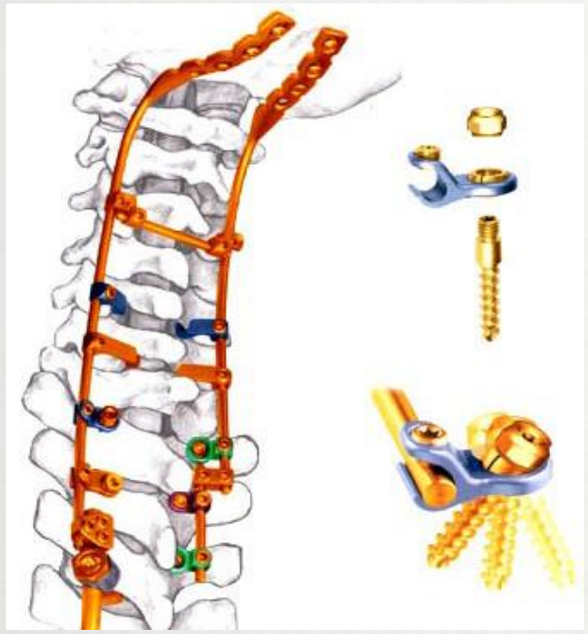
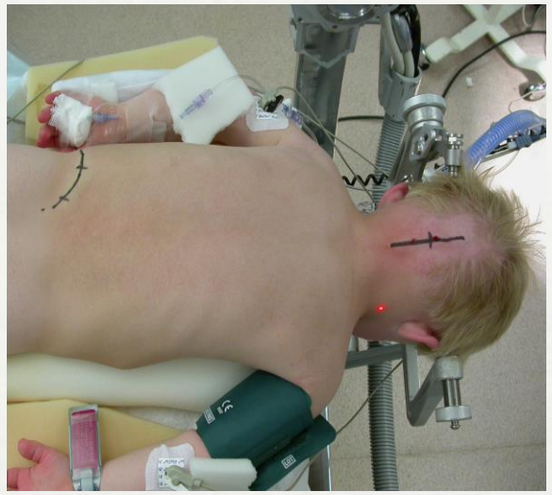
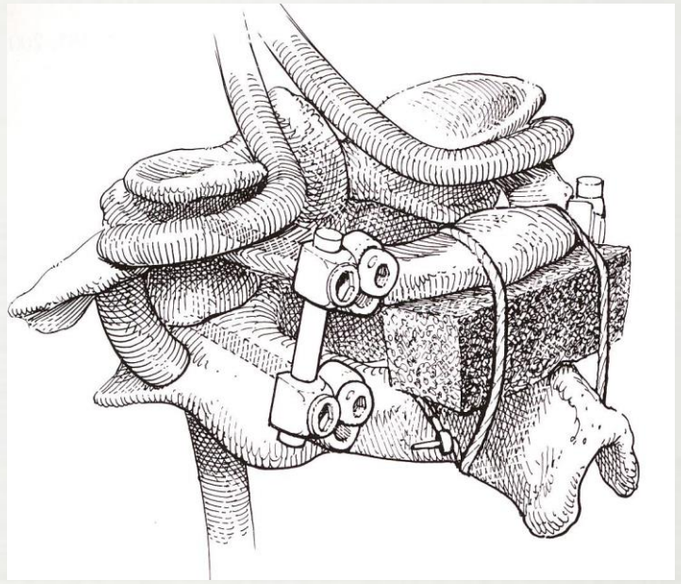
Options For Craniocervical Fixation In Very Small Patients







Douglas Brockmeyer MD
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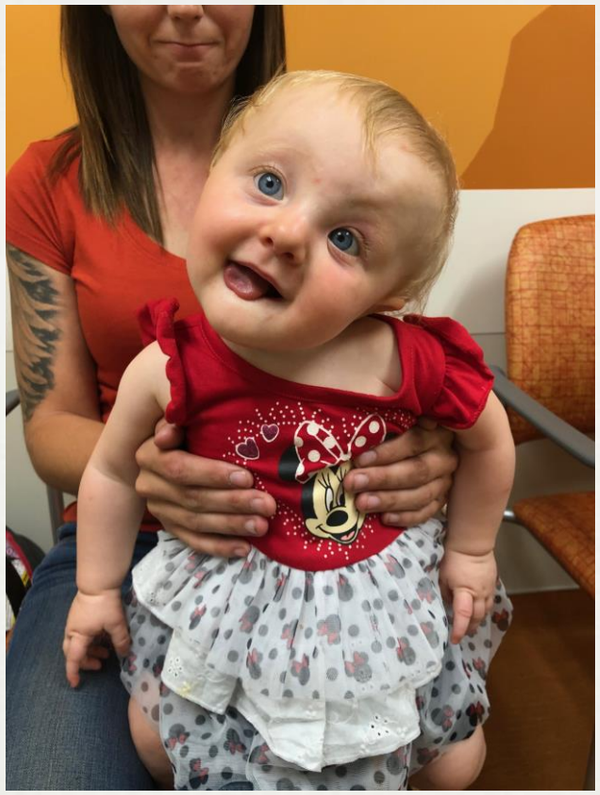
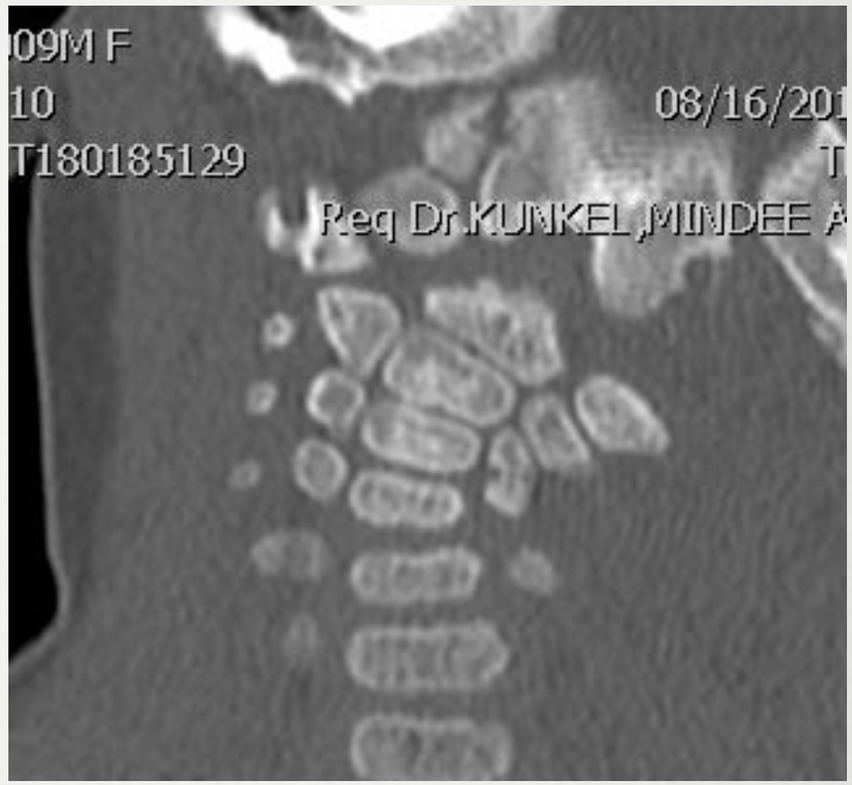
PRIMARY CHILDREN'S MEDICAL CENTER
IHC A Service of Intermountain Health Care

The University of Utah
Division of Pediatric Neurosurgery

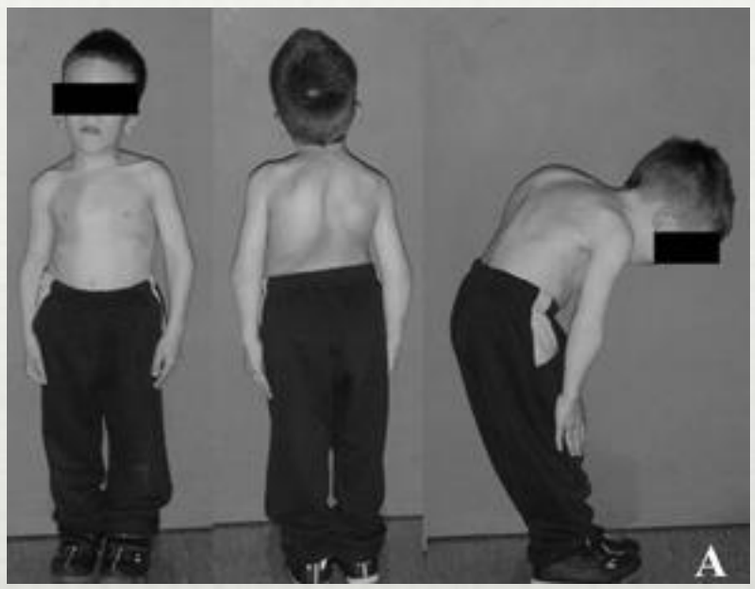
What Is Very Small?

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

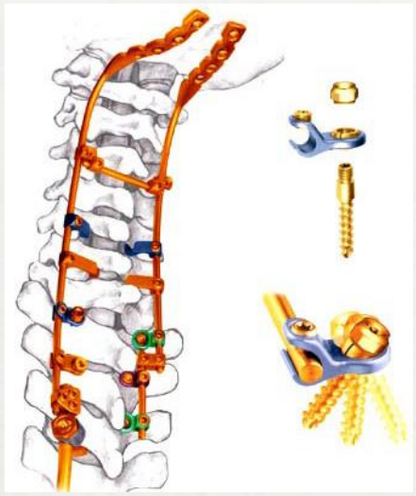
Below 2 years (approximately)

