Posterior atlantoaxial stabilization: new alternative to C1–2 transarticular screws

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Object. Surgical treatment of atlantoaxial instability has evolved to include various posterior wiring techniques including Brooks, Gallie, and Sonntag fusions in which success rates range from 60 to 100%. The Magerl–Seemans technique in which C1–2 transarticular screws are placed results in fusion rates between 87 and 100%. This procedure is technically demanding and requires precise knowledge of the course of the vertebral arteries (VAs). The authors introduce a new C1–2 fixation procedure in which C-1 lateral mass and C-2 pedicle screws are placed that may have advantages over C1–2 transarticular screw constructs.

Methods. A standard posterior C1–2 exposure is obtained. Polyaxial C-2 pedicle screws and C-1 lateral mass screws are placed bilaterally. Rods are connected to the screws and secured using locking nuts. A cross-link is then placed. Fusion can be performed at the atlantoaxial joint by elevating the C-2 nerve root.

The technique for this procedure has been used in four cases of atlantoaxial instability at the author's institution. There have been no C-2 nerve root– or VA-related injuries. No cases of construct failure have been observed in the short-term follow up period.

Conclusions. Atlantoaxial lateral mass and axial pedicle screw fixation offers an alternative means of achieving atlantoaxial fusion. The technique is less demanding than that required for transarticular screw placement and may avoid the potential complication of VA injury. The cross-linked construct is theoretically stable in flexion, extension, and rotation. Laminectomy or fracture of the posterior elements does not preclude use of this fixation procedure.

KEY WORDS • atlantoaxial stabilization • cervical spine • screw fixation • pedicle

Various techniques of atlantoaxial fixation have been described in the literature. Since Gallie[12] reported atlantoaxial arthrodesis by using a posterior wiring and autologous graft technique in 1939, various authors have reported modifications of the Gallie procedure in which wires or interlaminar clamps are used. Magerl and Seemann introduced the technique for C1–2 transarticular screw fixation in 1979. The C1–2 transarticular screw procedure is technically demanding and requires precise intraoperative and radiological knowledge of VA anatomy to minimize the risk of causing iatrogenic injury.

We introduce a new C1–2 fixation technique originally described by Jurgen Harms; the procedure requires C-1 lateral mass screw and C-2 pedicle screw placement and may have several significant advantages over previously performed posterior fixation techniques.

CLINICAL MATERIAL AND METHODS

Four patients with atlantoaxial instability were treated with a new fixation technique at our institutions between 1999 and 2001. Fixation was performed using the Depuy-AcroMed Summit polyaxial screw system (Raynham, MA) in all cases. The goal of the surgical procedure is to achieve atlantoaxial stability by placing C-1 lateral mass screws and C-2 pedicle screws, avoiding or minimizing the risk associated with C1–2 transarticular screws.

Operative Technique

The procedure requires the patient to be placed in a prone position after induction of general anesthesia while the head is secured in a Mayfield holder and maintained in a neutral position. When severe instability or spinal cord compression is present, a cervical collar or other rigid-type orthoses is used while turning the patient to reduce the risk of SCI. Lateral fluoroscopy is performed at intervals during the procedure. The posterior suboccipital and cervical region is prepared and draped in the usual fashion as for a C1–2 fusion procedure. A posterior C1–2 exposure is obtained, and self-retaining retractors are used to maintain the exposure.

The C-2 pedicle and C-2 nerve root are cleared of soft tissues, which can induce variable amounts of venous bleeding controllable with bipolar electrocautery and gentle Gelfoam/thrombin application. Fusion at C1–2 is accomplished by elevating the C-2 nerve root to visualize the joint, decorticating the joint by using a curette or a high-speed drill, and packing the joint with small bone fragments obtained from the adjacent lamina or iliac crest.

