Axial translaminar screw placement using three-dimensional fluoroscopy-based navigation

Rajasekaran S, Avadhani A, Shetty A P

ABSTRACT

Introduction: To circumvent the risk to the vertebral artery with C2 pars or pedicle screws, C2 laminar screws were considered as a method for rigid fixation of the axis. Although considered to be a relatively safe method, ventral spinal canal violations have been reported. Three-dimensional (3D) fluoroscopy-based image guidance may enhance the accuracy and safety of the technique. There is only one previous report in the literature on its use in the placement of C2 laminar screws. The purpose of this study was to assess the accuracy of C2 translaminar screws inserted using 3D fluoroscopy-based navigation.

Methods: Data from a single centre was gathered retrospectively and then analysed. 3D fluoroscopy-based navigation was used to insert five translaminar screws in four patients (two male, two female). Their mean age was 45.3 years and the average follow-up period was 13.8 months. The accuracy of screw placement and fusion was ascertained using postoperative computed tomography imaging.

Results: There were no complications in this series. No breach in the dorsal or ventral laminar wall was noted for any of the translaminar screws inserted. The average time required to set up the navigation platform and screen was 18 minutes. Successful fusion was observed in all four patients at six months follow-up.

Conclusions: Although considered a relatively safe technique, laminar cortical violations have been reported with C2 translaminar screws. 3D fluoroscopy-based image guidance can greatly enhance the accuracy of C2 translaminar screw insertion, as this technology provides real-time images during screw insertion and permits accurate screw sizing.

Department of Orthopaedics and Spine Surgery, Ganga Hospital, 313 Mettupalayam Road, Coimbatore 641043, Tamil Nadu, India

Rajasekaran S, PhD
Director and Head

Shetty AP, MS, DNB
Consultant

Avadhani A, MS, DNB, FNB
Spine Fellow

Correspondence to: Dr Rajasekaran S
Tel: (91) 422 2485000
Fax: (91) 422 245144
Email: sr@gangahospital.com

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INTRODUCTION

The C2 translaminar screw, pioneered by Wright in 2004, has gained popularity due to the large size of the C2 lamina, the rigid fixation of the axis and the reduced risk of injury to the vertebral artery.[1,2] The biomechanical comparability with other fixation techniques has now been established.[3,4] Although it is considered to be a relatively safe method, laminar violations have been reported.[1,2] Transgression of the ventral cortical wall of the lamina with the translaminar screws can have devastating complications. Also, the reliability of intraoperative plain radiographs in detecting violations of C2 intralaminar screws has been called into question.[5] The advent of the three-dimensional (3D) fluoroscopy-based image-guidance technique has permitted safe and accurate spinal instrumentation at all vertebral levels, including placement into the odontoid, C2 pars, C2 pedicle and the C1–C2 transarticular junction.[6-12] However, there has only been one previous report on the use of 3D fluoroscopy-based image guidance for the placement of C2 laminar screws.[13]

METHODS

We retrospectively studied four patients (two female and two male) who underwent posterior cervical fusion, incorporating the axis with the placement of C2 laminar screws using the Brainlab (Brainlab Inc, Westchester, IL, USA) image-guided system in conjunction with the Siremobil Iso-C3D (Siemens Medical Solutions, Erlangen, Germany) between January 2007 and December 2008. The average patient age was 45.3 years and the mean follow-up period was 13.8 months. Postoperative computed tomography (CT) images were reviewed for the accuracy of screw placement.

All the patients were operated in a prone position under general anaesthesia on a radiolucent operation

Table I. Summary of the data of four patients who underwent posterior cervical fusion with image-guided placement of C2 translaminar screws.