Posterior bone on-lay

Posterior bone and wire/suture/cable

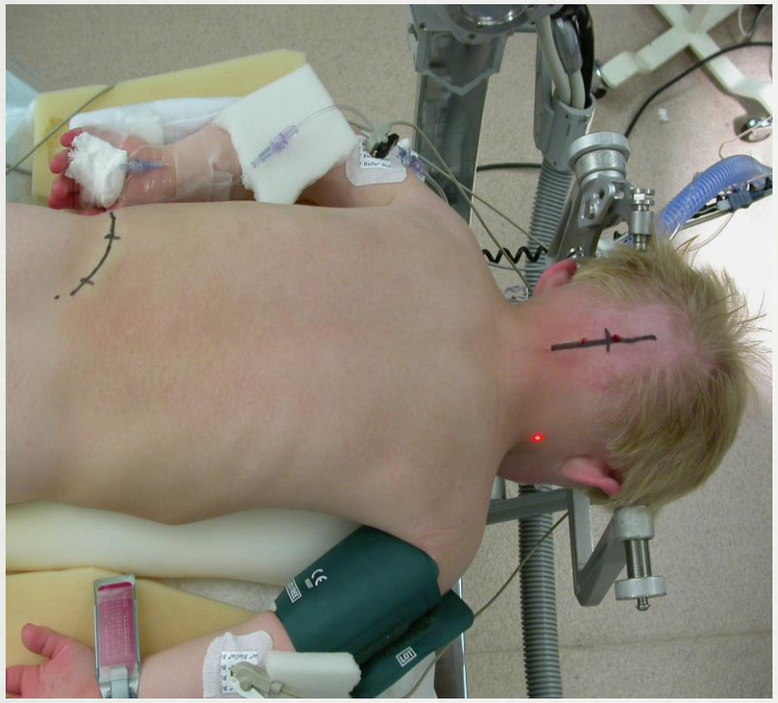
Modern Craniocervical Fusion Techniques

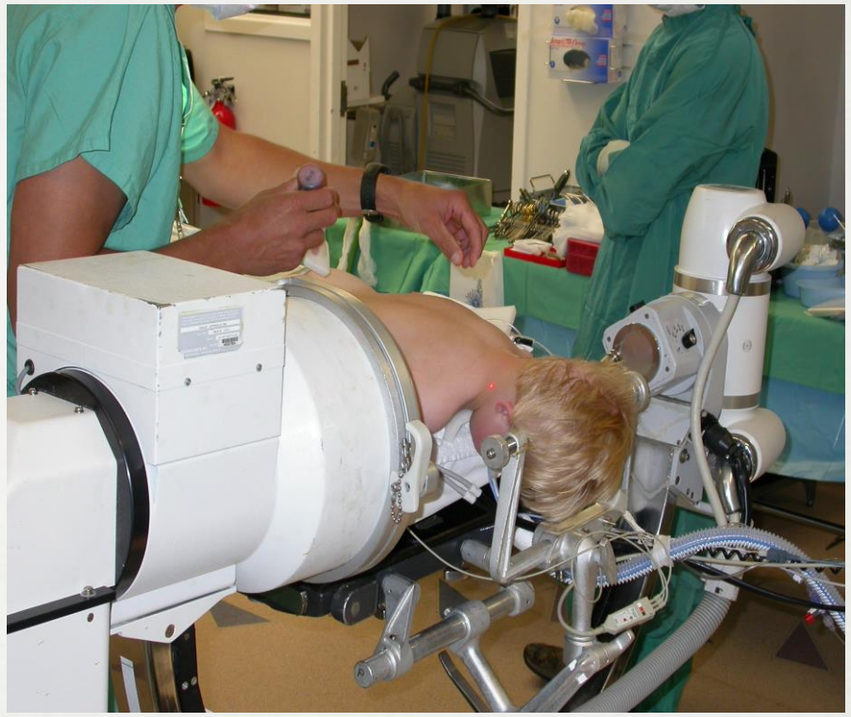
Screw fixation and rigid instrumentation:
Top-loading polyaxial screws with rod or rod/plate connectors

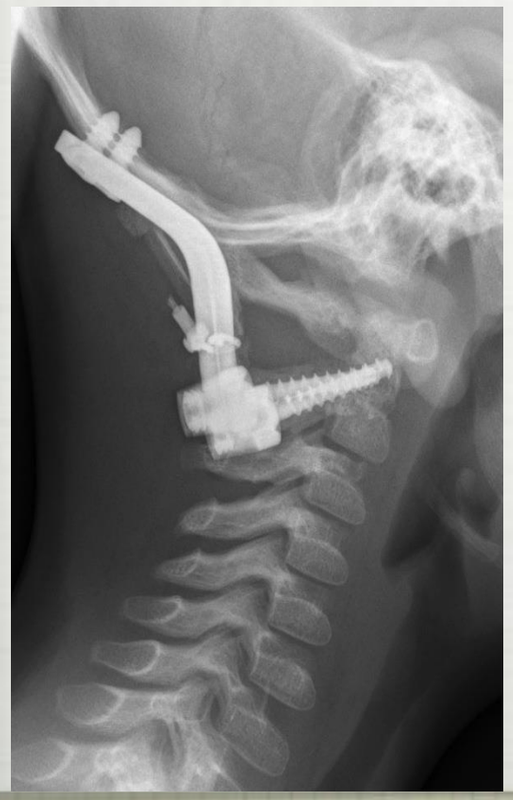


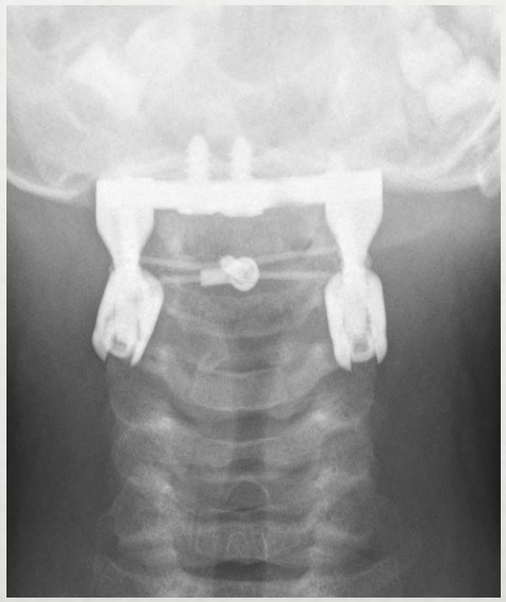
These techniques are VERY ADAPTABLE, and can be used in pediatric patients to about two years of age
Available screws: 3.5 and 4.0 mm OD
Drill OD 2.7 mm

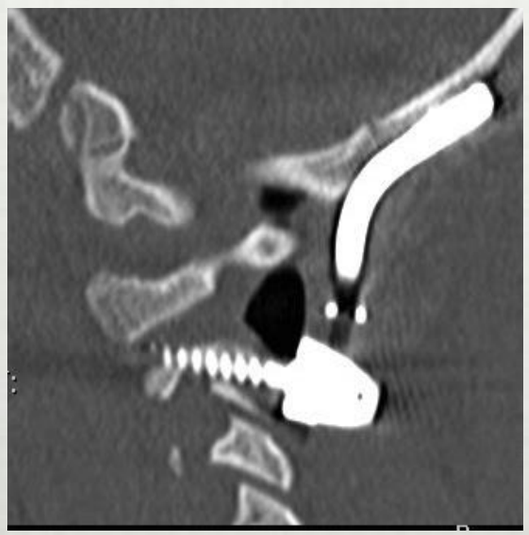
Surgical Management

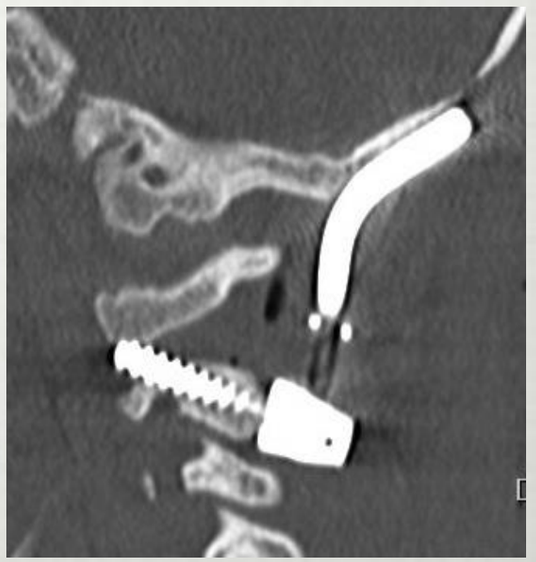




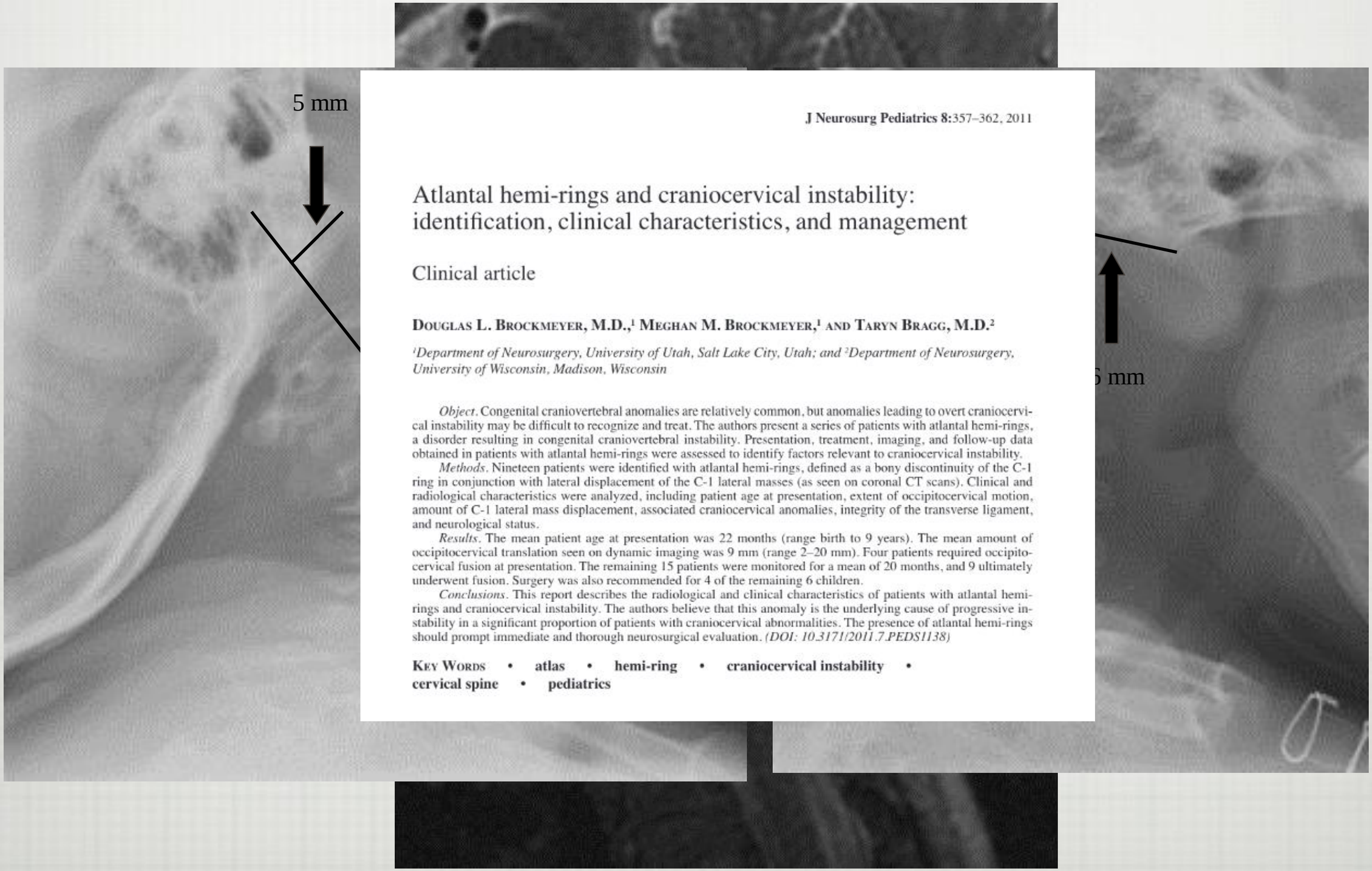








Abnormal Bony Anatomy: C1 Hemirings
5 y/o Boy with Kniest Syndrome



J Neurosurg Pediatrics 8:357–362, 2011

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

Clinical article

Douglas L. Brockmeyer, M.D.,[1] Meghan M. Brockmeyer,[1] and Taryn Bragg, M.D.[2]

[1]*Department of Neurosurgery, University of Utah, Salt Lake City, Utah; and* [2]*Department of Neurosurgery, University of Wisconsin, Madison, Wisconsin*

Object. Congenital craniovertebral 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 craniovertebral instability. Presentation, treatment, imaging, and follow-up data obtained in patients with atlantal hemi-rings were assessed to identify factors relevant to craniocervical instability.

