J Neurosurg Spine 5:172–177, 2006

Atlantoaxial stabilization with the use of C1–3 lateral mass screw fixation

Technical note

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✓Atlantoaxial stabilization has evolved from simple posterior wiring to transarticular screw fixation. In some patients, however, the course of the vertebral artery (VA) through the axis varies, and therefore transarticular screw placement is not always feasible. For these patients, the authors have developed a novel method of atlantoaxial stabilization that does not require axial screws. In this paper, they describe the use of this technique in the first 10 cases.

Ten consecutive patients underwent the combined C1–3 lateral mass–sublaminar axis cable fixation technique. The mean age of the patients was 62.6 years (range 23–84 years). There were six men and four women. Eight patients were treated after traumatic atlantoaxial instability developed (four had remote trauma and previous nonunion), whereas in the other two atlantoaxial instability was caused by arthritic degeneration. All had VA anatomy unsuitable to traditional transarticular screw fixation.

There were no intraoperative complications in any of the patients. Postoperative computed tomography studies demonstrated excellent screw positioning in each patient. Nine patients were treated postoperatively with the aid of a rigid cervical orthosis. The remaining patient was treated using a halo fixation device. One patient died of respiratory failure 2 months after surgery. Follow-up data (mean follow-up duration 13.1 months) were available for seven of the remaining nine patients and demonstrated a stable construct with fusion in each patient.

The authors present an effective alternative method in which C1–3 lateral mass screw fixation is used to treat patients with unfavorable anatomy for atlantoaxial transarticular screw fixation. In this series of 10 patients, the method was a safe and effective way to provide stabilization in these anatomically difficult patients.

Key Words • **vertebral artery** • **cervical spine** • **fracture** • **fusion** • **fixation**

Instability at the atlantoaxial junction commonly occurs following traumatic fracture of the axis or is due to degenerative processes. Since Magerl and Seeman[20] first described the technique of atlantoaxial fixation, the use of transarticular screw fixation of this joint has become the preferred method.[1,4,6,10,11,15,21] Although the procedure-related complication rate is relatively low, certain complications can be devastating.

One of the more troubling complications is damage to one or both VAs, the incidence of which has been reported to range between 2.6 and 4.1%.[6,32] Although this complication has not been described in many large series, the potential for a devastating neurological outcome exists with this technique.[1,4,11] In fact, the authors of a study from our institution demonstrated that 18 to 23% of patients had VA anatomy on at least one side that was considered too dangerous for transarticular screw placement.[26] Because of this potentially serious complication, several alternative techniques for atlantoaxial fixation have been developed.[7,12,29,31] In the present study we report a novel technique of fixating the atlantoaxial complex by using C1–3 lateral mass screw fixation in conjunction with C-2 sublaminar wires.

Abbreviation used in this paper: VA = vertebral artery.

Clinical Material and Methods

Beginning in June 2001 at our institution, the technique of fixating the atlantoaxial joint by C1–3 lateral mass screw placement, connected by rods and C-2 sublaminar wires, was implemented by the senior author (V.K.H.S.). This technique was developed solely to treat patients who had VA anatomy that was unfavorable for placement of C1–2 transarticular screws, either bilaterally or unilaterally. In addition, the anatomy in each patient was unsuitable for the placement of pars interarticularis or pedicle screws at C-2. The common anatomical consideration in each case was superiorly and medially oriented VAs at the level of the axis. Patient data were maintained prospectively in a database, but some aspects of the data were obtained in a retrospective manner. Thus, the study is appropriately classified as a retrospective case series. Approval to access the patients' data was obtained from the Institutional Review Board of St. Joseph's Hospital and Medical Center.

In each case, the patient was placed in a Mayfield headholder in gentle flexion. The amount of flexion needed for the screw trajectories was significantly less than that required for placing atlantoaxial transarticular screws. After a midline suboccipital and upper cervical incision was made, the soft tissue was dissected to expose the C-1 posterior arch, C-2 lamina, and C-3 lateral masses. In each case, the main goal was to stabilize the unstable atlantoaxial junction. The reason for extending the construct down to C-3 was the inability of proper screw fixation at C-1 because of the unfavorable anatomy, as described earlier. In two patients, however, the construct was extended to C-4 because of the concern of poor bone quality. The C-1 lateral mass screws were placed as previously described.[8,12,27] Briefly, after exposure of the C-1 lateral masses, pilot holes were drilled and 3.5-mm-diameter fully threaded screws with polyaxial heads were inserted under fluoroscopic guidance to traverse the majority of each lateral mass. Bicortical purchase was not the explicit goal for each C-1 lateral mass screw. In each case a commercially available hardware system (Vertex [Medtronic, Inc., Minneapolis, MN]; or Axon [Synthes Spine, Paoli, PA]) was used for fixation.

