The anatomical suitability of the C1–2 complex for transarticular screw fixation

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Posterior transarticular screw fixation of the C1–2 complex has become an accepted method of rigid internal fixation for patients requiring posterior C1–2 fusion. The principal limitation of this procedure is the location of the vertebral artery, because an anomalous position may prohibit screw placement. In this study, a consecutive series of computerized tomography (CT) scans was reviewed, and the suitability of each patient for transarticular screw fixation was evaluated.

All of the fine-slice axial C1–2 CT scans and reconstructions performed on a spiral scanner over 2 years were reviewed. A novel screw trajectory reconstruction was designed to visualize the potential path of a transarticular screw in the plane of the reconstruction. Scans were reviewed for bone anatomy and the position of the transverse foramen.

Seventeen (18%) of 94 patients had a high-riding transverse foramen on at least one side of the C-2 vertebra that would prohibit the placement of transarticular screws. The left side was involved in nine patients and the right in five. Three patients had bilateral anomalies. The mean age of the group with anomalies (35.9 years, range 10–76) was not significantly different from the overall mean age (35.7 years, range 6–94). An additional five patients (5%) were considered to have anatomy in which screw placement was feasible but risky. On the basis of these data, it is postulated that 18% to 23% of patients may not be suitable candidates for posterior C1–2 transarticular screw fixation on at least one side.

KEY WORDS • atlantoaxial fusion • transarticular screw fixation • cervical disc anatomy • anatomical study

Magerl and Seeman⁵ and Grob, et al.,³ did not report VA injury in their retrospectively reviewed series of more than 180 patients. Remarkably, all of these patients received bilateral screw placement. Stillerman and Wilson¹ achieved bilateral screw placement in all 22 of their patients, but in one patient a single screw was removed intraoperatively because of poor purchase. None of these authors reported changing their operative approach because the VA had an anomalous position. Marcotte, et al.,⁶ reported one patient who received a single atlantoaxial transarticular screw because of an aberrant course of the VA. An updated review of the senior author’s (V.K.H.S.) experience reveals that 11 of 42 patients have received only one screw. Several of these patients had an enlarged transverse foramen, which conceivably housed a tortuous VA.

The use of CT scanning with reconstructions performed in the sagittal and coronal planes allows a detailed examination of the transverse foramen of C-2 and the C1–2 facet joint. However, a direct line of sight along the screw trajectory is not afforded by these traditional formats. Therefore, a new reconstruction was designed to allow the
entire screw trajectory for both sides to be viewed on a single slice. This new modality was used to evaluate the atlantoaxial anatomy of a group of patients consecutively examined to determine the suitability of a general population for atlantoaxial transarticular screw fixation.

Clinical Material and Methods

We reviewed all of the 1-mm fine-slice C1–2 CT scans performed on one high-speed spiral CT scanner (General Electric Corp., Milwaukee, WI) between January 1994 and March 1995 at our institution. The age and sex of each patient were recorded; patients younger than 6 years of age were not included. All patients were being evaluated for cervical trauma.

In addition to traditional axial slices with coronal and sagittal reconstructions, a special screw trajectory reconstruction was obtained for each study and performed as follows (Fig. 1). A midline sagittal reconstruction was performed with the console in the interactive mode. A marker was placed on the midportion of the image of the anterior arch of C-1, which corresponds to the target seen on the image intensifier when performing this procedure in the operating room. The sagittal image was dialed laterally until the image shown was 2 to 3 mm from the lateral border of the spinal canal, as demonstrated by the inset axial scout image. A second marker was then placed on the sagittal image approximately 4 mm superior to the C2–3 facet joint; this marker corresponds to the screw entry point. The two markers were connected and reconstructions were performed in the plane described by this line and the lateral axis. Reconstructed slices several millimeters above and below this initial scan complete the reconstruction process.

Each CT scan and reconstruction was reviewed carefully. Scans were rejected if fractures were present, if artifacts blurred the images, or if rotation distorted the images, making side-by-side comparisons impossible. Scans were reviewed by the first and senior authors for the suitability of each C1–2 joint to receive a transarticular screw. Each joint was assigned a grade of acceptable, possible but risky, or unacceptable.