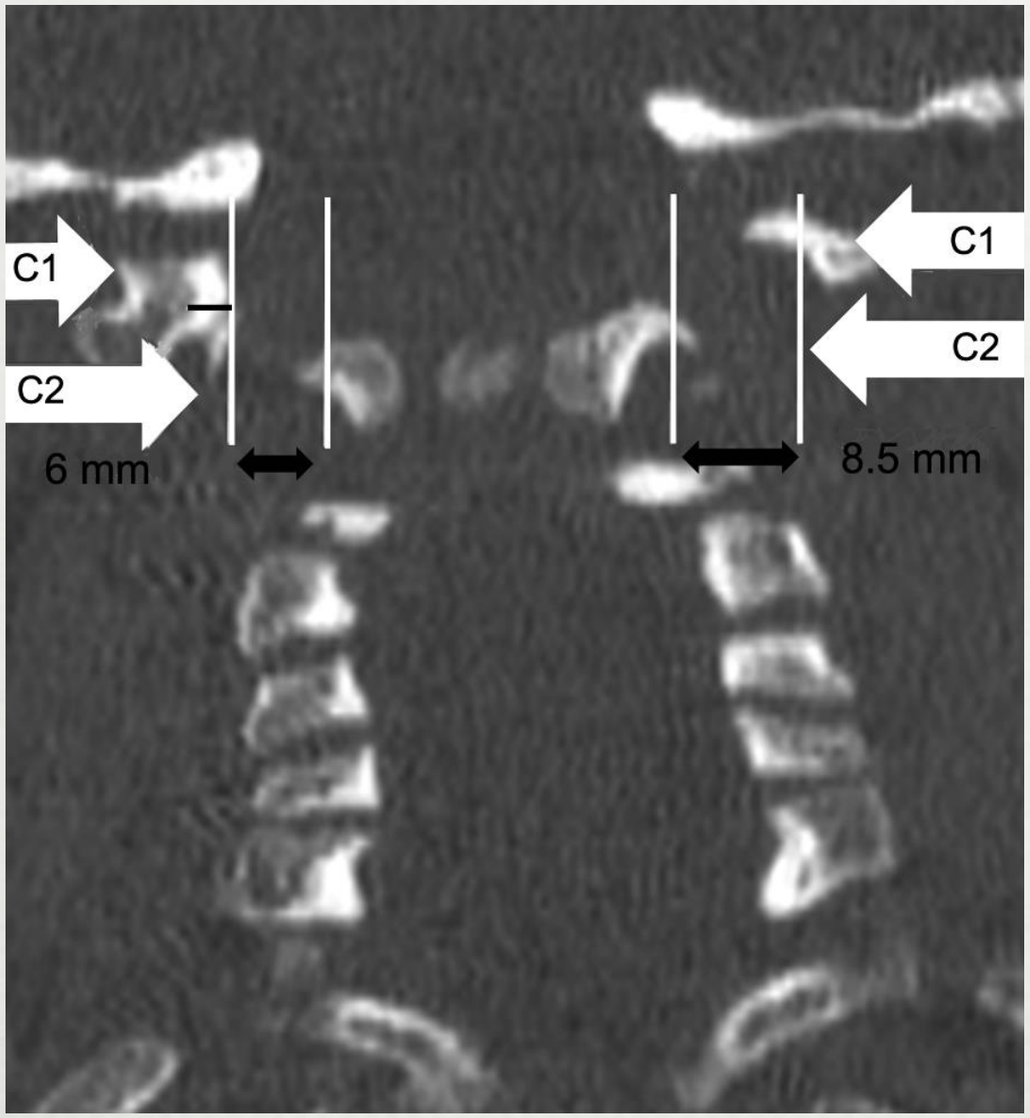
Methods. Nineteen patients were identified with atlantal hemi-rings, defined as a bony discontinuity of the C-1 ring in conjunction with lateral displacement of the C-1 lateral masses (as seen on coronal CT scans). Clinical and radiological characteristics were analyzed, including patient age at presentation,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

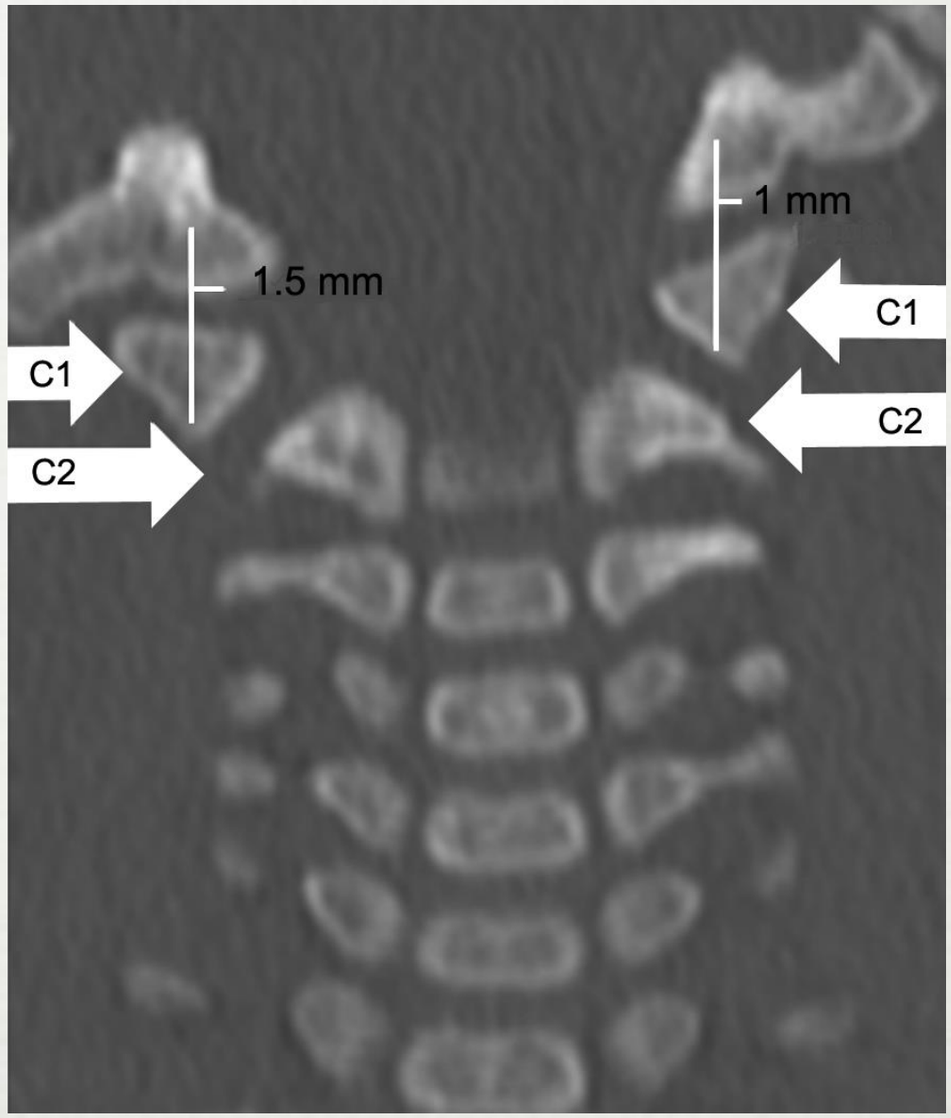
Results. The mean patient age at presentation was 22 months (range birth to 9 years). The mean amount of occipitocervical translation seen on dynamic imaging was 9 mm (range 2–20 mm). Four patients required occipitocervical fusion at presentation. The remaining 15 patients were monitored for a mean of 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.PEDS1138)*

Key Words • **atlas** • **hemi-ring** • **craniocervical instability** • **cervical spine** • **pediatrics**

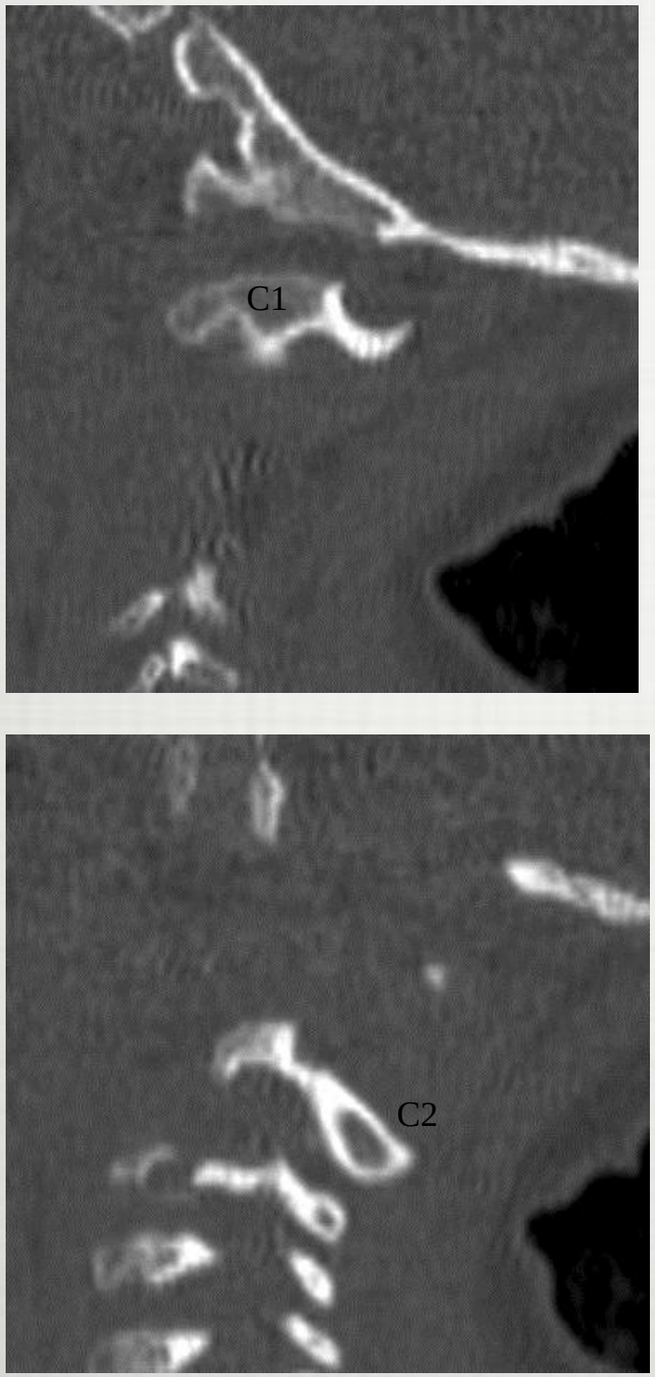
Abnormal Bony Anatomy: C1 Hemirings:





Abnormal Bony Anatomy: C1 Hemirings

Right



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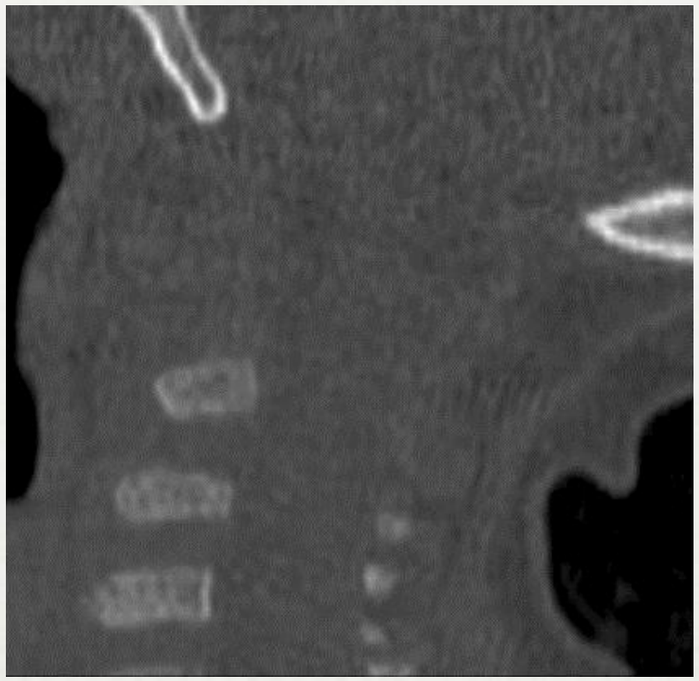

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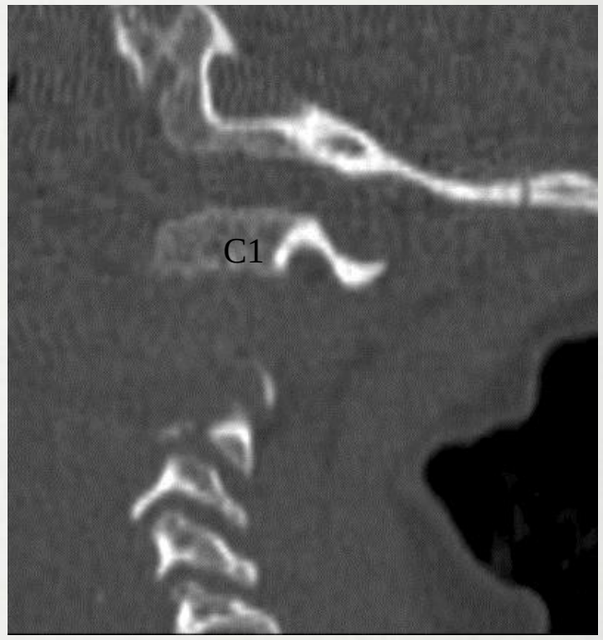
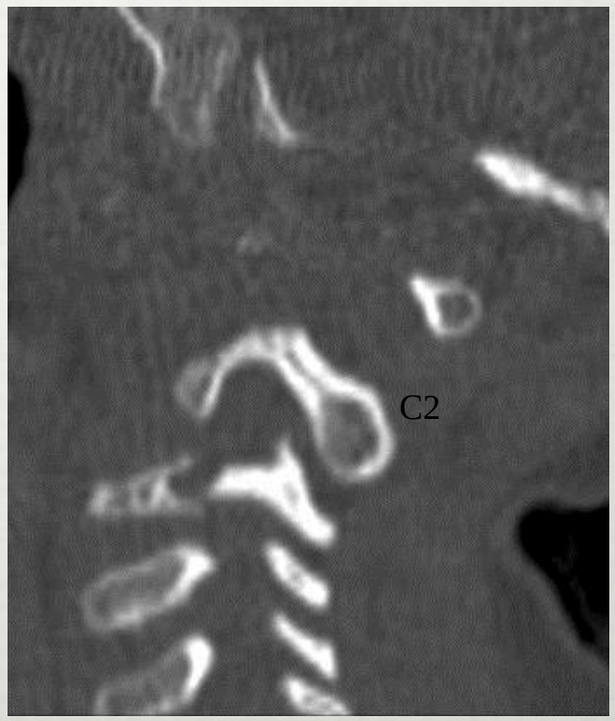
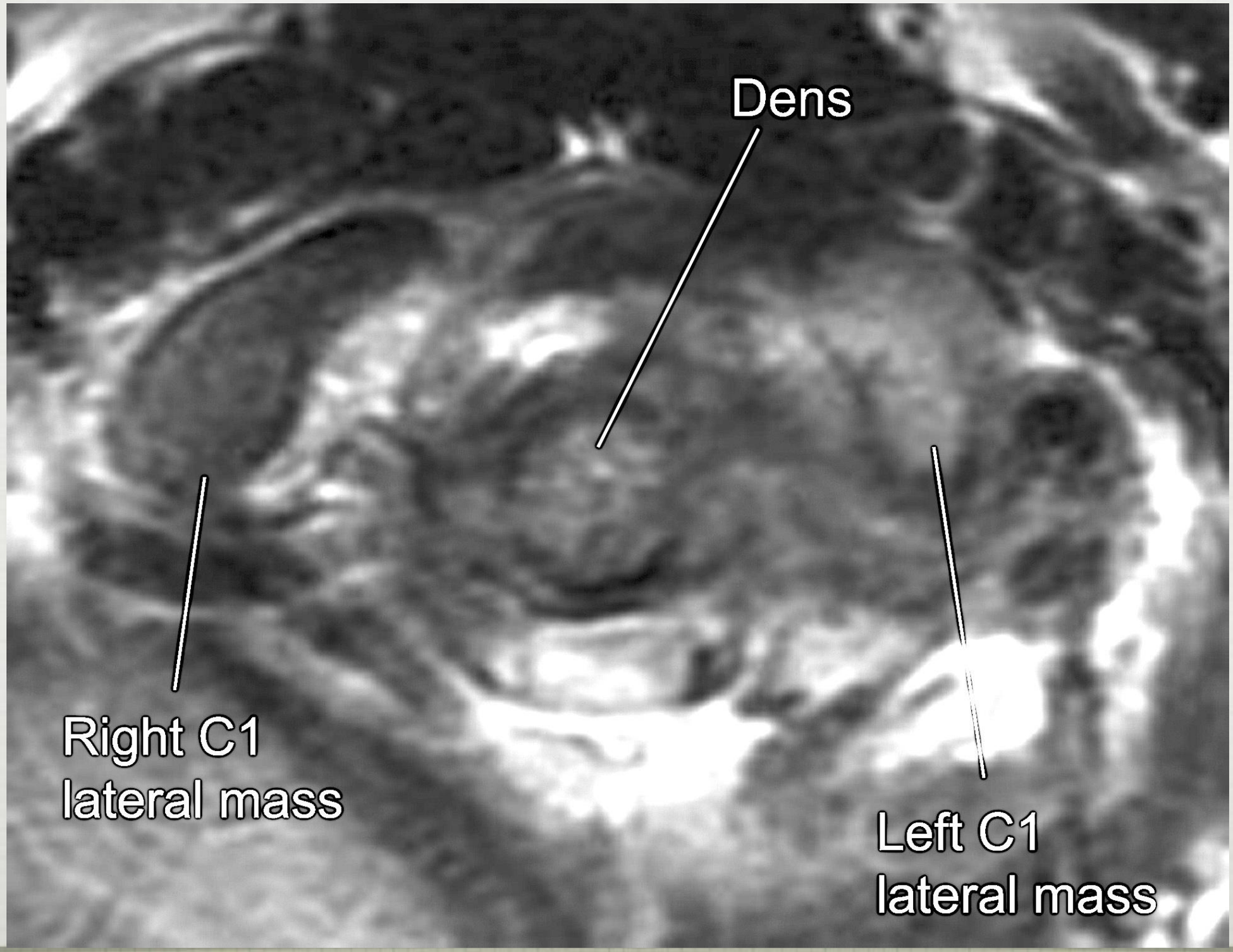




Abnormal Bony Anatomy: C1 Hemirings



Abnormal Bony Anatomy: C1 Hemirings

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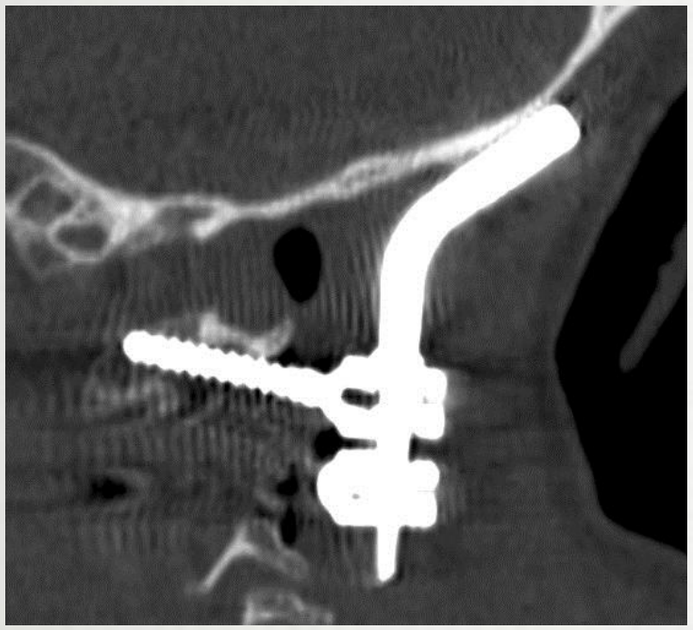

