Pediatric atlantoaxial fixation with bilateral, crossing C-2 translaminar screws

Technical note

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The authors describe the cases of three children in whom atlantoaxial instability was caused by os odontoideum, all requiring surgical fixation. Although C1–2 rod/cantilever constructs involving C-2 pedicle screws and C1–2 transarticular screws have been widely applied in adults, only C1–2 transarticular screw fixation has been reported in children. Both of these constructs potentially place the vertebral artery (VA) at risk because of the variable location of the transverse foramen. Atlantoaxial fixation with C-2 translaminar screws has recently been reported in adult cases in which the risk of VA injury was reduced. The authors report the successful results of rigid atlantoaxial fixation in three children in whom bilateral crossing C-2 translaminar screws were placed, and they discuss the possible advantages of this technique in the pediatric population.

KEY WORDS • atlantoaxial fixation • translaminar screw • os odontoideum • pediatric neurosurgery

WHEN instability of the atlantoaxial complex requires surgical stabilization, various procedures may be undertaken in adult patients. For atlantoaxial fixation, posterior wiring methods, such as the Brooks–Jenkins3 and the Sonntag modified Gallie4 approaches, are technically simple procedures but have been associated with high rates of fusion failure because of the absence of rotatory stabilization and because rigid postoperative immobilization is required.18 The transarticular C1–2 screw technique introduced by Magerl10 provides rigid fixation in all axes of motion and yields high fusion rates, but it is technically demanding in adult patients because of the variable location of the transverse foramen and the risk of VA injury.19 Although technically challenging, several small series of pediatric atlantoaxial fixation involving the Magerl transarticular screw technique have been reported.12,13,16

The authors of recent technical reports have described C-2 PS fixation for atlantoaxial stabilization in conjunction with the placement of C-1 lateral mass screws in a rod/cantilever construct.9,14,15 Other authors have reported similar C-1 and C-2 screw fixation constructs connected by rigid plates.6–8 Atlantoaxial rod/cantilever fixation has been proposed as a safer procedure that is applicable in more patients than transarticular screw fixation;14 however, C-2 PS placement remains technically difficult because of the variable location of the transverse foramen. The authors of cadaveric studies have suggested that C-2 PS placement is associated with an unacceptably high rate of violation of the transverse foramen in adult patients.5 No pediatric cases of C-2 pedicle fixations have been reported to date, possibly because of the technical difficulties of placing C-2 PSs in this population.

One author has recently reported on a series of adult patients with atlantoaxial instability in which a novel C-2 fixation technique with bilateral crossing translaminar screws was used.17 Because this technique does not require screw placement near the transverse foramen, there is no risk of VA injury. Furthermore, the technique’s simplicity compared with transarticular screw or C-2 PS fixation may facilitate its application in the pediatric population. We report on the successful treatment of three pediatric patients in whom atlantoaxial instability was corrected using bilateral crossing translaminar screws.

Clinical Material and Methods

We studied three consecutive patients at St. Louis Children’s Hospital with atlantoaxial instability (Table 1). All three patients required posterior cervical fixation extending to include C-2. Preoperative radiography, CT, and MR imaging studies were obtained in all cases. Details of each case will be described separately.

Surgical Treatment

All patients were placed prone with the head and cervical spine maintained in the neutral position in a Mayfield headholder. The posterior upper cervical spine and craniocev-
small ball probe was used to palpate the length of the hole and we verified that no cortical breakthrough into the spinal canal had occurred. A 4-mm-diameter polyaxial screw was carefully inserted along the same trajectory (Fig. 2 lower left). The screw length varied between 16 and 28 mm, depending on the length of the laminar surface as determined on the preoperative images. In the final position, the screw head remained at the junction of the spinous process and lamina on the left, with the length of the screw within the right lamina.

A small cortical window was then made at the junction of the spinous process and lamina of C-2 on the right, close to the caudal aspect of the lamina. Using the aforementioned technique, a 4-mm-diameter screw was placed into the left lamina, with the screw head remaining on the right side of the spinous process (Fig. 2 lower right). After placing the screw, all exposed laminar surfaces were decorticated using the high-speed drill. Rods were then cut to size and inserted. For constructs including the axis, each C-1 lateral mass screw was connected to the ipsilaterally projecting screw head of the C-2 laminar screws, thus fixing each C-1 lateral mass to the contralateral C-2 lamina (Fig. 3).