Case	Age/gender	Diagnosis	Operative procedure	Follow-up (mths)	Accuracy
1	35/M	C1–C2 instability	Posterior C1–C2 fusion	16	No bony breach
2	62/F	C4–5 neurofibroma	Posterior C2–C7 fusion	9	No bony breach
3	38/M	C4 angiosarcoma	Posterior C2–C6 fusion	12	No bony breach
4	46/F	C1–C2 instability	Posterior C1–C2 fusion	18	No bony breach

M: male; F: female; C: cervical

table, with the head attached firmly to the head ring of the table. After the posterior elements of the upper cervical spine were exposed, the minimally invasive reference array (MIRA) was attached to the base of the C3 spinous process. Subsequently, the isocentric C-arm was positioned, ensuring that the C1-C2 junction was in the centre of the fluoroscopic field in the lateral and anterior-posterior plane. A 190° orbital isocentric spin of the C-arm was then accomplished and the acquired images were transferred to the computer navigation platform VectorVision (Brainlab Inc, Westchester, IL, USA). Accurate axial and sagittal images of C1 and C2 were obtained and checked using a tool navigator. The tool navigator, along with the 3D real-time images were used to determine the entry point, trajectory, length, depth, thickness and the direction of the C2 lamina and C1 lateral mass screws (Fig. 1).

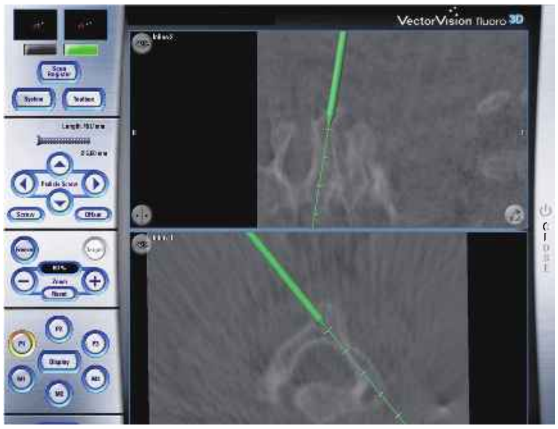

Fig. 1 Intraoperative planning of the C2 translaminar trajectory using the 3D image-guidance technique.

The entry point was prepared at the junction of the C2 spinous process and lamina using a 2.5 mm high-speed diamond burr that was calibrated to the navigation system so that real-time images could be obtained during drilling. When two crossing laminar screws were planned, caution was exercised in planning the entry points of the holes so that the crossing C2 laminar screws did not intersect in the middle. Drilling was performed in stages in order to double-check the accuracy of the trajectory at multiple depths. Subsequently, the integrity of the drill holes was confirmed with a small ball-probe to ensure that there was no bony breach. The holes were tapped and the bony wall integrity reconfirmed, and only then were the screws inserted. A 3.5 mm diameter screw with a polyaxial head of a length of 22–26 mm was used depending on the anatomic variance in each patient and as determined by the Brainlab image-guided platform (Fig. 2). C1 lateral mass and subaxial cervical pedicle screws were placed based on the case requirement. Rods were then connected to the polyaxial screws with locking caps. Fusion was performed with autologous bone grafts in all cases.

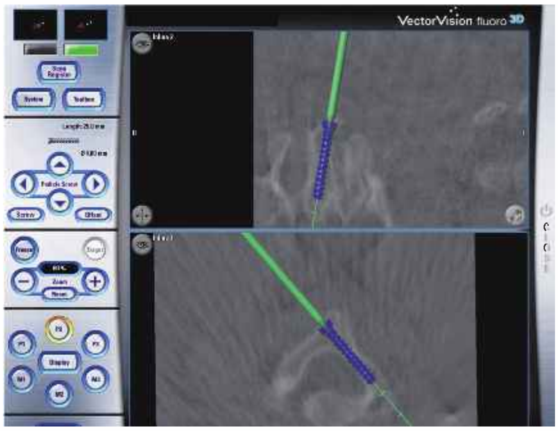

Fig. 2 Precise measurement of the screw length and diameter using the Brainlab image platform.