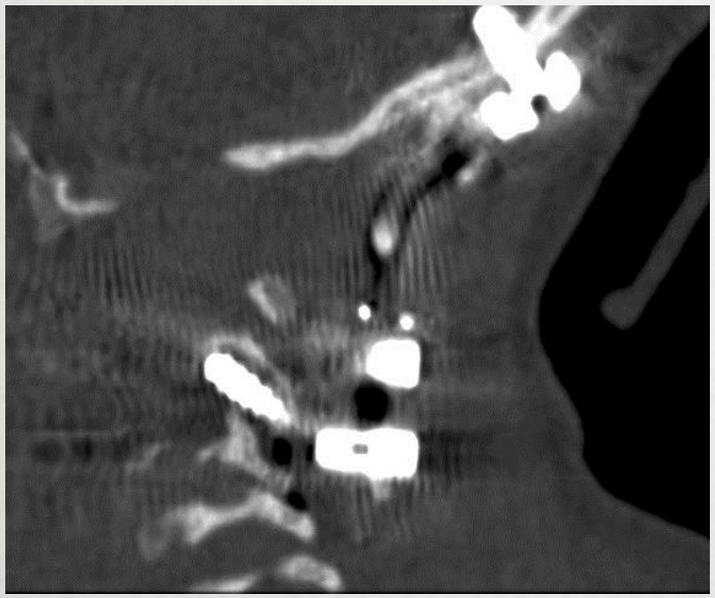

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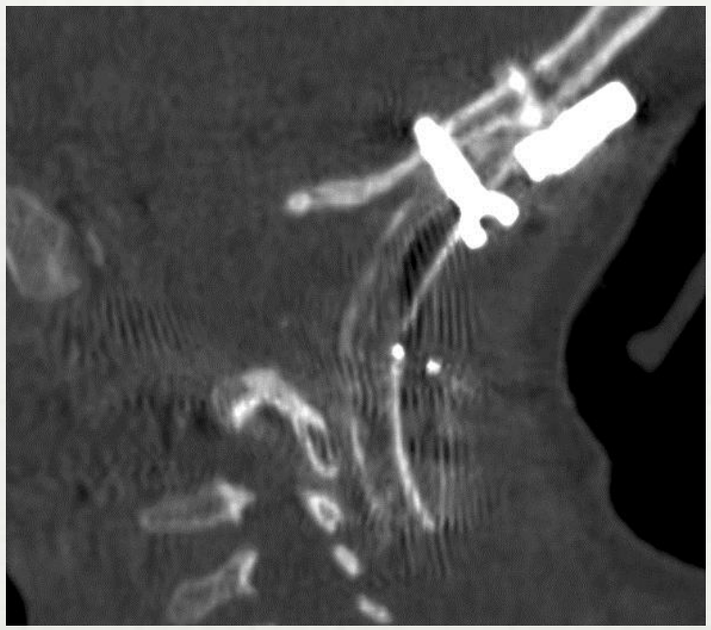

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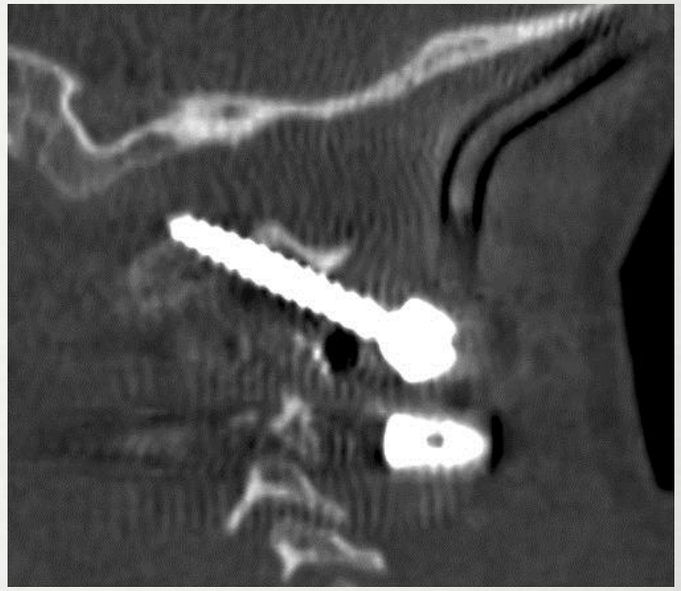
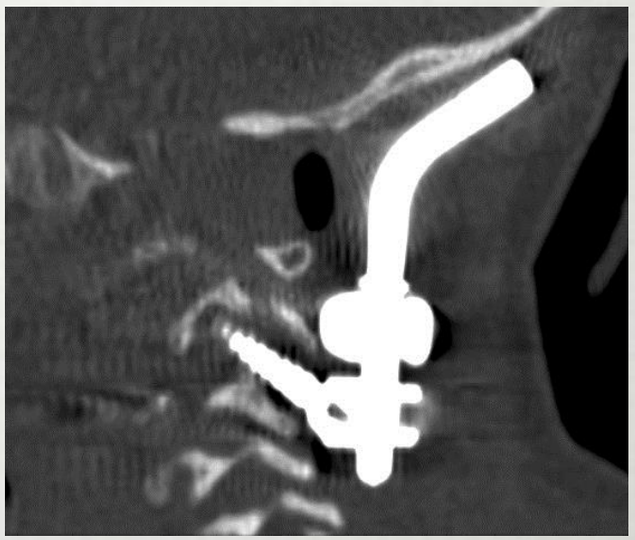
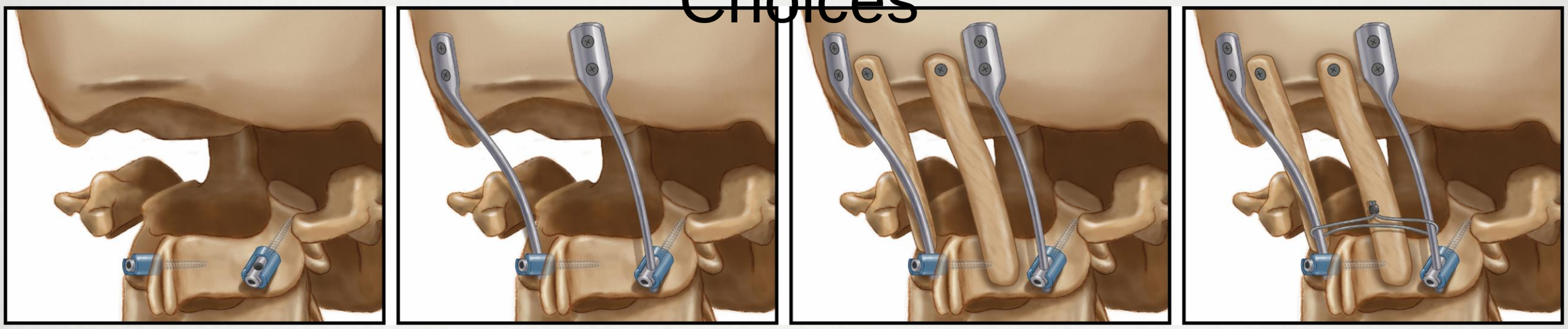




Abnormal Bony Anatomy: C2 Instrumentation Choices



J Neurosurg (1 Suppl Pediatrics) 107:36–42, 2007

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

RICHARD C. E. ANDERSON, M.D.,[1] BRIAN T. RAGEL, M.D.,[2] J MOCCO, M.D.,[1] LEIF-ERIK BOHMAN, B.A.,[1] AND DOUGLAS L. BROCKMEYER, M.D.[2]

[1]Department of Neurosurgery, Children's Hospital of New York, Columbia University College of Physicians and Surgeons, New York, New York; and [2]Department of Neurosurgery, Primary Children's Medical Center, University of Utah, Salt Lake City, Utah

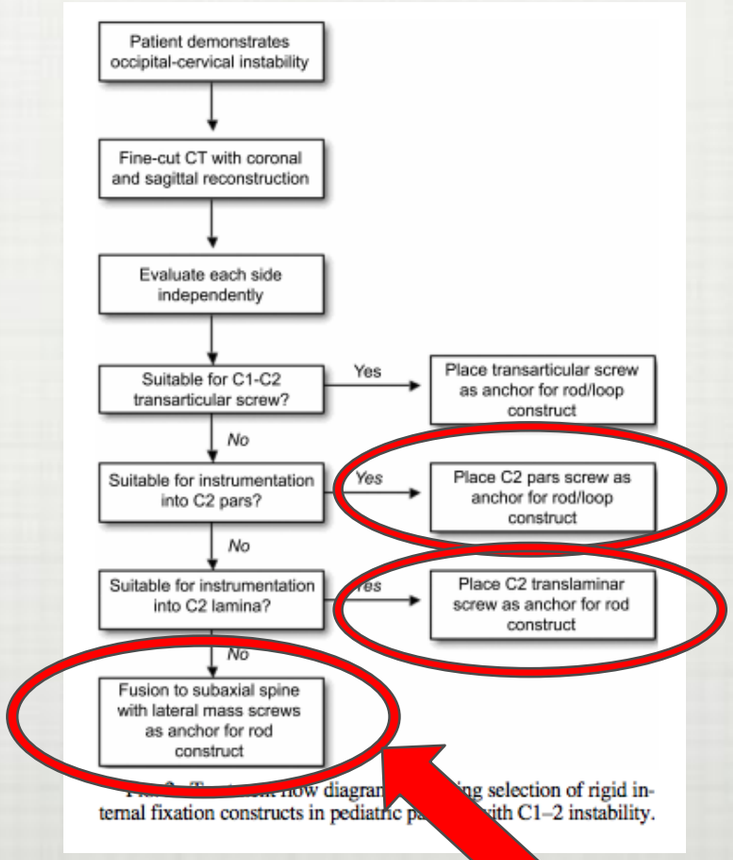
Object. Atlantoaxial and occipitocervical instability in children have traditionally been treated with posterior bone and wire fusion and external halo orthoses. Recently, successful outcomes have been achieved using rigid internal fixation, particularly C1–2 transarticular screws. The authors describe flow diagrams created to help clinicians determine which method of internal fixation to use in complex anatomical circumstances when bilateral 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 craniocervical anatomy in 25 patients (six atlantoaxial and 19 occipitocervical fixations [26%]) required alternative methods of internal fixation. Types of screw fixation included loop or rod constructs anchored by combinations of C1–2 transarticular screws (15 constructs), C-1 lateral mass screws (11), C-2 pars screws (24), C-2 translaminar screws (one), and subaxial lateral mass screws (six). The mean age of the patients (15 boys and 10 girls) was 9.8 years (range 1.3–17 years). All 22 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 stabilizations. Use of these flow diagrams has led to successful fusion in 25 pediatric patients with difficult anatomy requiring less common constructs. *(DOI: 10.3171/PED-07/07/036)*

KEY WORDS • **atlantoaxial stabilization** • **craniovertebral junction** • **occipitocervical stabilization** • **pediatric neurosurgery** • **rigid internal fixation**



ternal fixation constructs in pediatric pa ith C1–2 instability.

"Load Sharing"

Abnormal Bony Anatomy: Unilateral Fixatio

NEUROSURGICAL FOCUS

Neurosurg Focus 38 (4):E9, 2015

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

Marcus D. Mazur, MD, Vijay M. Ravindra, MD, and Douglas L. Brockmeyer, MD

Department of Neurosurgery, Clinical Neurosciences Center, University of Utah, Salt Lake City, Utah

OBJECT Patients with occipitocervical (OC) instability from congenital vertebral anomalies (CVAs) of the craniocervical 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.