Tricortical and morcellized autologous iliac crest bone graft was harvested from the right posterior iliac crest in the usual fashion in the two older patients (Cases 1 and 3). Rib graft was harvested in the younger patient (Case 2). Depending on the specific fixation construct, the tricortical graft was inserted between the posterior arch of C-1 and the C-2 spinous process and wedged underneath the rods connecting the C-1 and C-2 screws. The morcellized autologous iliac crest bone graft was packed around the remaining exposed bone surfaces and into the decorticated facet joint complexes. The position of the translaminar screw heads prevented placement of a supplementary wire construct to hold the graft in place; however, by carefully using rongeurs to shape the iliac crest to fit between the laminae (of C-1 and C-2, or C-2 and C-3) and then wedging the graft under the overlying rods, the grafts were securely held in place.

Illustrative Cases

Case 1

History and Examination. After this 16-year-old boy presented with complaints of neck pain, imaging studies demonstrated an os odontoideum. Flexion radiography revealed 7-mm atlantoaxial translation that corrected upon extension of the neck. Despite recommendations of neurosurgical intervention, the family chose initially to treat the lesion conservatively. One year later, the patient returned with progressive neck pain and after having sustained several falls. On neurological examination, he exhibited normal motor and sensory responses, but hyperreflexia was present. Magnetic resonance imaging revealed no signal change within the spinal cord.

Operation. Because of debilitating neck pain, the patient underwent atlantoaxial fusion in which C-1 lateral mass screws and bilateral crossing translaminar screws were placed in the axis.

Postoperative Course. Radiography studies demonstrated normal atlantoaxial alignment. The patient was treated with a cervical orthosis for 6 weeks. By 3 months, he was free of pain. At 6 months, dynamic radiography revealed stability.

### Table 1

Summary of demographic and procedural data in three patients with atlantoaxial instability*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Cause of Instability</th>
<th>Fixation Level</th>
<th>Screw Size (mm)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16, M</td>
<td>os odontoideum</td>
<td>C1–2</td>
<td>4 × 28</td>
<td>4 × 30</td>
</tr>
<tr>
<td>2</td>
<td>3, M</td>
<td>os odontoideum, platybasia, basilar invagination</td>
<td>occipit–C2</td>
<td>NA</td>
<td>4 × 16</td>
</tr>
<tr>
<td>3</td>
<td>16, M</td>
<td>os odontoideum</td>
<td>C1–2</td>
<td>4 × 28</td>
<td>4 × 28</td>
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* NA = not applicable.
† Values represent width × diameter of the screws.
of the atlantoaxial complex (Fig. 4), and axial CT scanning demonstrated good placement of the laminar screws in the axis (Fig. 5). At 1 year postsurgery, he remains pain free.

Case 2

Presentation and Examination. This 3-year-old boy presented with respiratory arrest due to a presumed foreign-body aspiration. Once extubated, the child was found only to be moving his right lower limb. Magnetic resonance imaging of the head and cervical spine, as well as spinal CT scanning, demonstrated significant foramen magnum disease including os odontoideum, platybasia, and basilar invagination.

First Operation. Initially the child underwent a C-1 decompression and an attempted noninstrumented fusion, in which onlay bone graft was placed between the occiput and C-2, as well as halo placement performed by another surgeon. While in rehabilitation, the child recovered upper- and lower-extremity strength during a period of several months. He continued, however, to experience intermittent episodes of left hemiparesis that would resolve during the course of a week. Repeated MR imaging of the cervical spine revealed no bone fusion as well as significant residual foramen magnum compression.

Second Operation. The patient underwent a posterior fossa decompression and occipitoulantoaxial fusion in which we placed occipital screws and bilateral crossing translaminar screws in the axis.

Postoperative Course. He was kept in a halo vest for 3 months postoperatively, at which time CT scanning demonstrated solid fusion and normal cervical alignment. Radiography studies also revealed normal alignment. He has experienced no further episodes of intermittent motor weakness. One year later, he remains neurologically intact and is doing well.

Case 3

Presentation and Examination. During an evaluation for growth delay, spondyloepiphysial dysplasia was diagnosed in this 16-year-old boy. The skeletal survey showed hypoplasia of the odontoid and an os odontoideum, but the cervical abnormalities produced no symptoms or neurological deficits in the patient. Dynamic cervical radiographs, however, revealed a 7-mm atlantoaxial translation in flexion that corrected upon extension of the neck. Flexion and extension sagittal MR imaging revealed no evidence of cord impingement, but significant narrowing of the spinal canal.

Operation and Postoperative Course. The patient underwent posterior atlantoaxial fusion in which we placed C-1 lateral mass screws and bilateral crossing translaminar screws in the axis. He was treated with a cervical orthosis for 6 weeks. By 3 months after the operation, he was free of pain; dynamic radiography showed no evidence of abnormal motion. At 1 year postoperative, he remains pain free and neurologically intact.