The accuracy of the screw placement was again verified by coronal and sagittal images using 3D fluoroscopy-based navigation at the end of the procedure. Postoperative radiographs and CT images of the cervical spine confirmed that all screws had been placed as planned, with no breach of the cortex on either the side of the spinal canal or the vertebral artery canal (Fig. 3). Serial radiographs and CT imaging were used to ascertain the fusion status.

RESULTS

Five translaminar screws were placed in four patients. We preferred the use of C2 pedicle screws as they were amenable to be placed safely with 3D fluoroscopy-based navigation (Table I). The mean operative time for all the patients was 280 minutes, while the average amount of time required to set up the navigation platform and screen was 18 minutes. Two patients with isolated atlantoaxial instability had a mean operative time of 205 minutes. The mean follow-up period was 13.8 (range 9–18) months. Follow-up CT images were available for all patients, which allowed for an assessment of the accuracy of translaminar screw placement. There were no complications in this series, i.e. no dorsal bony or ventral spinal canal breach in any patient. Successful arthrodesis was achieved in all the patients within six months.

DISCUSSION

Axis laminar screw placement appears to be safe in the hands of surgeons who are proficient in this technique, although its safety profile has yet to be established by larger studies.[5] The technique, as described by Wright and in subsequent studies, is based entirely on anatomical landmarks with or without the use of intraoperative fluoroscopy.[1-4,14] The absence or presence of a dorsal laminar breach is easily verifiable intraoperatively through visual inspection. Unfortunately, this is not true for a ventral breach, which is clearly important to ensure safe intralaminar screw placement.

Lehman et al studied the reliability of intraoperative plain radiographs in detecting violations of C2 intralaminar screws in cadaveric models and expressed concerns about the overall accuracy rate of 77.4%.[5] The authors also cautioned that when both C2 intralaminar screws were out, the accuracy was reduced to 63.9%, suggesting that in over 36% of bilateral screw perforations, plain radiographs cannot be depended on to detect the violation. Wang studied the CT images of 59 intralaminar screws in 30 patients and confirmed partial dorsal laminar breach in 11 patients and violation of the spinal canal in one patient.[15] It is difficult to visualise the translaminar screw in the anterior, posterior or lateral plane due to its oblique trajectory, and this raises questions about the value of two-dimensional fluoroscopy in screw insertion.[13] As safe screw insertion is paramount, navigation can enhance the precision of translaminar screw fixation. There is a single previous report of isocentric C-arm-guided C2 translaminar screw insertion. Nottmeier and Foy reported only one minimal dorsal laminar breach in 13 screws, evaluated by postoperative CT images.[13] No laminar breaches were found to have occurred in our study, thus confirming the accuracy of this technique.

Traditionally, 3D image-guidance systems were based on point registration. A paucity of focal anatomic landmarks on the C1 and C2 dorsal elements and a