Results

Ninety-four patients met the criteria for inclusion in this study. Of these, 17 had anatomy unacceptable for transarticular screw placement on at least one side (Fig. 2). The left side was involved in nine patients and the right side in five patients. In three patients the involvement was bilateral. In five patients transarticular screw placement was possible but risky because of the anatomy. The mean age of the study population was 35.7 years (range 6–94 years), whereas the group with unacceptable anatomy had a mean age of 35.9 years (range 10–76 years). Males outnumbered females 71 to 23, as might be expected in a trauma population. However, there were no significant differences in the suitability of screw placement for either sex.

The screw trajectory reconstruction complemented the standard axial and perpendicular reconstructions (Figs. 3

FIG. 1. Diagrams showing the procedure followed in the reconstruction, which is performed using the console of a spiral computerized tomography (CT) scanner. An axial scout image (upper left) is used to determine the midline of a reconstruction in the sagittal plane (upper right). A marking cursor is placed in the midpoint of the anterior arch of C-1 on this reconstructed image. This point (x) represents the ideal target for C1–2 transarticular screws as placed in the operating room. Next, the line on the axial scout image is moved laterally (lower left), approximately 2 to 3 mm from the medial aspect of the facet joint. This creates a new sagittal reconstruction (lower right). A second cursor (y) is placed 4 mm cephalad to the C2–3 facet joint, as demonstrated on the sagittal reconstruction (lower right). This point (y) represents the ideal entry point for C1–2 transarticular screws. Finally, a line is drawn between the two cursor points. This line and the horizontal axis form the plane describing the screw trajectory reconstruction. One-millimeter-thick CT scans above and below this initial scan complete the reconstruction process.

FIG. 2. Axial fine-slice computerized tomography (CT) scans showing a normal cervical spine. Left: Axial scan showing the inferior portion of C-2 at the level of the C2–3 disc space and the C2–3 facet. The arrow corresponds to the entry point of a transarticular screw for C1–2 fixation. Right: Axial CT scan showing C-2 at the level of the pars interarticularis. The triangular wedge-shaped portion of bone posterior to the transverse foramen represents the site of purchase and passage of the C1–2 transarticular facet screws. In this patient, there is adequate room for the passage of the screws without endangering the vertebral arteries.
Like other reconstruction modalities, the quality of the image was directly affected by the positioning of the patient in the scanner. As a result, several dozen images were rejected for study because of crooked positioning. In addition to providing vital information about the position of the VA, the reconstruction allowed the thickness of the pars interarticularis to be measured directly. Thus, the selection of the appropriate screw diameter could be simplified.

Discussion

Although few complications from atlantoaxial transarticular screw fixation have been reported, we remain concerned about the potential for injury to the VA. Using conventional axial CT scans with perpendicular reconstructions, we have found enough anomalies to prevent us from placing bilateral screws in 20% of our patients undergoing atlantoaxial screw fixation (VKH Sonntag, et al., unpublished data). This finding led to the present review of a consecutive series of trauma patients undergoing fine-slice C1–2 CT scanning. The screw trajectory reconstruction was devised to assist in evaluating the information derived from the CT scan in the most efficient manner.

This study supports our clinical findings that approximately 20% of patients will have a high-riding transverse foramen on at least one side. Although there is no guarantee that the VA is actually in the foramen where the screw would cross, we have chosen not to place screws in these instances. In such cases MR angiography or contrast-enhanced three-dimensional CT might be able to trace the course of the VA more accurately, but we have been content with the results obtained with one transarticular screw and a posterior interspinous wiring construct. Our findings indicate that the anatomy of a small number of patients (3%) is unsuitable for transarticular screw fixation on both sides, and thus, these patients require halo bracing after posterior atlantoaxial fusion.

The screw trajectory reconstruction is easily performed on CT scanners with spiral software. The patient may
undergo scanning in the traditional supine position, with 1-mm thick reconstructions based on the axial images. Thus, scanning potentially unstable patients at complicated angles can be avoided. The resolution of the reconstructed images is excellent, with less of the distortion experienced with earlier generations of CT scanners. Although no reconstruction supersedes the information available on the initial axial scan, the ability to view the entire screw path on one image allows subtleties such as the diameter of the pars interarticularis and the lateral–medial screw trajectory, which are critical to planning the procedure, to be more readily appreciated.

Transarticular screw fixation of the atlantoaxial joint is becoming a routine procedure. The development of better imaging modalities has made it easier to recognize a subset of patients in whom this procedure may be inappropriate. Careful scrutiny of the VA will enable the surgeon to avoid inflicting a potentially catastrophic injury when this procedure is performed.

References


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