The C-1 and C-2 screw entry points, trajectories, and depths are illustrated in Fig. 1. The C-1 lateral mass screw

Abbreviations used in this paper: AP = anteroposterior; CT = computerized tomography; SCI = spinal cord injury; VA = vertebral artery.

trajectory is 0° to 10° medial in the AP plane through the midportion of the lateral mass with an entry point immediately inferior to the C-1 posterior arch. The C-2 nerve root exits laterally from the spinal canal overlying the C1–2 joint and must be protected during the drilling of the pilot hole and subsequent screw placement. A high-speed drill may be needed rather than an awl to start the pilot hole precisely, which is drilled with a 3-mm bit. A caudal-to-rostral trajectory toward the anterior tubercle of C-1 is used, as seen on the lateral fluoroscopic view, and is drilled through the anterior cortex of the lateral mass to obtain bicortical purchase (Fig. 2). The pilot hole is then tapped, and a long 26- to 28-mm minipolyaxial screw is placed with the screw head above the C-1 posterior arch.

The C-2 screw entry point is in the inferior midportion of the facet joint, similar to the point used in C1–2 transarticular screw placement (Fig. 1). The trajectory is also similar to that used for transarticular screws but is directed more caudally and medially to the transverse foramen. A pilot hole is drilled and tapped to a 14- to 18-mm depth for screw placement (Fig. 3). A preoperative CT can be studied and used to choose adequate screw depth to avoid lengths that could potentially penetrate the transverse foramen. Contoured longitudinal rods are placed in the polyaxial screw heads and secured in position. A cross-link is then placed to complete the reconstruction. A completed construct is shown in Fig. 4.

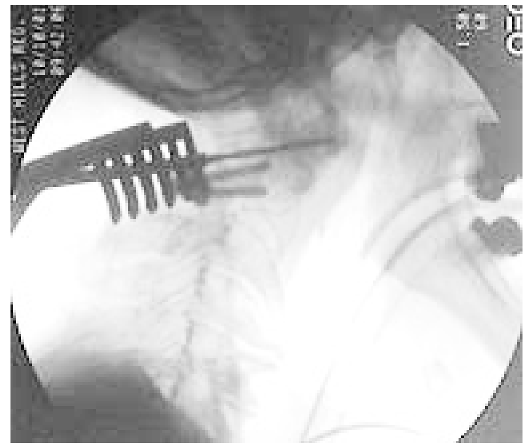

Fig. 2. Intraoperative lateral fluoroscopic image demonstrating the drill orientation for placement of the C-1 screws. The anterior cortex is penetrated for bicortical purchase.

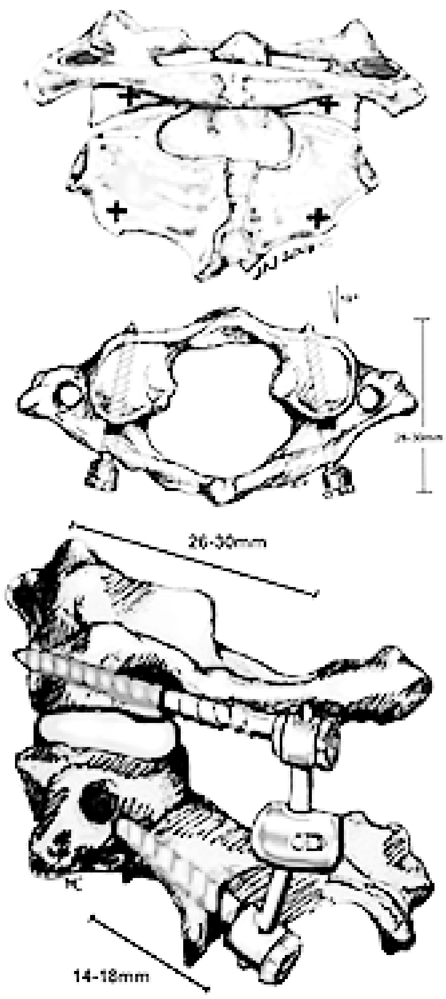

Fig. 1. *Upper:* The entry points for the C-1 lateral mass and C-2 pedicle screws are demonstrated. Note that the C-1 lateral mass screw entry point is located just beneath the lateral arch of C-1. *Center:* Axial schematic of the C-1 screw trajectory. These screws are angled 0 to 10° medially and should penetrate the anterior cortex for bicortical purchase. *Lower:* Lateral schematic demonstrating C1–2 screw trajectory and depth of penetration. Note, again, the bicortical purchase of the C-1 screws. Note that the C-2 screws stop short of the transverse foramen.