Results

All patients underwent operative treatment. There were no complications, and postoperative stability was excellent. All C-1 and C-2 screws were placed without incident and no
neurological or vascular complications occurred. The postoperative course in all patients was otherwise unremarkable.

Discussion

Prior to the introduction of rigid screw fixation techniques, the mainstay of surgical fixation of the pediatric atlantoaxial complex was posterior wiring procedures such as those introduced by Gallie, Brooks–Jenkins, and Sonntag (the modified Gallie technique). These techniques have been associated with higher nonfusion rates and often require postoperative halo immobilization.

Screw fixation of the posterior cervical spine typically yields higher fusion rates than posterior wiring procedures, and it obviates the need for rigid external immobilization. This is primarily due to the increased stiffness in rotation and translation, especially in cases of the atlantoaxial fixation. Transarticular C1–2 screws placed using the Magerl technique provide very rigid fixation across the atlantoaxial joint, but the insertion procedure is technically demanding because of the danger of VA injury. The authors of cadaveric studies have shown anatomical anomalies with an incidence of up to 20% in adults, precluding safe transarticular screw placement; analysis of clinical experience has suggested a 4% rate of VA injury during screw placement.

Although successful transarticular screw fixation of the atlantoaxial complex has been extensively reported in adult series, only small series of its use in pediatric populations have been reported. Brockmeyer alone and with coworkers, in the largest series to date, has reported on the treatment of 31 patients younger than the age of 16 years with atlantoaxial instability. Preoperative CT scanning in three patients in this study (10%) revealed anatomy that precluded the safe placement of transarticular screws on one side, whereas the anatomy was shown to preclude bilateral screw placement in another three. All patients in whom anatomical anomalies were absent underwent safe screw placement. Rahimi, et al., reported the successful treatment of two children with transarticular screws, and Wang, et al., reported on 13 patients treated safely with transarticular screw fixation. None of the patients in these small series sustained any neurological or vascular injury as a result of the surgery. In all of these series the investigators concluded that, while technically challenging, atlantoaxial stabilization is possible in the pediatric population when using transarticular screw fixation.

In part because of the anatomical limitations complicating transarticular screw placement in adults, variations of C1–2 screw fixation have been reported in adult patients in whom independent C-1 lateral mass screws and C-2 PSs were connected with either a rigid plate or a rod/cantilever system. Atlantoaxial rod/cantilever fixation has been suggested as a safer procedure, applicable in more patients despite variations in anatomy, because the C-2 screw is
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placed independently of the C-1 screw. Thus, the steep caudorostral trajectory needed for transarticular screws can be avoided and the C-2 pedicle trajectory chosen to minimize the danger of violation of the transverse foramen.

Axial PS placement, however, is still technically challenging and the risk of VA injury persists. The angle of the pedicle and the location of the transverse foramen vary, and proper trajectory of the screw must avoid the transverse foramen in the lateral aspect of the C-2 vertebral body. In cadaveric studies of the C-2 pedicle, investigators have also reported high rates of violation of the transverse foramen during attempted PS placement. Smaller C-2 pedicles or medial localization of the VA may preclude safe C-2 PS placement in some patients. Possibly because of these limitations, C-2 PSs have not yet been reported in the treatment of atlantoaxial instability in the pediatric population.

A novel technique of atlantoaxial fixation involving the application of crossing bilateral translaminar screws in the axis has recently been reported in a series of adult patients. We have now successfully used this technique in the treatment of three pediatric patients with atlantoaxial instability. No neurological or vascular injuries occurred and fusion was demonstrated on postoperative imaging in all cases.

Rigid translaminar screw fixation of the axis removes the risk of VA injury and is applicable to most indications in which the posterior elements of C-2 remain intact. Screw placement is not dependent on the variances in pedicle anatomy or the position of the transverse foramen, and it does not require intraoperative neuronavigation or fluoroscopy. The improved technical ease of screw insertion may also make this method less daunting for the surgeon uncomfortable with transarticular screw placement.

Conclusions

Atlantoaxial instability in the pediatric patient, albeit rare, presents the surgeon with several challenges because of the smaller size of the spine. Previous methods of posterior wiring are technically straightforward but are associated with lower fusion rates and often postoperative halo immobilization. More recent rigid screw fixation techniques have allowed the surgeon to address these limitations, but they are technically challenging even in the adult population.

The application of bilateral crossing translaminar screws in cases requiring rigid atlantoaxial fixation offers a safer method of stabilization in the pediatric population. Because this procedure does not require placement near the transverse foramen, there is little risk of VA injury, and placement is not constrained by variations in the anatomy of the axis.

References


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