Options For Craniocervical Fixation In Very Small Patients

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What Is Very Small?

Small by age?

Small for age?
General concepts:

**Occipitocervical**
- 2 years and above
  - Rigid instrumented fusion, collar, no halo
- Below 2 years (approximately)
  - Bone and cable/wire
  - Collar as a bridge to fusion

**Subaxial**
- 2 years and above
  - Rigid instrumentation, collar, no halo
- Below 2 years (approximately)
  - Posterior bone on-lay
  - Posterior bone and wire/suture/cable
Modern Craniocervical Fusion Techniques

Screw fixation and rigid instrumentation:
Top-loading polyaxial screws with rod or rod/plate connectors

These techniques are VERY ADAPTABLE, and can be used in pediatric patients to about two years of age
Available screws: 3.5 and 4.0 mm OD
Drill OD 2.7 mm
Surgical Management
Abnormal Bony Anatomy: C1 Hemirings
5 y/o Boy with Kniest Syndrome

Atlantal hemi-rings and craniocervical instability: identification, clinical characteristics, and management

Clinical article

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Object. Congenital craniocervical anomalies are relatively common, but anomalies leading to overt craniocervical instability may be difficult to recognize and treat. The authors present a series of patients with atlantal hemi-rings, a disorder resulting in congenital craniocervical instability. Presentation, treatment, imaging, and follow-up data obtained in patients with atlantal hemi-rings were assessed to identify factors relevant to craniocervical instability.

Methods. Nineteen patients were identified with atlantal hemi-rings, defined as a bony discontinuity of the C-1 ring in conjunction with lateral displacement of the C-1 lateral masses (as seen on coronal CT scans). Clinical and radiological characteristics were analyzed, including patient age at presentation, extent of occipitocervical motion, amount of C-1 lateral mass displacement, associated craniovertebral anomalies, integrity of the transverse ligament, and neurological status.

Results. The mean patient age at presentation was 22 months (range birth to 9 years). The mean amount of occipitocervical translation seen on dynamic imaging was 9 mm (range 2-20 mm). Four patients required occipitocervical fusion at presentation. The remaining 15 patients were monitored for a mean of 20 months, and 9 ultimately underwent fusion. Surgery was also recommended for 4 of the remaining 6 children.

Conclusions. This report describes the radiological and clinical characteristics of patients with atlantal hemi-rings and craniocervical instability. The authors believe that this anomaly is the underlying cause of progressive instability in a significant proportion of patients with craniocervical abnormalities. The presence of atlantal hemi-rings should prompt immediate and thorough neurosurgical evaluation. (DOI: 10.3171/2011.7.PEDS11158)

Keywords: atlas • hemi-ring • craniocervical instability • cervical spine • pediatrics
Abnormal Bony Anatomy: C1 Hemirings:
Abnormal Bony Anatomy: C1 Hemirings

Right

Midline

Left
Abnormal Bony Anatomy: C1 Hemirings

- Dens
- Right C1 lateral mass
- Left C1 lateral mass
Abnormal Bony Anatomy: C1 Hemirings
Abnormal Bony Anatomy: C2 Instrumentation Choices

Selection of a rigid internal fixation construct for stabilization at the craniovertebral junction in pediatric patients

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Object: Atlantoaxial and occipitocervical instability in children has traditionally been treated with posterior bone and wire fixation and internal halo orthosis. Recently, successful outcomes have been achieved using rigid internal fixation, particularly C1-2 transarticular screws. The authors describe flow diagrams to help clinicians determine which method of internal fixation to use in complex anatomic circumstances when typical transarticular screw placement is not possible.

Methods: The records of children who underwent either atlantoaxial or occipitocervical fixation with rigid internal fixation over an 11-year period were retrospectively reviewed to define flow diagrams used to determine treatment protocols.

Results: Among the 95 patients identified who underwent atlantoaxial or occipitocervical fixation, the craniovertebral anatomy in 25 patients (11 atlantoaxial and 14 occipitocervical fusions) required alternative methods of internal fixation. Types of screw fixation included loop or rod constructs anchored by combinations of C1-2 transarticular screws (13 constructs), C-1 lateral mass screws (11), C-2 pars screws (24), C-2 transarticular screws (4), and subaxial lamina screws (1). The mean age of the patients (5 boys and 80 girls) was 8.9 years (range 1.3-17 years). All 25 patients with greater than 3-month follow-up duration achieved solid bone fusion and maintained stable constructs on radiographic studies. Clinical improvement was seen in all patients who had preoperative symptoms.