RESULTS

The fixation technique in this fusion procedure was successfully applied in all cases. No VA injuries occurred, nor were any C-2 nerve root injuries or SCIs documented. There were no cases of instrumentation failure. Because fusion is difficult to assess radiographically within the C1–2 lateral masses, the success of fusion is determined clinically and by obtaining and assessing flexion–extension radiographs 3 months postoperatively. Successful fusion at 4 to 12 months follow up was documented in all patients.

ILLUSTRATIVE CASE

Presentation. This 82-year-old Caucasian woman with a medical history of rheumatoid arthritis presented with cervical myelopathy. She had a several-month history of neck pain and progressive difficulty with upper-extremity fine motor coordination and difficulty with ambulation. She deteriorated clinically 1 week prior to presentation.

Examination. Physical examination demonstrated findings that were consistent with severe cervical myelopathy. We found that she had difficulty with manual fine motor skills and had bilateral Hoffmann signs. Diffuse hyperreflexia in the upper and lower extremities with pathological spreading was noted. Her gait was spastic.

Sagittal T_2-weighted MR images of the cervical spine are presented in Fig. 5. She was started on a course of intravenous steroid medication, and some improvement was shown. Surgical intervention was recommended.

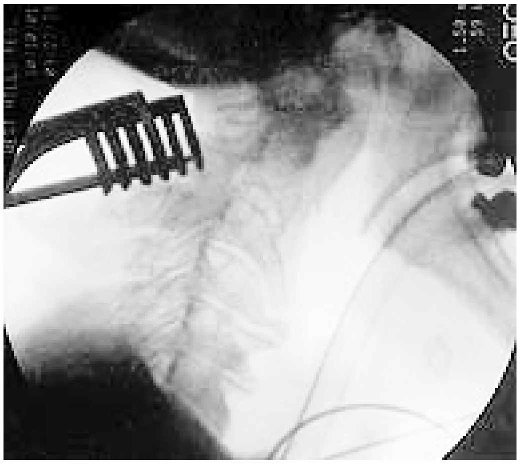

Fig. 3. Intraoperative lateral fluoroscopic image revealing drill orientation for C-2 pedicle cannulation. Note that the caudal-to-rostral angle is slightly less than that of transarticular screws, allowing penetration of the pedicle and avoiding the C1–2 joint.

Operation and Outcome. The patient underwent a posterior C-1 decompressive laminectomy and C1–2 posterior fusion in which the aforementioned technique was used. Intraoperative fluoroscopy was performed. She tolerated the procedure, and there were no postoperative complications. Postoperative AP and lateral radiographs of the cervical spine were obtained (Fig. 6). A postoperative CT scan of the cervical spine (Fig. 7) demonstrated the position of the C-1 lateral mass and C-2 screws.

DISCUSSION

Atlantoaxial instability may arise secondary to various pathological conditions such as trauma, inflammatory arthritis, tumor, infection, developmental anomalies, or skeletal dysplasia. The atlantoaxial joint has the greatest mobility of any spinal motion segment in flexion, extension, and rotation. Stability at this joint is conferred by the dens and the ligamentous structures surrounding it, including the transverse, apical, and alar ligaments. The typical indications for atlantoaxial fusion are documented or progressive junctional instability, as occurs in cases of rheumatoid arthritis.

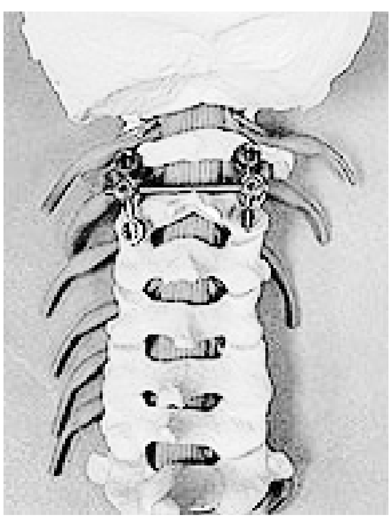

Fig. 4. The completed construct is shown in a sawbones model. The C-1 and C-2 pedicle screws have been placed with a cross connector.

