade 1, 90–180° as Grade 2, 180–270° as Grade 3, and 270–360° as Grade 4 [Fig. 1].

2.2. Statistical analysis

The patient population was described with summary statistics. Student *t* test was used to compare continuous variables. Chi-square test, with Yates correction when necessary, was used to compare categorical variables. Multiple logistical regression analysis was performed to identify relationship of outcome variables with pertinent covariates. We controlled for age, sex, osteoporosis, and race in the regression model. Bone density was preoperatively assessed in all patients via dual-energy X-ray absorptiometry (DEXA) scans and osteoporosis was defined as bone density equal to or greater than 2.5 standard deviations below the average. A p-value of ≤ 0.05 was used to assume statistical significance. All statistical analyses were performed using Stata (College Station, Texas).

3. Results

According to our selection criteria, 341 C2 pedicle screws were placed in 181 patients [Tables 1 and 2] that were followed for an average of 2 years. The range of screw length used was 12–34 mm and the screw width was either 3.5 mm or 4 mm. Mean patient age at the time of the operation was 57.9 ± 15.1 years. The majority of patients were operated for degenerative diseases of the spine (48.6%) followed by tumor (14.8%), trauma (11.5%), rheumatoid