Conclusions: Novel flow diagrams are suggested to help guide selection of rigid internal fixation constructs when performing pediatric C1-2 and occipitocervical stabilization. Use of these flow diagrams has led to successful fusions in 25 pediatric patients with difficult anatomy requiring less common constructs.

Key Words: atlantoaxial stabilization • craniovertebral junction • occipitocervical stabilization • pediatric neurosurgery • rigid internal fixation

“Load Sharing”
Abnormal Bony Anatomy: Unilateral Fixation

Unilateral fixation for treatment of occipitocervical instability in children with congenital vertebral anomalies of the cranio cervical junction

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OBJECT: Patients with occipitocervical (OC) instability from congenital vertebral anomalies (CVA) of the cranio cervical junction (CCJ) often have bony abnormalities that make instrumentation placement difficult. Within this patient population, some bilateral instrumentation constructs either fail or are not feasible, and a unilateral construct must be used. The authors describe the surgical management and outcomes of this disorder in patients in whom unilateral fixation constructs were used to treat OC instability.

METHODS: From a database of CC fusion procedures, the authors identified patients who underwent unilateral fixation for the treatment of OC instability. Patient characteristics, surgical details, and radiographic outcomes were reviewed in each patient. CT scans were performed at least 4 months after surgery to evaluate fusion.

RESULTS: Eight patients with CVAs of the CCJ underwent unilateral fixation for the treatment of OC instability. For 4 patients, the procedure occurred after a failed CC construct failed or infection forced hardware removal. For the remaining 4, it was the primary procedure. Two patients required reoperation for hardware revision and 1 developed resorption requiring revision of the bone graft. Ultimately, 7 patients demonstrated bone fusion on CT scans and 1 had a stable fusion arthrodesis.

CONCLUSIONS: These findings demonstrate that unilateral CC fusion is effective for the treatment of CC instability in children with CVAs of the CCJ in whom bilateral screw placement fails or is not feasible.

KEY WORDS: cranio cervical; instability; scoliosis; fixation; pediatric; congenital vertebral anomalies; unilateral; spine, instrumentation
**Other Options**


**Neonatal C1 TO C2 osteomyelitis leading to instability and neurological decline: novel treatment with occiput-C1-C2 fusion and occiput to thorax growing rods. A case report.**

Glotzbecker MP, Wasser AM, Troy MJ, Proctor M, Emans JB.


**Instrumented fusion in a 12-month-old with atlanto-occipital dislocation: case report and literature review of infant occipitocervical fusion.**

Hale AT, Dewan MC, Patel B, Geck MJ, Tomycz LD.


**Instrumented arthrodesis for non-traumatic craniocervical instability in very young children.**

Janjua MB, Hwang SW, Samdani AE, Pahys JM, Baaj AA, Härtl R, Greenfield JP.


Dickerman RD, Morgan JT, Mittler M.
Atlantoaxial Instability

Study each patient’s anatomy:
Can the bone accept a screw?
Understand C2 pars anatomy
Is there rotation or translation?
Reducibility options
Combination constructs
Grafting options

Atlantoaxial transarticular screw fixation: a review of surgical indications, fusion rate, complications, and lessons learned in 67 pediatric patients

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Study each patient’s anatomy:
Can the bone accept a screw?
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Selection of a rigid internal fixation construct for stabilization at the craniovertebral junction in pediatric patients

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Selection of a rigid internal fixation construct for stabilization at the craniovertebral junction in pediatric patients.
Atlantoaxial Instrumentation

C1-2 Transarticular screws
- Preferred method
- 2 y/o and above
- Simple, elegant
- Technically demanding
- Unilateral screw OK
- Can easily reduce deformities

Goel-Harms construct
- Excellent second option
- Bleeding around C1 screw
- Sacrifice C2 root?
- Less able to reduce deformities
C1-2 Transarticular Screws: Technique

A bone and cable girth-hitch technique for atlantoaxial fusion in pediatric patients

Technical note

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A new technique for performing a posterior rib and multistranded cable atlantoaxial fusion in children is described. The technique has been used successfully, in two patients, 22 and 18 months of age, respectively. In both cases, fusion was used to augment C1-2 transarticular screw fixation, and solid arthrodesis was achieved without a halo orthosis.

