Use of an aiming device in posterior atlantoaxial transarticular screw fixation

Technical note

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Posterior atlantoaxial transarticular screw fixation was developed by Magerl and Seemann16 in 1979. This technique is mechanically superior to those used in conventional posterior wiring,13,19,21 and higher fusion rates in clinical series have been reported.5,6,12,14,15,23 This technique, however, has potential risks because of the proximity of the screw path to important structures such as the spinal cord and the VA. Spinal cord injury can be avoided by obtaining adequate exposure of the isthmus of C-2 and a direct view of the lateral border of the spinal canal. The VA can be injured, however, because its location varies, and the isthmus in some patients is too narrow.15,17,20 Vertebral artery injury sometimes causes catastrophic complications that may be fatal.1,4,15,24,26 To avoid such complications, preoperative computerized tomography (CT) reconstructions revealed a high-risk high-riding unilateral VA in three patients. Postoperative CT reconstructions demonstrated that all screws but one were inserted as planned, and successfully cleared the vertebral groove.

In conclusion, this newly designed device is practical and useful for the accurate insertion of screws, thus avoiding VA injury during atlantoaxial transarticular screw fixation.

KEY WORDS • atlantoaxial subluxation • atlantoaxial stabilization • transarticular screw • vertebral artery

Abbreviations used in this paper: CT = computerized tomography; VA = vertebral artery.

Clinical Material and Methods

The Device

The instruments consist of a specially designed aiming device (Fig. 1 upper left and right) and the Reunion Bone Screw System (Surgical Dynamics Inc., Norwalk, CT). The latter is composed of guide wires, a flexible cannulated drill, a tap, a hex screwdriver, and titanium cannulated lag screws. The inner diameter of each screw is 2.7 mm and the outer diameter 4 mm. The aiming device can be assembled with a flexible cannulated hex screwdriver, which makes the guide wire pass 1 mm from the tip of the device (Fig. 1 lower). The sleeve of the aiming device has a slit to facilitate its removal from the operative field once the guide wire is inserted through the atlantoaxial joint (Fig. 1 upper right).
Surgical Technique

The patient is placed prone and the head is rigidly fixed using a Mayfield clamp. Under lateral fluoroscopic guidance, the patient’s atlantoaxial subluxation is reduced by slightly flexing the cervical spine and elevating the head posteriorly. A midline posterior skin incision is made to expose the laminae of C1–3. The superior aspect of the C-2 isthmus is exposed subperiosteally, and the C-2 nerve and its surrounding vessels are retracted superiorly and laterally. Venous plexus bleeding, if any, is effectively controlled using a packing of an absorbable collagen hemostat. These procedures allow a view of the lateral border of the spinal canal and the posterior edge of the atlantoaxial joint. A high-density polyethylene thread (Secure Strand; Surgical Dynamics Inc.) is then passed beneath the C-1 posterior arch. Using a small diamond burr, a pit for the tip of the aiming device is made on the ridge of the C-2 isthmus just posterior to the atlantoaxial joint (Fig. 2). This point is located near the medial edge of the isthmus. The insertion point of the screw is also marked with a diamond burr at the cortex of the distal edge of the inferior articular process of C-2, just behind the pit on the isthmus, so that the screw path will be straight in the sagittal plane or slightly medial to it (Fig. 2). A flexible cannulated screwdriver is introduced percutaneously at the T-1 level into the operative field and is assembled with the aiming device in the operative field. The tip of the aiming device is placed in the pit on the isthmus, and the tip of the screwdriver is placed at the insertion point (Fig. 3). Once the devices are positioned, they become fairly stable. Under lateral fluoroscopic control, a guide wire is inserted into the C-1 lateral mass through the isthmus of C-2. The guide wire should pass just under the superior cortex of the isthmus and then into the most posterior part of the atlantoaxial joint (Figs. 2 and 3). The guide wire is usually directed above the anterior arch of C-1. The screwdriver is withdrawn, as is the aiming device, leaving the guide wire in position. Using the same technique, another guide wire is inserted through the atlantoaxial joint on the contralateral side. At this point, the positions of the guide wires are checked on the anteroposterior fluoroscopic images. After measuring the screw length, a flexible cannulated drill is used under lateral fluoroscopic control. If the bone is very hard, a flexible tap is used instead as the aiming device. C-1 lateral mass. The guide wire is then removed. After the insertion of bilateral screws, an iliac bone strut is fixed on C1–2 by using the polyethylene thread (Secure Strand), according to the Gallie method.