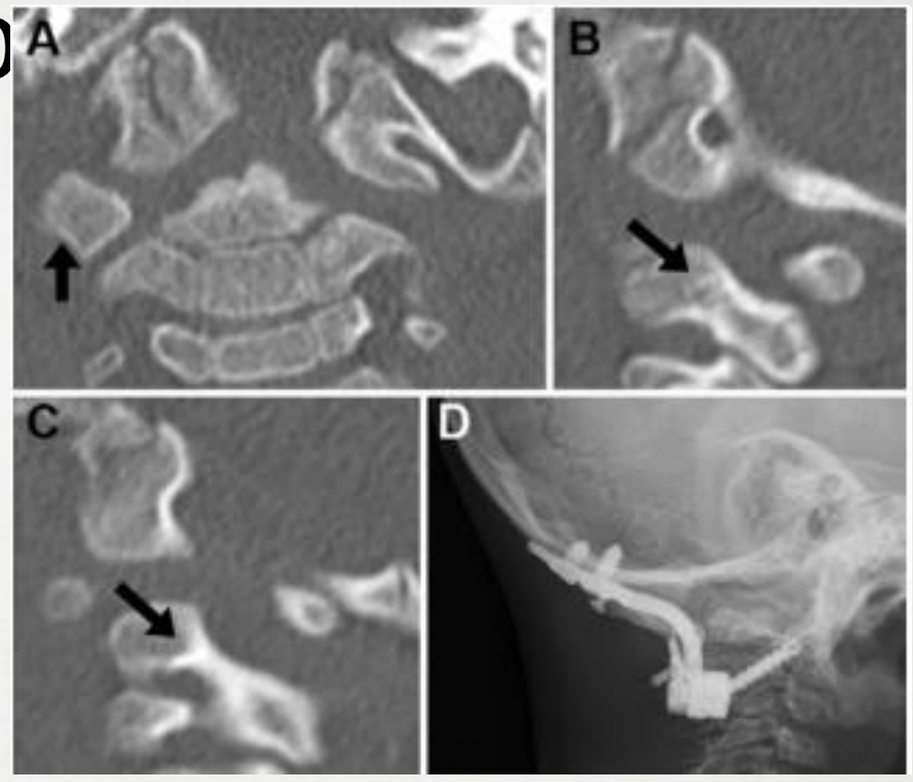
METHODS From a database of OC fusion procedures, the authors identified patients who underwent unilateral fixation for the management of OC instability. Patient characteristics, surgical details, and radiographic outcomes were reviewed. In each patient, CT scans were performed at least 4 months after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

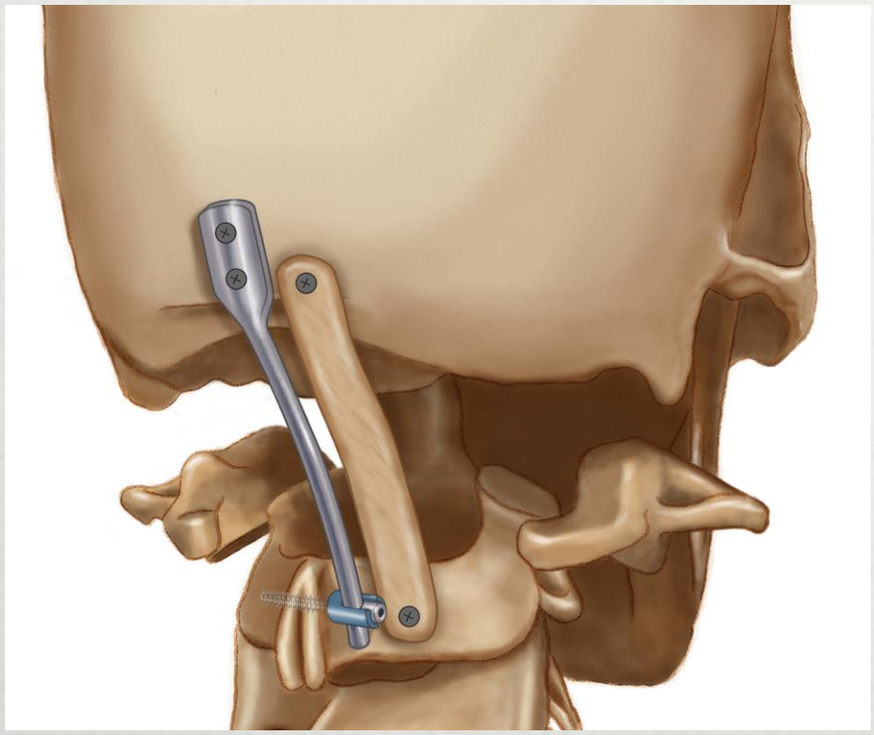
RESULTS Eight patients with CVAs of the CCJ underwent unilateral fixation for the treatment of OC instability. For 4 patients, the procedure occurred after a bilateral OC construct failed or infection forced hardware removal. For the remainder, it was the primary procedure. Two patients required reoperation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

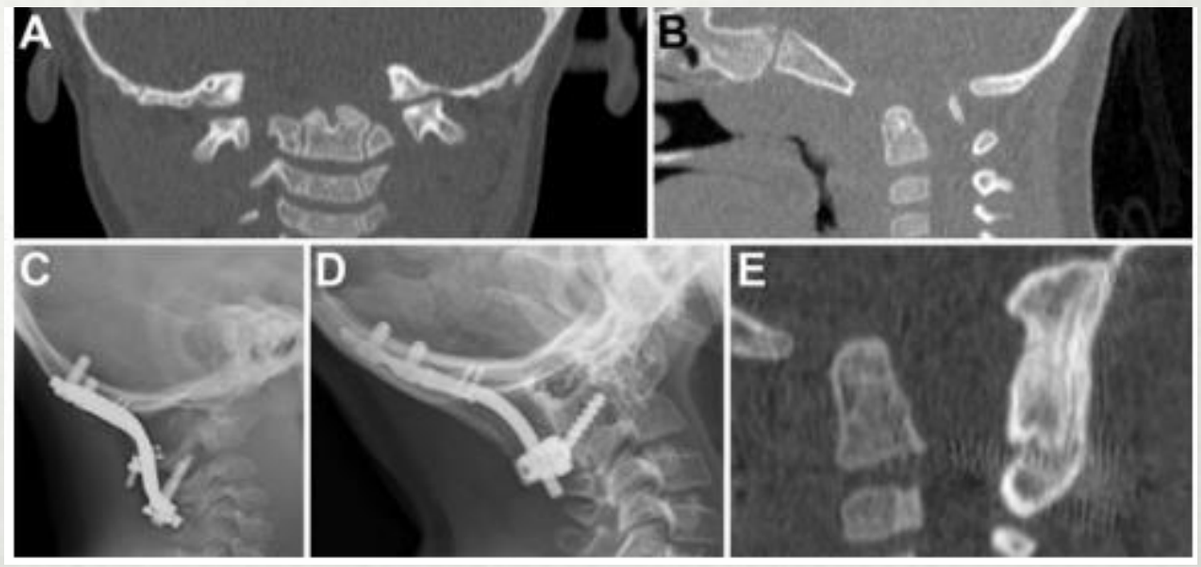
CONCLUSIONS These findings demonstrate that a unilateral OC fixation is effective for the treatment of OC instability in children with CVAs of the CCJ in whom bilateral screw placement fails or is not feasible.

http://thejns.org/doi/abs/10.3171/2015.1.FOCUS14787

KEY WORDS craniocervical; instability; occipitocervical fusion; pediatric; congenital vertebral anomalies; unilateral; spine; instrumentation







Other Options

J Pediatr Orthop. 2015 Jun;35(4):379-84. doi: 10.1097/BPO.0000000000000309.

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[1], Wasser AM, Troy MJ, Proctor M, Emans JB.

Childs Nerv Syst. 2017 Aug;33(8):1253-1260. doi: 10.1007/s00381-017-3497-8. Epub 2017 Jul 6.

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

Hale AT[1,2], Dewan MC[3,4], Patel B[5], Geck MJ[6], Tomycz LD[7].

Childs Nerv Syst. 2018 Jun 29. doi: 10.1007/s00381-018-3876-9. [Epub ahead of print]

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

Janjua MB[1,2,3], Hwang SW[4], Samdani AF[4], Pahys JM[4], Baaj AA[5], Härtl R[5], Greenfield JP[5].

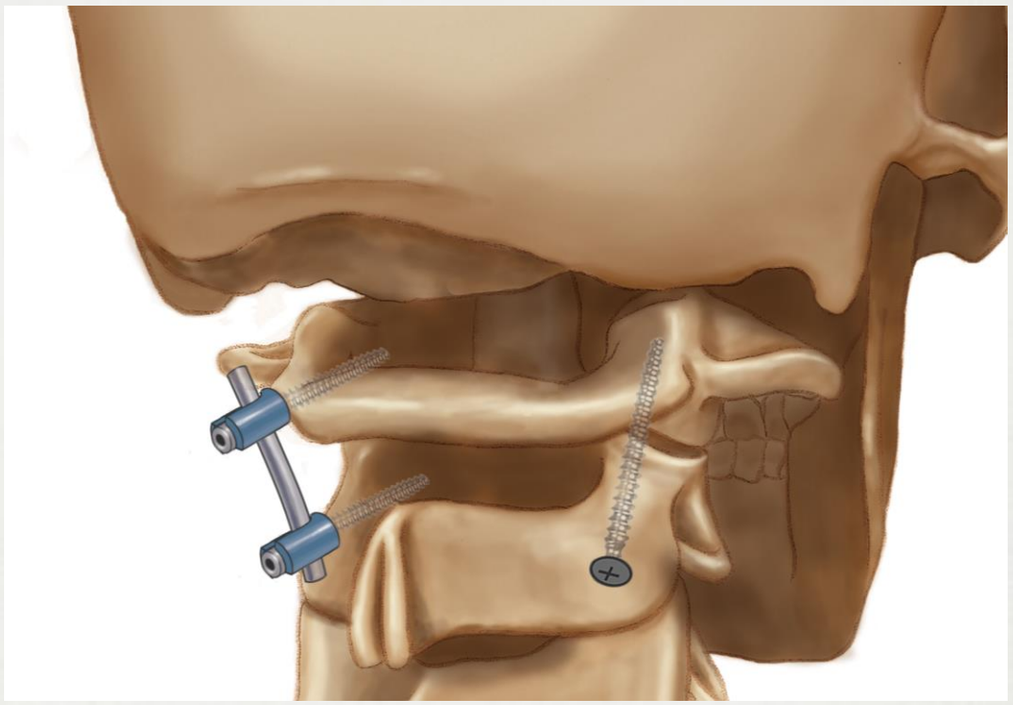
Pediatr Neurosurg. 2005 Mar-Apr;41(2):88-92.