Key Words • atlantoaxial joint • spinal fusion • children
Management of subaxial cervical instability in very young or small-for-age children using a static single-screw anterior cervical plate: indications, results, and long-term follow-up

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OBJECTIVE Subaxial cervical instability in very young or small-for-age children is uncommon and typically arises from trauma or skeletal dysplasia. Various operative techniques have been used to achieve stabilization in pediatric patients with evidence of instability, including anterior, posterior, and combined approaches. In this study, the authors report their results with subaxial cervical instability in this patient population treated using a static single-screw anterior cervical plate (ACP) system and allograft fusion.

METHODS In a retrospective chart review, the authors identified all patients 6 years of age or younger who underwent an anterior cervical fusion procedure using a static single-screw ACP system either as a stand-alone construct or as part of an anterior-posterior stabilization procedure. Reasons for fusion included trauma, tumor, and congenital anomalies.

RESULTS Five patients 6 years of age or younger underwent anterior cervical fusion using a static single-screw system during the 19-year study period. Follow-up ranged from 12 to 51 months (mean 26.8 months). Two patients underwent repeat surgery, one 7 days after and the other 21 months after their initial procedure. At last follow-up, a mean vertical growth of 22.8% was seen across the fused segments, with no evidence of kyphotic or lordotic abnormalities.

CONCLUSIONS In very young or small-for-age children, the use of a static single-screw ACP system appears to be a safe and effective option to manage subaxial cervical instability. Bony fusion and continued longitudinal growth occur within the fused segments, with no evidence of long-term cervical malalignment.

http://thejns.org/doi/abs/10.3171/2015.10.SPINE15537

KEY WORDS cervical; instability; anterior; pediatrics
Subaxial Plating

**FIG. 1.** Case 1. Extension (A) and flexion (B) radiographs of the cervical spine showing anterior subluxation of C-3 onto C-4. Sagittal noncontrast CT scan (C) of the cervical spine shows a hypoplastic C-4 vertebral body. Postoperative lateral cervical spine radiograph (D) obtained at 17-month follow-up showing bony fusion around the plate and no evidence of subsidence or hardware failure.

**FIG. 2.** Case 2. A: Sagittal (left), coronal (center), and midsagittal (right) noncontrast CT scans of the cervical spine showing an anterior cervical bone cyst involving the posterior elements of C-2. B: Lateral radiograph of the cervical spine after resection of the cyst showing kyphosis of C-2 on C-3. C: Lateral radiograph of the cervical spine after C2–3 ACDF showing appropriate hardware position but kyphosis at C3–4. D: Lateral radiograph of the cervical spine after C3–4 ACDF and removal of the C2–3 and C2–4 plates. The hardware is in good position and anatomical alignment is maintained.

**TABLE 1.** Demographic and surgical characteristics of 5 patients who underwent fusion with a static single-screw ACP system

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age</th>
<th>Sex</th>
<th>Pathology</th>
<th>Neurologically intact</th>
<th>Preoperatively</th>
<th>Procedure</th>
<th>Follow-Up (mos)</th>
<th>Fusion</th>
<th>Revision</th>
<th>% Vertical Growth</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>55</td>
<td>M</td>
<td>Congenital C-2 pars defect w/ squint/lophosis</td>
<td>Yes</td>
<td>No</td>
<td>C2–3 ACDF</td>
<td>51</td>
<td>Yes</td>
<td>None</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>M</td>
<td>Diastrophic dysplasia w cervical kyphosis</td>
<td>Yes</td>
<td>No</td>
<td>C3-5 fusion, C-4 corpectomy</td>
<td>17</td>
<td>Yes</td>
<td>None</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
<td>F</td>
<td>Klippel-Feil syndrome</td>
<td>Yes</td>
<td>Yes</td>
<td>C2-4 ACDF, Oc-C2 PCE</td>
<td>36</td>
<td>No</td>
<td>C2-4 ACDF due to progressive kyphosis</td>
<td>34</td>
</tr>
<tr>
<td>4</td>
<td>59</td>
<td>M</td>
<td>Traumatic C5-7 posterior dislocation</td>
<td>Yes</td>
<td>Yes</td>
<td>C6-7 ACDF, C6-7 PCE</td>
<td>10</td>
<td>Yes</td>
<td>None</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>78</td>
<td>M</td>
<td>Anosymetrical bone cyst w posterior dislocation kyphosis</td>
<td>Yes</td>
<td>Yes</td>
<td>C3-4 ACDF, C2-4 plating due to kyphosis</td>
<td>12</td>
<td>No</td>
<td>C3-4 ACDF, C2-4 plating due to kyphosis</td>
<td>10</td>
</tr>
</tbody>
</table>