After the C-1 screws had been placed, the C-3 lateral mass screws were inserted using the standard technique described by Jeanneret, et al.[16] Two sublaminar braided cables (Medtronic, Inc.) were then positioned under the axial lamina and each was secured to the ipsilateral titanium rod connecting C-1 and C-3. In each patient, an autologous hip autograft was obtained and secured between the C-1 and C-2 lamina using a C-1 sublaminar braided cable attached to the C-2 spinous process, as previously described.[2] A cross-link between the two rods was placed in the interlaminar space between C-2 and C-3. A schematic of the construct is shown in Fig. 1.

Postoperatively, nine patients were placed in rigid cervical collars. One patient wore a halo brace that had been placed to treat an axial fracture sustained prior to the C1–3 fixation procedure. The status of the patients' fusion was followed using serial radiographs, and clinical outcomes were determined by routine clinic visits and telephone follow-up interviews.

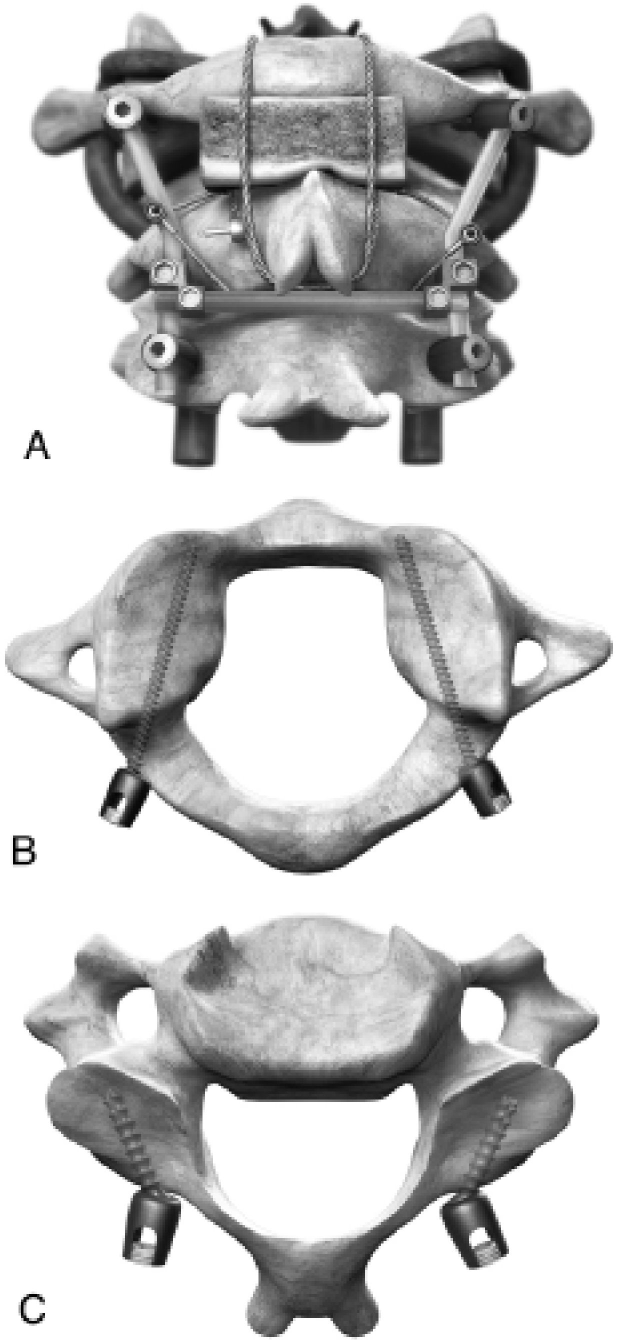

FIG. 1. Schematic illustrations showing the technique of C1–3 lateral mass fixation with C-2 sublaminar wiring and graft placement. Posterior view (A) of the final construct. Axial views of the lateral mass screws in C-1 (B) and C-3 (C). Reprinted with permission from Barrow Neurological Institute.