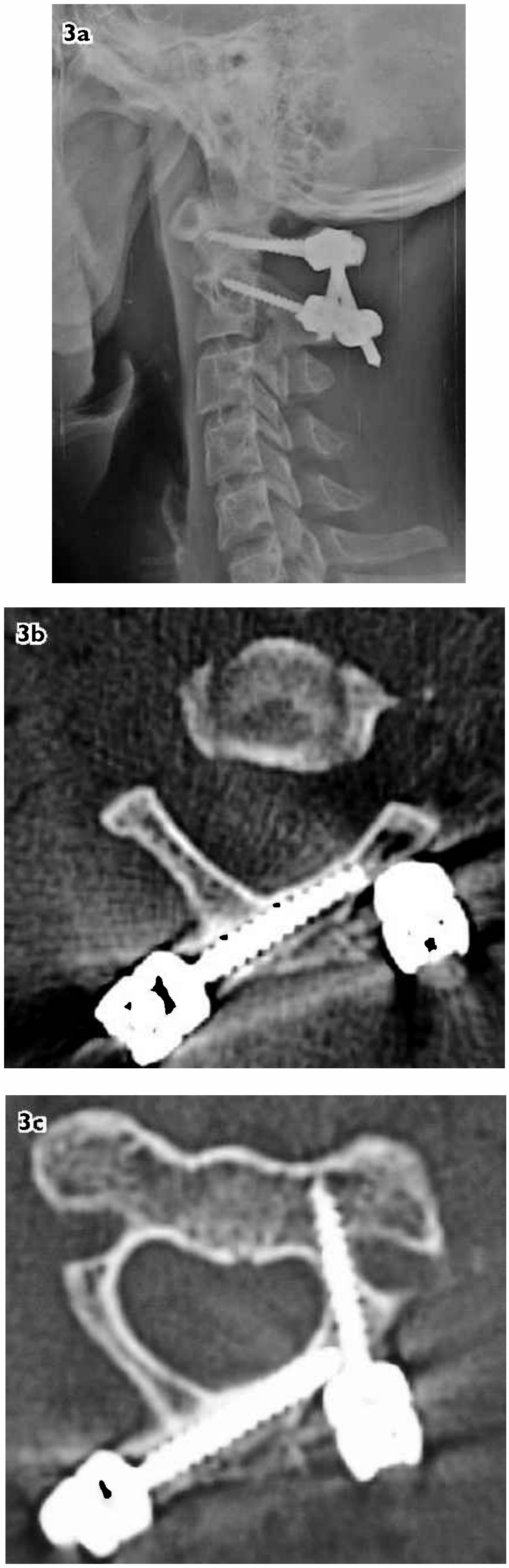

Fig. 3 Postoperative (a) radiograph and (b & C) CT images show accurate placement of the C2 translaminar and pedicle screws.

decreased surface area can make registration difficult in the atlantoaxial region. Further, point registration systems permit a single vertebral level registration at a time. These inadequacies can be circumvented by 3D fluoroscopy using an isocentric C-arm.[13] Additionally, real-time images allow the surgeon to repeatedly check the screw trajectory in multiple planes to ensure the accuracy of screw placement. The approximate diameter and the length of the screw can also be determined using the Brainlab image-guided platform. Nottmeier and Foy were able to insert 4 mm screws in all but one of their patients.[13] In contrast, in our study, we found 3.5 mm screws to be the safest largest diameter screws that could be accommodated into the C2 lamina without a cortical breach. In a cadaveric study, Wang reported that 47% of the specimens could not accommodate 4 mm diameter screws bilaterally and that 37% of their specimens had at least one C2 lamina that could not accommodate a 3.5 mm diameter screw. It must be noted that these were speculated with a 1 mm bony tolerance on either side.[16]

The limitations of the study are the small sample size and the absence of a non-navigated group for comparison. However, it must be noted that in a recent comparative study of 167 patients, Parker et al found that radiographic breach was higher with C2 pedicle screws than with C2 translaminar screws, although the rate of operative revision was higher with C2 translaminar screws at one-year follow-up.[17] Moreover, the biomechanical stability of the C2 translaminar screw seems to be marginally inferior to that of the C2 pedicle screw, but superior to the C2 pars screw.[18,19] The authors concur with these studies and believe that a C2 translaminar screw should be used only if a C2 pedicle screw is either impracticable, or in order to salvage a C2 pedicle screw (Fig. 3). This accounted for the small sample size of the study. C2 translaminar screw placement has gained popularity as a new alternative for rigid fixation to the axis. Although it is considered to be a relatively safe technique, laminar cortical violations have been reported and its safety profile has not been validated by long-term studies. The authors have shown that 3D fluoroscopy-based image guidance can greatly enhance the accuracy of C2 translaminar screw insertion as this technology provides real-time images during screw insertion, and permits accurate screw sizing. If required, intraoperative repeat imaging may be performed to determine the accurate placement of translaminar screws.

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