Oc = occiput, PCE = posterior cervical fusion.
Multilevel cervical disconnection syndrome: initial description, embryogenesis, and management

Report of two cases

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Two cases of a previously undescribed cervical spinal anomaly distinct from cervical spondylolysis are presented. The authors report the first detailed description of a congenital vertebral anomaly characterized by multilevel cervical spondylolysis, sagittal deformity, and spinal cord compression. The sine qua non of the condition is a lack of communication between the anterior and posterior columns of the cervical spinal canal, which may occur over several vertebral levels. A kyphotic deformity of the anterior column occurs, whereas the posterior column may have relatively normal alignment. The underlying biomechanical stresses caused by the anterior-posterior column disconnection result in spinal instability and progressive kyphotic deformity, often to a profound degree. Two children, 2 and 3 years of age, presented with congenital multilevel disconnection and myelopathy. In the first stage of treatment, each underwent an anterior decompression, reduction, and reconstruction of the involved segments. This was followed by posterior stabilization and fusion as a separate procedure. In both patients, the myelopathy improved and a solid, circumferential fusion was achieved. The authors’ success in treating these patients indicates that management of these conditions can be based on the principles of deformity correction, spinal cord decompression, and combined anterior-posterior arthrodesis.

Key Words: congenital anomaly • cervical disconnection syndrome • pediatric neurosurgery

Fig. 1. Case 1. A: Sagittal CT scan depicting the reverse swan-neck or buckling sagittal deformity and the hypoplastic pedicles. B: Sagittal T2-weighted MR image showing the degree of spinal cord compression and high signal change within the cord.

Fig. 4. Case 2. Plain lateral x-ray film (A) and sagittal CT scan (C) depicting the buckling deformity of the neck, with the spinal cord compression ventrally as shown in the sagittal MR image (B). The absence of an ossuous bridge between the anterior and posterior elements and the enlarged and abnormally shaped foraminal transverse are seen in initial CT scans (D and E).
Multilevel cervical disconnection syndrome: initial description, embroyogenesis, and management

Report of two cases

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Two cases of a previously undescribed cervical spinal anomaly distinct from cervical spinal dysraphism are presented. The authors report two typical presentations of congenital cervical anomaly characterized by absence of cervical vertebral elements with associated malformation of the spinal canal and cord, in which many cases present with spinal cord abnormality and kyphosis at a cervical level in infants and young children. This entity is distinct from other anomalies, such as diastematomyelia, and congenital cervical spinal dysraphism. The authors present two cases, one of which presents with cervical canal stenosis, kyphosis, and cervical disconnection syndrome at C6-7 level. The second case presents with symptomatic cervical disconnection syndrome at C7-T1 levels. Repair of cervical spinal canal abnormality in these patients may be necessary, and those in need of surgical intervention can be treated with a limited posterior decompression fusion, with or without anterior cervical fusion. The authors conclude that these cases demonstrate the need for further investigation into this newly described entity.

Key Words: congenital anomaly • cervical disconnection syndrome • pediatric neurosurgery

Fig. 5. Case 2. Anteroposterior (A), lateral (B), and flexion (C) plain x-ray films obtained postoperatively. Note the instability that developed at the C6–7 level with flexion; the lateral masses almost become perched. This required an extension of the posterior construct.

Fig. 3. Case 1. Postoperative sagittal CT reconstruction (left) and three-dimensional models (center and right) demonstrating solid anterior and posterior fusion constructs. Right: Note the posterior wire and titanium disc construct.

Fig. 7. Diagrams depicting the reduction, decompression, and reconstruction of the anterior column as performed in our patients. Resection of the kyphos apex is followed by reduction of the deformity (upper) and placement of an interbody graft and fixation devices (lower).

Fig. 8. Drawing depicting our multilevel posterior wiring technique using autologous rib grafts and cables with titanium discs.
3 m/o M with short limbs, dyspnea

Chondrodysplasia Punctata
Long-term Growth

40 Children under 6 years old, 9 centers
3 year minimum follow up
9 AA fusions had mean 30% C/S growth within fusion
16 OC fusions had meaningful growth
9 OC fusions had no growth
6 OC fusions had loss of height (AOD)
Good alignment seen in all
Conclusions:

Occipitocervical options:
On-lay bone
Bone and wire/suture/cable
Semi-rigid construct
Rigid construct

Subaxial options:
ACDF +/- plating
Posterior bone on-lay
Posterior bone and wire/suture/cable

+/- Halo
Thank You