Previous Atlantoaxial Wiring Techniques

Various techniques are available for fixation of the atlantoaxial joint. Posterior C1–2 wiring techniques were introduced in 1939 by Gallie.[12] He reported a technique for C-1 sublaminar and C-2 spinous process wiring in which he used iliac crest bone graft. Brooks and Jenkins[7] modified the technique by placing sublaminar wires bilaterally at C-1 and C-2 with interposed iliac crest graft. Further modification of the Gallie technique, introduced by Sonntag in 1991, involved placing a wire under the lamina of C-1, around an interposed graft, and around the spinous process of C-2.[9] In this technique the difficult sublaminar wire placement at C-2 and its associated risks of SCI were avoided. The rates of successful fusion range from 60 to 100% when the posterior wiring techniques are used.[2,3,7,9,13,24] The interlaminar clamp was also used as a fixation device for atlantoaxial fusion, but generally poor results were achieved. Whereas they eliminate the potential hazard of sublaminar wire placement, these clamps may become dislodged and occupy the area necessary for bone grafting. Clamp-related failures have been reported in more than 20% of the published series.[23,26] Some degree of success has been reported using posterior wiring and clamp techniques; however, failures may be due to the fact that the clamp constructs allow considerable motion in rotation and translation.[8]

Atlantoaxial Transarticular Screws

In an effort to enhance the fusion rate at C1–2, Magerl and Seemann[22] developed a fixation procedure involving the transarticular screw technique. The advantages of this technique are twofold. First, it does not require intact posterior elements or the passage of sublaminar wires. These are important when laminectomy is required or there is trauma-induced disruption of the posterior elements, al-

Fig. 5. Preoperative T_2-weighted magnetic resonance sequences revealing compression of the cervical cord by the posterior arch of C-1. Note that cord signal change is present.

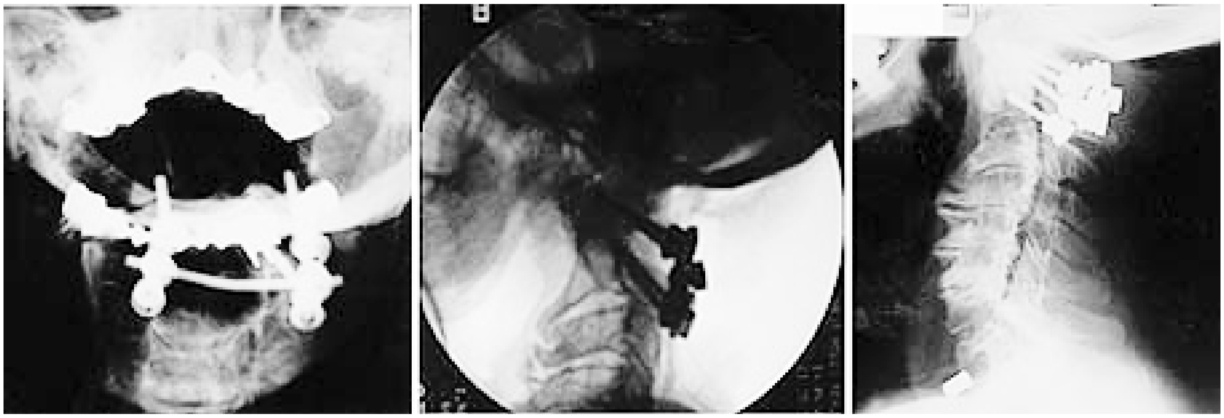

Fig. 6. *Left:* Postoperative AP view of the atlantoaxial construct. *Center* and *Right:* Lateral views of the atlantoaxial construct.