Results

Between June 2001 and May 2005, 10 patients were treated with this novel method of atlantoaxial fixation. The demographic information for each patient is shown in Table 1. The average age for all patients (six men and four women) in the series was 62.6 years (range 23–84 years). Eight of the 10 patients presented after traumatic injury, which led to atlantoaxial instability. Initial treatment with atlantoaxial fixation had failed in four of these patients. One patient had degenerative instability due to rheumatoid arthritis, and another patient underwent a transoral odontoidectomy followed by C1–3 fixation to treat degenerative instability. All patients had unfavorable VA anatomy at the level of the axis on at least one side, which precluded the use of transarticular screw fixation (Fig. 2).

In eight patients the fixation spanned from C-1 to C-3. Figure 3 shows an intraoperative photograph of a typical final construct. In the other two patients, the construct was

TABLE 1

*Summary of demographic data in 10 patients treated using the C1–3 fixation technique**

Case No.	Age (yrs), Sex	Diagnosis	Procedure	FU (mos)	Outcome
1	40, M	acute C1–2 distraction	C1–3 lat mass screw fixation	NA	returned to home nation lost to F/U
2	42, M	prev odontoid fx w/ instability from failed fusion	C1–3 lat mass screw fixation	NA	lost to F/U
3	84, F	acute odontoid fx	C1–3 lat mass screw fixation	27	fusion, no complications
4	79, F	C-2 synovial cyst w/ myelopathy & C2–3 instability	transoral odontoidectomy & C1–4 lat mass fixation	NA	died at 2 mos postop (respiratory failure)
5	23, M	acute C-2 fx	C1–3 lat mass screw fixation after C2–3 ACDFP	16	fusion, no complications
6	74, M	acute odontoid fx	C1–3 lat mass screw fixation	19	fusion, no complications
7	82, F	prev odontoid fx & nonunion	C1–3 lat mass screw fixation	9	fusion, mild pain at graft site
8	60, F	C-2 degenerative cyst & C2–3 instability	C1–3 lat mass screw fixation	11	fusion, no complications
9	63, M	prev odontoid fx & nonunion	C1–3/4 lat mass screw fixation	4	fusion, no complications
10	79, M	prev odontoid fx & nonunion	C1–3 lat mass screw fixation	6	fusion, no complications

*ACDFP = anterior cervical discectomy, fusion, & plating; FU = follow up; fx = fracture; NA = not available; prev = previous.

extended to C-4 based on preoperative concerns about poor bone quality. One patient with a severe hangman fracture and atlantoaxial instability underwent C2–3 anterior cervical fixation before placement of the posterior construct. Nine patients were fitted with a rigid cervical collar after the procedure. One patient remained in a halo brace, which he had worn for 3 months to treat a previous axis fracture.

There were no intraoperative complications, and postoperative imaging studies confirmed excellent screw placement in all patients (Fig. 4). The mean hospital stay was 7.5 days (range 3–18 days). Four patients were discharged home, four were discharged to rehabilitation facilities, and the remaining two were discharged to skilled nursing facilities. One patient discharged to a rehabilitation facility was readmitted to the hospital with respiratory distress and died 6 weeks later. She was a 79-year-old woman who had undergone a transoral odontoidectomy to treat spinal canal compression followed by posterior C1–3 fixation for degenerative atlantoaxial instability.

Adequate follow-up data were available in seven of the 10 patients. The three patients who did not undergo follow up included the patient who died, one patient who was discharged to a skilled nursing facility outside the country, and a patient who was lost to follow up after 6 weeks. The average follow-up duration for the remaining seven patients was 13.1 months (range 4–27 months). In all of these patients there was radiographic evidence of a stable construct at last follow up. There were no long-term hardware failures, and only one patient complained of graft site pain.

Discussion

We have described a technique for fixation of the atlantoaxial joint in patients in whom the anatomy was not amenable to traditional transarticular screw fixation. This technique eliminates the risk of VA injury, which is a concern during transarticular screw placement.[6,32] The major drawback to this new method is the loss of motion at the

FIG. 2. Axial (A) and sagittal (B and C) reconstructed computed tomography scans obtained in a patient with an atlantoaxial distraction injury treated using the C1–3 fixation technique. Note the high-riding and medially oriented transverse foramina bilaterally in the axis *(black arrows)*.