Circumferential cervical spine surgery in an 18-month-old female with traumatic disruption of the odontoid and C3 vertebrae. Case report and review of techniques. Case report and review of techniques.

Dickerman RD[1], 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



J Neurosurg Spine 2:164–169, 2005

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

Wayne M. Gluf, M.D., and Douglas L. Brockmeyer, M.D.

Department of Neurosurgery, University of Utah, Primary Children's Medical Center, Salt Lake City, Utah

Object. In this, the second of two articles regarding C1–2 transarticular screw fixation, the authors discuss their surgical experience in treating patients 16 years of age and younger, detailing the rate of fusion, complication avoidance, and lessons learned in the pediatric population.

Methods. The authors retrospectively reviewed 67 consecutive patients (23 girls and 44 boys) younger than 16 years of age in whom at least one C1–2 transarticular screw fixation procedure was performed. A total of 127 transarticular screws were placed in these 67 patients whose mean age at time of surgery was 9 years (range 1.7–16 years). The indications for surgery were trauma in 24 patients, os odontoideum in 22 patients, and congenital anomaly in 17 patients. Forty-four patients underwent atlantoaxial fusion and 23 patients underwent occipitocervical fusion. Two of the 67 patients underwent halo therapy postoperatively.

All patients were followed for a minimum of 3 months. In all 67 patients successful fusion was achieved.Complications occurred in seven patients (10.4%), including two vertebral artery injuries.

Conclusions. The use of C1–2 transarticular screw fixation, combined with appropriate atlantoaxial and craniovertebral bone/graft constructs, resulted in a 100% fusion rate in a large consecutive series of pediatric patients. The risks of C1–2 transarticular screw fixation can be minimized in this population by undertaking careful patient selection and meticulous preoperative planning.

Key Words • atlantoaxial junction • craniocervical junction • instability • transarticular screw fixation • fusion • pediatric neurosurgery

J Neurosurg (1 Suppl Pediatrics) 107:36–42, 2007

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[1]Department of Neurosurgery, Children's Hospital of New York, Columbia University College of Physicians and Surgeons, New York, New York; and [2]Department of Neurosurgery, Primary Children's Medical Center, University of Utah, Salt Lake City, Utah

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

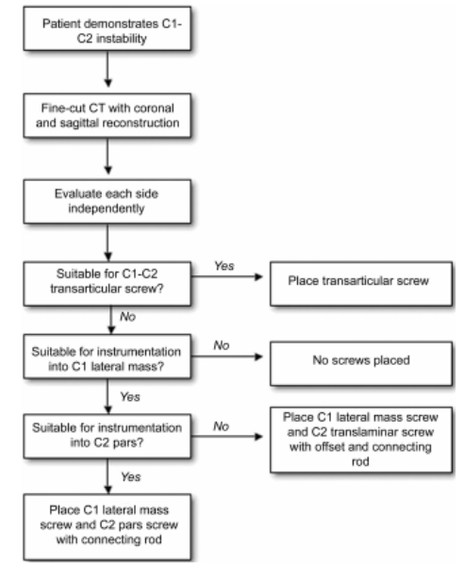
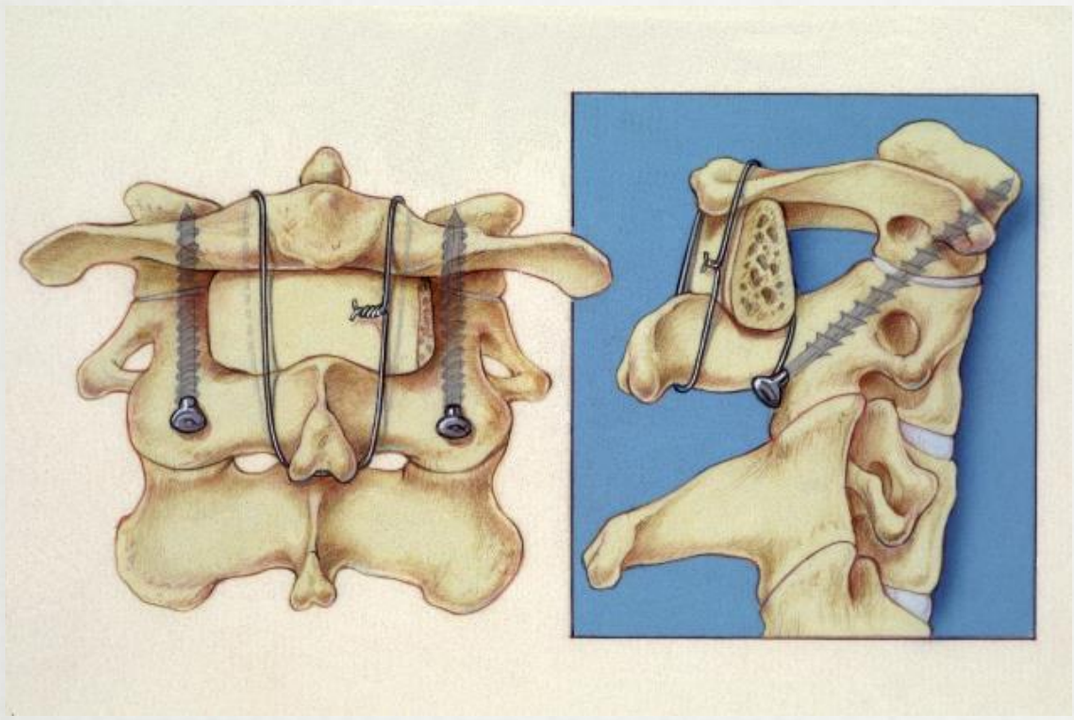


Fig. 1. Treatment flow diagram describing selection of rigid internal fixation constructs in pediatric patients with occipitocervical instability.

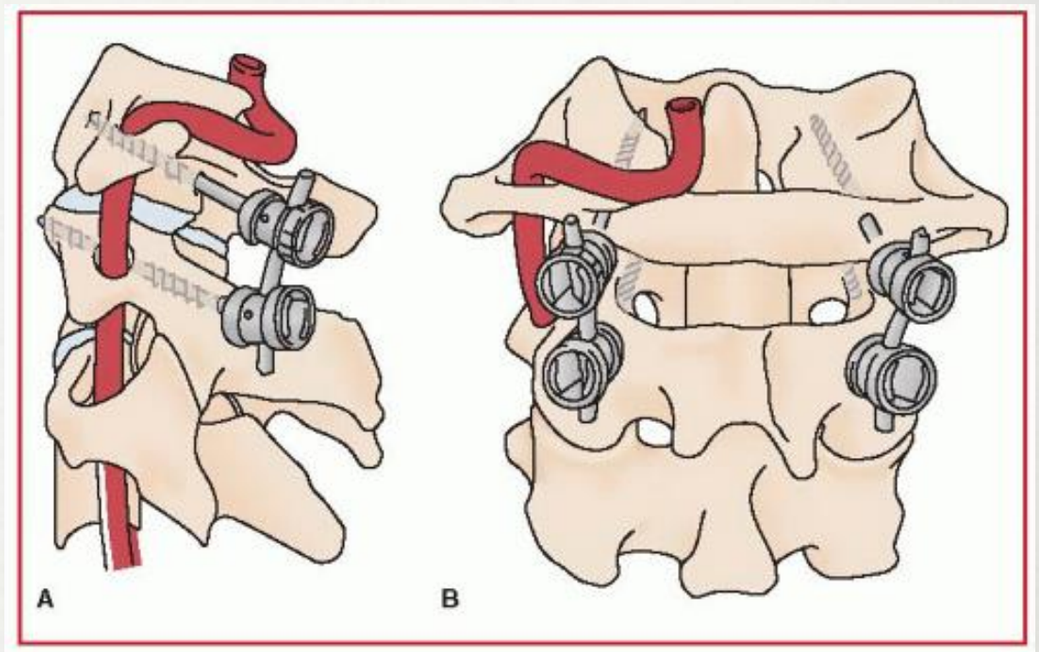
Atlantoaxial Instrumentation

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

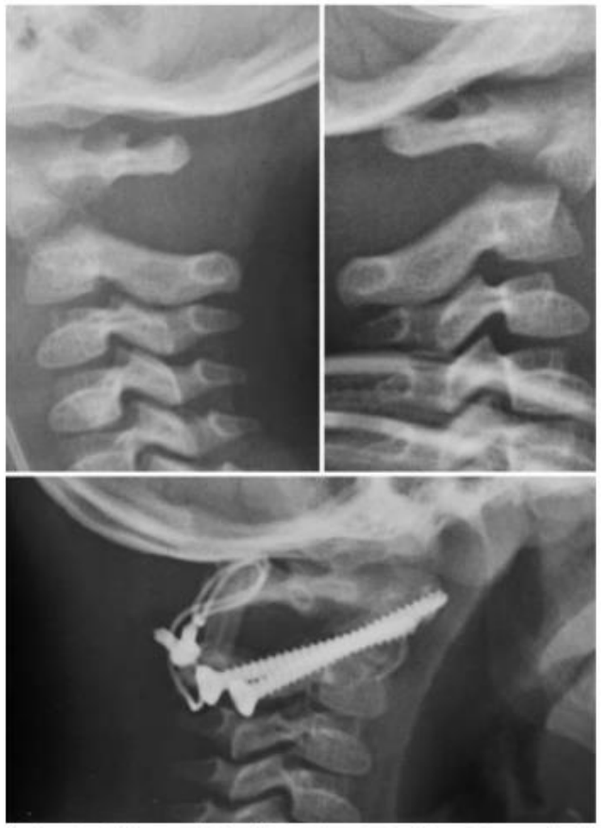


FIG. 2. Plain cervical radiographs obtai
girl with a Type II odontoid fracture.
through the odontoid base and synchondro
gulation and subluxation of the odontoid d
tion. *Lower:* Three-month postoperative
solid osseous union between C-1 and C-2.