Patients are advised to wear a Philadelphia collar for 3 months postoperatively.

Patient Population

Nine patients with atlantoaxial subluxation and one patient with atlantoaxial osteoarthritis (age range 54–77 years; one man and nine women) were treated using the aforementioned technique between December 2000 and July 2001. The causes of subluxation included rheumatoid arthritis (six patients), os odontoideum (one patient), traumatic injury (one patient), and likely the effects of inflammation (one patient). Patients complained of occipitalgia only (five patients), occipitalgia and upper-extremity numbness (three patients), and paresis of the extremities (one patient); in one patient there were no symptoms but a 10-mm atlantodental interval was demonstrated. Preoperative plain radiography, including flexion–extension lateral radiographs, was performed. In five patients, subluxation was not completely reduced (atlantodental interval > 4 mm) even during extension. A CT study with a 1-mm slice interval from C-1 to C-2 was also obtained in each patient, and sagittal and coronal scans were reconstructed at 3-mm intervals to allow evaluation of the location of the vertebral groove. Typically, two or three sagittal slices were obtained for each C-2 lateral mass. We selected the slice in which the isthmus of C-2 was thickest (usually the most medial one) and deemed that the VA was high riding and at high risk for the operation when the isthmus height was less than 5 mm² and/or the internal height of the lateral mass (measured from the roof of the vertebral groove to the surface of the superior facet) was...
less than 2 mm in the slice.\textsuperscript{2,15} By this definition, a high-riding unilateral VA was demonstrated in three cases.

In two patients, operations other than the routine one were performed. In one patient, previously implanted unsuccessful hardware was removed and the bone graft was modified because of the absent spinous process of C-2. In the other patient, a bone grafting procedure was performed according to Brooks\textsuperscript{3} because of the severe osteoporosis of the grafted bone.

To evaluate the screw positions, postoperative plain radiograms and CT reconstructions were obtained using the preoperative protocol.

**Results**

Screws were inserted bilaterally in all patients, and no massive bleeding was encountered. Other intraoperative or early postoperative complications, such as dural tear, infection, and neurological deficit, were not encountered. The mean operation time was 119 minutes (range 105–141 minutes), and the mean estimated blood loss was 67 ml (range 25–120 ml) in the eight patients in whom the routine operation was performed. In three of the five patients in whom subluxations could not be reduced, complete intraoperative reduction was impossible. Laminectomy of C-1 was not performed, however, because no or minimal myelopathy was present, and partial reduction was achieved.

Postoperative CT scans and CT reconstructions demonstrated that all but one screw successfully cleared the vertebral groove. Only one screw breached the cortex of a high-riding vertebral groove (isthmus height, 4 mm). Another screw was displaced to the medial edge of the lateral mass of C-1, although this screw cleared the vertebral groove and perforated the superior articular surface of C-2. This occurred because the C1–2 subluxation was not completely reduced and the screw path was directed too medially. Four screws (in three patients) slightly perforated the superior articular surface of C-1, although they caused no clinical symptoms. An example of a high-riding VA is shown in Fig. 4.

**Discussion**

Posterior atlantoaxial screw fixation is an excellent technique that is associated with very high postoperative fusion rates. The risk of VA injury, however, makes some surgeons reconsider using this technique because severe VA injury–related complications and fatalities have been reported.\textsuperscript{1,4,15,24,26} Wright and Laurysen,\textsuperscript{26} demonstrated that the risk of VA injury was 4.1% per patient, and the risk of neurological deficit from VA injury was 0.2% per patient. One reason it is difficult to avoid this complication completely is the variability in the course of the VA in C-2 and the consequent variability in the width and height of the C-2 isthmus through which the screw is inserted. The VA makes an acute reverse bend within the center or lateral half of the superior articular facet of the axis in approximately 80% of cases. In 15% of these cases, the VA can occupy almost two thirds of the superior facet of the axis.\textsuperscript{10} Madawi, et al.,\textsuperscript{15} reported that in 20% of patients the vertebral groove on one side was large
enough to reduce the width of the isthmus, thus preventing the safe passage of a 3.5-mm-diameter screw. Parme-
more, et al.\textsuperscript{20} postulated that atlantoaxial transarticular screw fixation on at least one side may not be applicable in 18 to 23\% of patients. Mandel, et al.\textsuperscript{17} reported that in 11.7\% of specimens the height of one or both isthmi was less than 5 mm. In the present study three (15\%) of 20 isthmi were considered high risk.