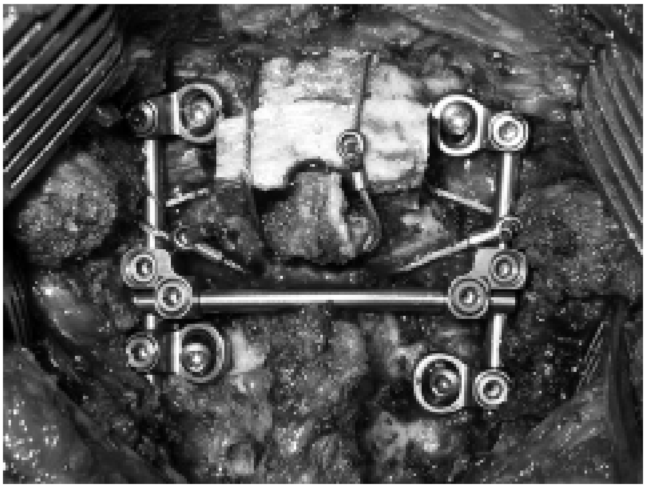

FIG. 3. Intraoperative photograph showing the final construct.

C2–3 level, which we believe is insignificant considering the overall loss of motion due to the atlantoaxial fixation. Even so, we believe that this method is only an alternative to transarticular screw placement to be used in patients at greater risk for VA injury or who have other variant anatomical conditions that make other methods of atlantoaxial fixation infeasible.

Transarticular screw placement has been the preferred method of atlantoaxial fixation since it was first reported by Magerl and Seeman in 1987.[20] The clinical outcomes achieved using this technique solely for atlantoaxial instability have been reported in several large series,[1,4,11,15] and the fusion rates have varied from 82.6 to 100%. This range compares favorably with posterior wiring techniques alone when the patient is maintained in a halo fixation device until fusion occurs.[2] Because the vast majority of patients treated with transarticular screw fixation only need a rigid cervical collar after surgery, this approach has supplanted wiring alone for atlantoaxial instability.

The biomechanical superiority of transarticular screw fixation over wiring alone has been demonstrated.[23,24] Compared with other atlantoaxial screw fixation techniques, the ability of transarticular screws to restrict motion has been varied. Transarticular screws have been shown to be inferior to screw–rod constructs, especially during flexion and extension.[17,18] In those reports, however, the constructs were tested without the addition of posterior wiring. When these two techniques have been tested with posterior wiring, there has been no difference in motion restriction between them.[14,22]

We have recently tested the technique described in this report and compared it with both transarticular screw fixation and the recently described axial translaminar screw technique.[30,31] This work has been presented in abstract form only. In terms of restricting motion we found that the C1–3 technique was comparable to transarticular screw and axial translaminar screw placement.[13] The C1–3 construct was slightly less rigid than transarticular screws during flexion and axial rotation but superior to the translaminar screws during lateral bending and axial rotation. Investigators of a recent biomechanical study, however, found the translaminar technique to be equally restrictive of motion compared with a screw–rod fixation technique.[9] We believe that these small differences between techniques are most likely clinically insignificant regarding adequate fixation in allowing fusion. Because they all significantly restrict motion compared with the unstable state, they will perform adequately to permit fusion.

Although transarticular screw fixation has been shown to be a safe and effective technique for treating atlantoaxial instability, there is the potential for VA damage and subsequent catastrophic neurological injury. A recent survey of neurosurgeons demonstrated a rate of known VA injury of 2.4% and a suspected injury rate of 1.7% per patient treated.[32] These injuries, however, only led to a neurological deficit in 3.7% of patients with a VA injury, and the overall risk for a neurological injury from VA compromise was 0.2% of all patients treated with this technique. These rates are similar to recent series that demonstrated between 0.4 and 8.2% of VA injury per patient treated and a neurological injury rate of 0 to 1.6% from these injuries.[1,6,19] Additionally, a series in the pediatric population demonstrated a VA injury rate of 3%.[5] Other large series, however, have demonstrated no incidence of VA damage.[4,10,11] Given the extremely serious sequelae that may result from VA injury, controversy surrounds the level of acceptable risk using the transarticular screw technique.