though this injury often requires postoperative halo vest immobilization. Second, the transarticular screws limit rotatory and translational motion, thereby increasing the stability of the construct and enhancing fusion rates. Analysis of biomechanical data demonstrates that this construct provides greater stability in reduction of rotatory movement but is similar to that of the wiring techniques in AP translation.[14,16] When combined with a posterior wiring technique, transarticular screws significantly limit motion in flexion, extension, and rotation,[25] and fusion rates between 87 and 100% have been reported[15,18,19,21,28] Although the fusion rate is high, the technique remains technically demanding and precise knowledge of the VA anatomy is necessary to avoid vascular injury. In a recent survey of the literature pertaining to transarticular screw placement the authors reported the risk of VA injury to be 2.2% per screw and the risk of neurological deficit to be 0.1% per screw.[29] In addition, aberrant anatomy demonstrated on preoperative imaging studies precludes the placement of transarticular screws in 18 to 23% of patients.[27] To enhance the accuracy of transarticular screw placement, image guidance can be used theoretically to reduce the risk of aberrant screw placement.[5]

Axial Pedicle Screws

Transpedicular screw fixation of C-2 was first described in 1964 by Leconte[20] for the management of traumatic-induced spondylolisthesis of the axis. Transpedicular screw fixation at C-2 has been described for the treatment of traumatic lesions of the cervical spine[1,6,19] but not for C1–2 fixation. The osseous anatomy that defines the C-2 pedicle has been the subject of some debate in the literature.[4,11,21] The precise distinction between the C-2 pedicle and the pars interarticularis has not been made. The pedicle has been defined as the portion beneath the superior facet and anteromedial to the transverse foramen. The pars interarticularis or isthmus is defined as the narrower portion between the superior and inferior facets. In a cadaveric study in which the safety of C-2 pedicle screw fixation was studied, the authors demonstrated that the anatomy in each patient must be assessed both pre- and intraoperatively by direct inspection of the C-2 pedicle to avoid perforating the pedicle and injuring the VA or spinal cord.[10] No in vivo studies addressing VA injury rate or medial wall perforation of the C-2 pedicle have been performed.

The Harms C1–2 Fusion Technique

By performing the technique described in this paper for C-1 lateral mass and C-2 pedicle screw fixation, many of the concerns with conventional wiring and transarticular techniques are eliminated or avoided. There is no need for sublaminar wire passage and the postential risk of SCI is

Fig. 7. *Upper:* Postoperative CT scan of the cervical spine after Harms atlantoaxial fusion. The C-1 lateral mass screws pass through the lateral mass at 0° and ideally penetrate the anterior cortex. *Lower:* Postoperative CT scan of the cervical spine after Harms atlantoaxial fusion. The C-2 screws are shown passing medially to the transverse foramina.

reduced. Similar to transarticular fixation, this procedure does not require the presence of intact posterior elements at C-1 or C-2; thus, it is attractive in cases in which laminectomy is required or the integrity of the C-1 ring or the of C-2 lamina is compromised. The need for halo vest immobilization is also eliminated. This rigid segmental fixation and cross-linking technique provide a unique and previously unattainable means of achieving atlantoaxial stabilization that will likely change the accepted treatment of C1–2 instability.

Potential pitfalls associated with the C-1 lateral mass screw placement procedure include lack of identification of and injury to the exiting C-2 nerve root. Because of its proximity, the C-1 screw could irritate the C-2 nerve root, or the C-2 root could be injured during the necessary traction required for C-1 screw placement. In addition, the risk of VA injury has not been well documented in cases of C-2 pedicle screw placement. In our experience with this technique, there have been no cases of C-2 nerve root injury or VA injury.

CONCLUSIONS

Atlantoaxial fixation can be accomplished using this unique technique for C-1 lateral mass and C-2 pedicle screw/rod placement. Rigid reconstruction, previously unattainable in this problematic region of the spinal column, can now be achieved. Biomechanical testing is indicated to assess the stability of this construct compared with that used in other fusion procedures. In addition, greater experience and longer follow-up periods are indicated to assess fusion rates and clinical outcomes as well as the safety of this procedure.

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