Many authors have recommended a preoperative evaluation of the width of the C-2 isthmus by using a CT reconstruction\textsuperscript{1,5,6,9,15,17,20} and some authors have advised that the insertion of the screw should be abandoned if the isthmus is too narrow.\textsuperscript{1,5,20,22,24} Furthermore, other authors have used additional devices to increase the accuracy of the screw path. Goffin, et al.\textsuperscript{11} used a custom-made drill guide that was designed based on three-dimensional CT scans of C-2. The use of a navigation system is a promising option, and some successful results have been reported.\textsuperscript{2,24,25} These systems are expensive, however, sometimes involving time-consuming procedures, and still require resolution of some technical problems.\textsuperscript{24}

Considering the anatomical course of the VA, the safest screw path is via the most posterior and medial part of the isthmus.\textsuperscript{10} This should hold true in all cases, and our method is therefore universally applicable when the isthmus is wider than the screw diameter. Madawi, et al.\textsuperscript{15} have reported that “in general terms, it would seem to be advisable always to aim “high” at the top of the tubercle, although this presents the greatest technical difficulty for surgeons.” Our device makes it easy to insert screws with such a trajectory. Furthermore, the devices required in our procedure are much less expensive, and the procedure itself is less time consuming than that required in the application of the aforementioned specialized devices. The idea of an aiming device, however, is not new. In 1994, Jeanneret\textsuperscript{14} reported the use of the original aiming device, which was perhaps based on the same concept as ours, although he did not use a flexible system or cannu-
lated screws; however, he did not describe the technique in detail. Gebhard, et al., assessed the safety and accuracy of screw placement using Jeanneret’s device in human cadavers, concluding that the device allowed the safe placement of instrumentation. In the present study, all screws but one were inserted as planned, although one screw breached the cortex of the vertebral groove, which occurred in a case with a high-riding VA, and the screw deviation was only 1 to 2 mm. Therefore, our device can be considered to be sufficiently safe.

In our technique, the screw is typically directed superior to the anterior arch of C-1 (Fig. 4), which differs from the usual method in which the screw is directed to the C-1 anterior arch. In other words, the screw trajectory we use is slightly more perpendicular than is usual. It is very difficult to insert the screw in this trajectory by using a solid drill and screwdriver because the back of the patient usually prevents the surgeon from inserting the screw at too steep angles; however, the flexible insertion system makes the insertion easy.

One of the disadvantages of our technique is its relative inaccuracy in the mediolateral direction compared with its accuracy in the sagittal direction. In the present study, one screw breached the cortex of the vertebral groove, and in another case the screw did not make adequate purchase on the C-1 lateral mass. In the former case the breach was caused by a 1- to 2-mm lateral deviation of the screw from the ideal position, rather than a deviation in the sagittal plane. In the latter case the subluxation was incompletely reduced, and the screw was directed too medially. Therefore, we now prefer a parallel positioning of the screws to a convergent positioning. Another disadvantage of our technique is possible occipitocervical joint injury because the screw path is more perpendicular and the screw may more easily perforate the superior articular surface of C-1. Four of 20 screws perforated the superior articular surface of C-1 without causing any side effects (Fig. 4).

In conclusion, our technique involving an aiming device allows more accurate, simpler, and safer screw placement, thus making atlantoaxial transarticular screw fixation less stressful for the surgeon. Finally, it must be emphasized that our technique does not necessarily preclude the preoperative evaluation of the course of the VA, because some anomalous VA courses may prohibit screw placement altogether.

References


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