The potential for VA injury in which the transarticular screw fixation technique is used can be minimized with careful screening using preoperative computed tomography scanning. One of the most common anatomical variants that places a patient at greater risk of VA injury is a high-riding transverse C-2 foramen. This may occur in up to 23% of patients selected for atlantoaxial fixation.[26] If

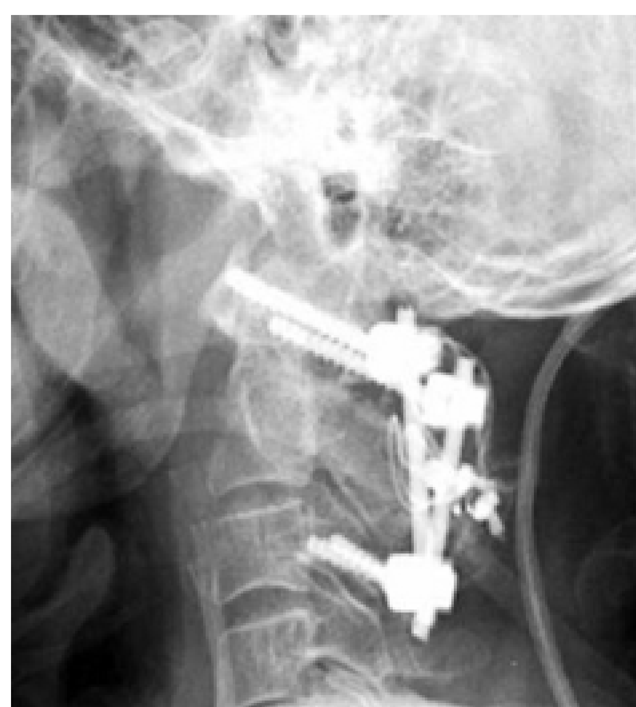

FIG. 4. Postoperative lateral radiograph confirming excellent screw and graft placement.

this variant is only present on one side, a unilateral transarticular screw may be placed in conjunction with the posterior wiring. This technique was associated with similar fusion rates as bilateral screws in a small clinical series.[28] When tested biomechanically, the unilateral technique provided significant rigidity but did not perform as well as bilateral screws.[25] These two techniques, however, were not tested side by side, and the comparison was based on reported rates of rigidity achieved after bilateral transarticular screw placement.

In another technique of atlantoaxial fixation, lateral mass screws are placed in the atlas which is connected via a rod or plate to the C-2 pedicle or pars interarticularis screws.[7,12,27,29] This technique allows biomechanical rigidity similar to that provided by transarticular screws.[14,22] Additionally, many believe that the risk of VA injury is less with this technique compared with transarticular screw placement. Indeed, there have been no reported VA injuries in more than 200 patients treated using this technique.[7,12,27,29] Because the axial screw travels just medial to the transverse foramen using this technique, there is still the potential for VA injury. In fact, analysis of a recent study in cadavers demonstrated impingement on the transverse foramen in 12.5 to 25% of axial screws placed, depending on the method used.[3]

Only two methods of atlantoaxial screw fixation virtually eliminate the risk to the VA and provide adequate fixation: the axial translaminar technique and the novel method of C1–3 fixation presented here. Both are excellent alternatives in patients with unfavorable anatomy for transarticular screw placement. The drawback to the translaminar technique is the inability to place a bone graft under tension held in place by cables between the posterior arches of C-1 and C-2. Also, the high profile of the screw heads in the axis may be problematic in patients of small stature. Given these potential limitations, excellent clinical results have been attained using this technique.[30,31] The main drawback of using the C1–3 technique is loss of normal C2–3 motion. When considering the amount of motion lost from the atlantoaxial fixation, we believe that the small additional restriction is insignificant compared with the benefit of risk reduction gained from this technique.

Conclusions

We present the first reported series of a technique for atlantoaxial stabilization. In this technique the lateral masses of C-1 to C-3 were fixated using polyaxial screws and rods, which were then connected to the axis using sublaminar wires and coupled with a standard posterior atlantoaxial wiring of an autologous bone graft. This technique was safe and provided excellent fixation and fusion. This technique is most appropriate for patients who are not suitable to undergo traditional transarticular screw fixation for atlantoaxial instability because it presents no risk of injury to the VA.

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Manuscript received January 12, 2006.
Accepted in final form May 8, 2006.
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