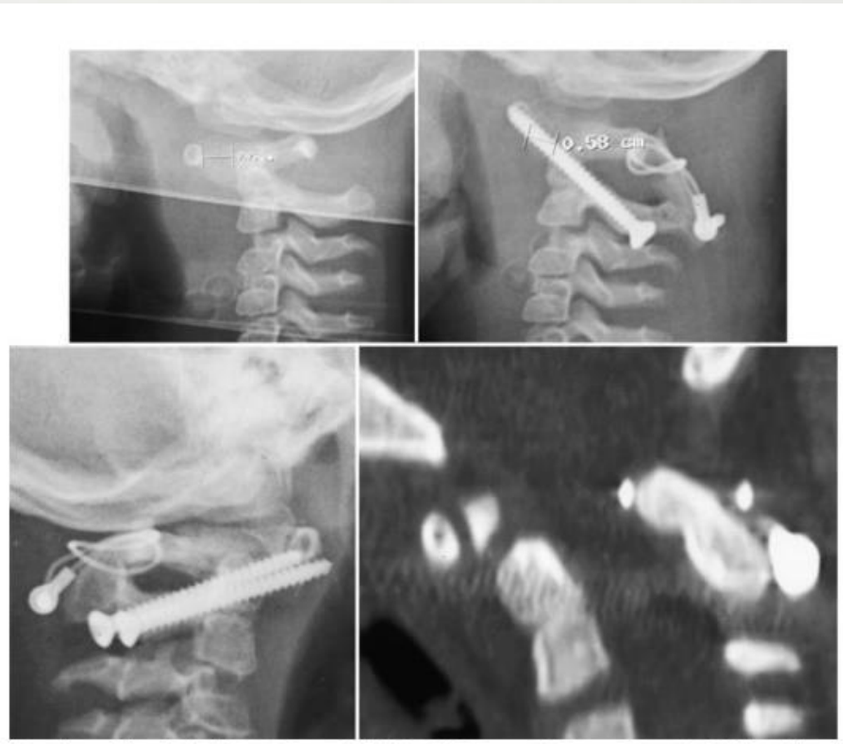


FIG. 3. Imaging studies obtained in an 18-month-old girl with Down syndrome. *Upper Left:* Plain radiograph revealing atlantoaxial subluxation. *Upper Right:* Immediate postoperative lateral radiograph demonstrating the completed fusion and transarticular screw fixation. *Lower Left:* Plain lateral radiograph obtained at 3 months postoperatively revealing a successful C1–2 fusion. *Lower Right:* Midsagittal reconstruction of a thin-cut CT scan obtained 1 year after surgery demonstrating a solid atlantoaxial arthrodesis.

J Neurosurg (Spine 3) 97:400–402, 2002

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

Technical note

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Division of Pediatric Neurosurgery, Primary Children's Medical Center, University of Utah, Salt Lake City, Utah

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

JNS SPINE

CLINICAL ARTICLE

J Neurosurg Spine 24:892–896, 2016

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

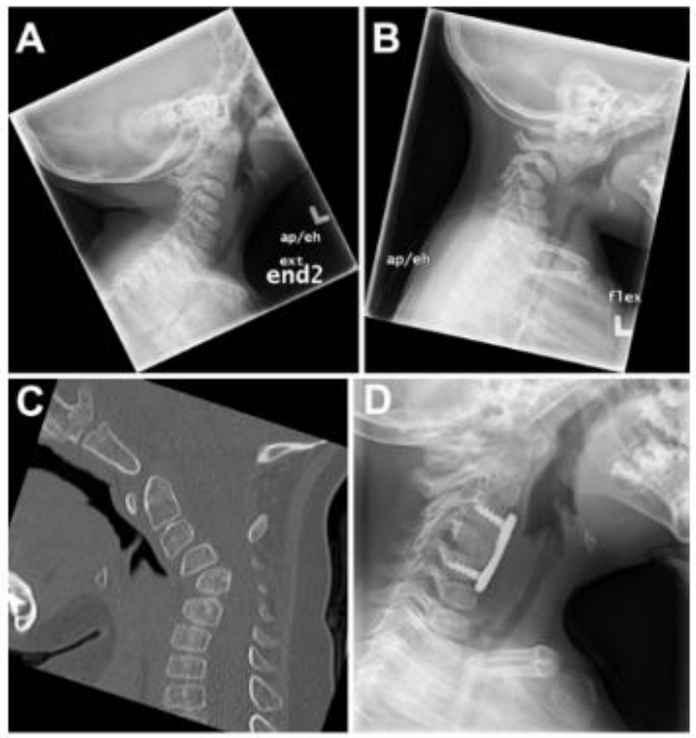

FIG. 1. Case 1. Extension (**A**) and flexion (**B**) radiographs of the cervical spine showing anterior subluxation of C-3 onto C-4. Sagittal noncontrast CT scan (**C**) of the cervical spine shows a hypoplastic C-4 vertebral body. Postoperative lateral cervical spine radiograph (**D**) obtained at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

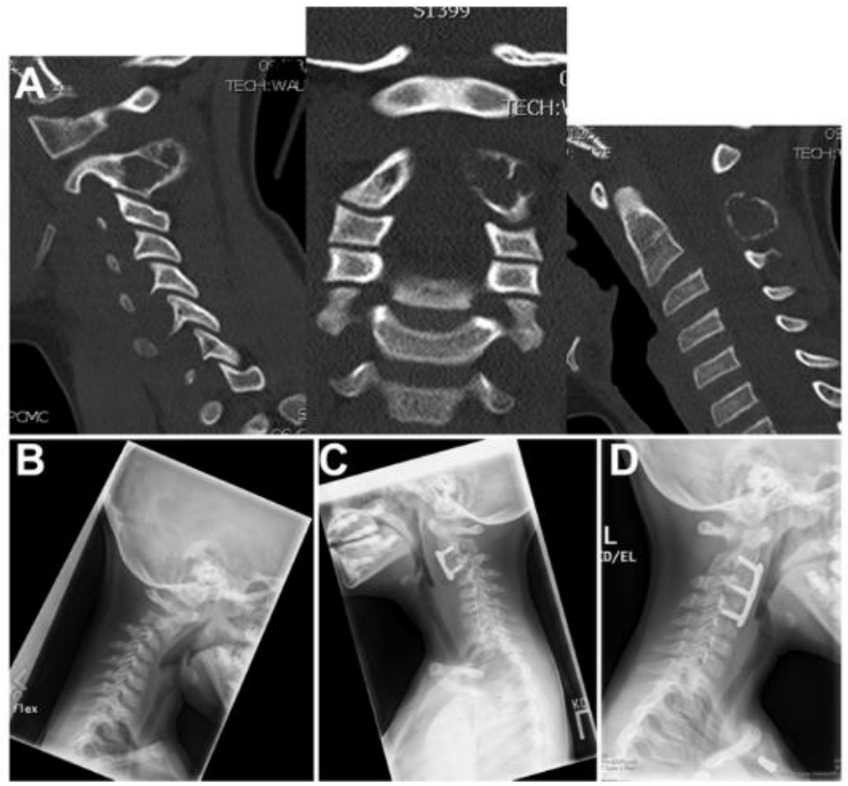

FIG. 2. Case 2. **A:** Sagittal (*left*), coronal (*center*), and midsagittal (*right*) noncontrast CT scans of the cervical spine showing an aneurysmal bone cyst involving the posterior elements of C-2. **B:** Lateral radiograph of the cervical spine after resection of the cyst showing kyphosis of C-2 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

Patient No.	Age (mos), Sex	Pathology	Neurologically Intact Preoperatively	Procedure	Follow-Up (mos)	Fusion	Revision	% Vertical Growth
1	15, M	Congenital C-2 pars defects w/ spondylolisthesis	No	C2–3 ACDF	51	Yes	None	40
2	35, M	Diastrophic dysplasia w/ cervical kyphosis	No	C3–5 fusion, C-4 corpectomy	17	Yes	None	20
3	67, M	Klippel-Feil syndrome	Yes	C3–5 ACDF, Oc–C2 PCF	36	No	C2–4 ACDF due to progressive kyphosis	34
4	59, F	Traumatic C6–7 perched facets	Yes	C6–7 ACDF, C6–7 PCF	18	Yes	None	10
5	76, M	Aneurysmal bone cyst w/ postlaminectomy kyphosis	Yes	C2–3 ACDF	12	No	C3–4 ACDF, C2–4 plating due to kyphosis	10

Oc = occiput; PCF = posterior cervical fusion.

Other Options

J Neurosurg (3 Suppl Pediatrics) 104:181–187, 2006

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

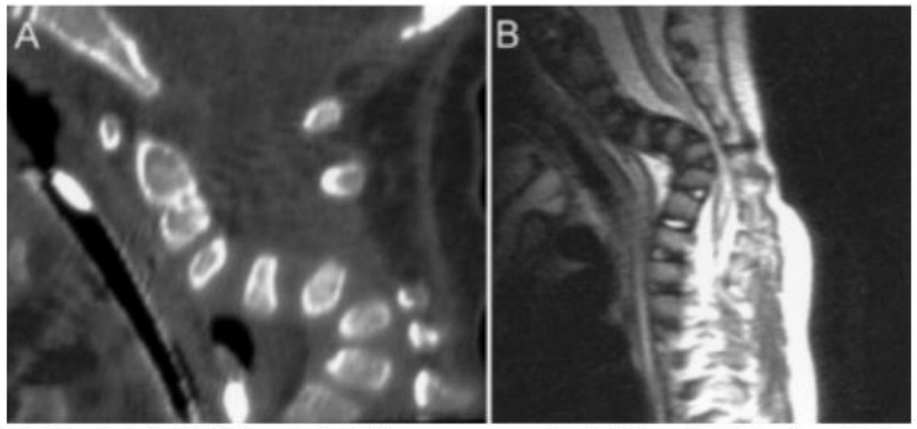


Fig. 1. Case 1. A: Sagittal CT scan depicting the reverse swan-neck or buckling sagittal deformity and the hypoplastic pedicles. B: Sagittal T_2-weighted MR image showing the degree of spinal cord compression and high signal change within the cord.

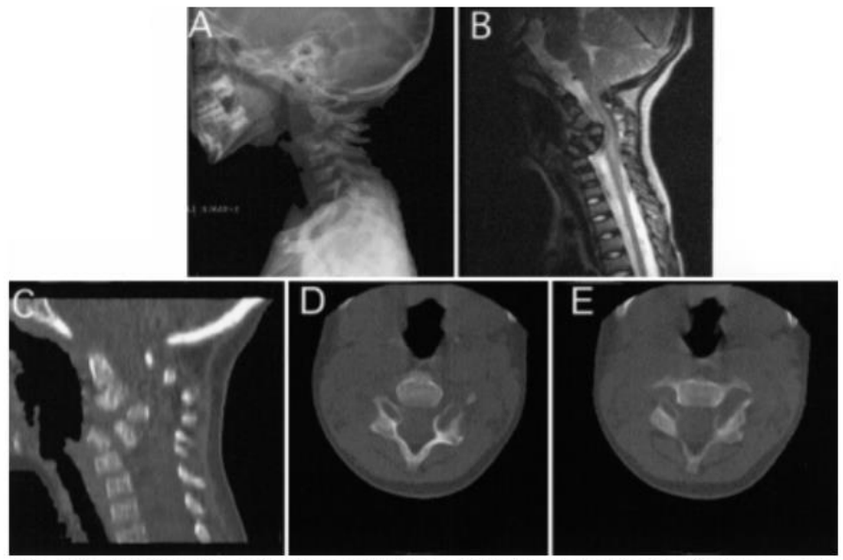


Fig. 4. Case 2. Plain lateral x-ray film (A) and sagittal CT scan (C) depicting the buckling deformity of the neck, with the spinal cord compression ventrally as shown in the sagittal MR image (B). The absence of an osseous bridge between the anterior and posterior elements and the enlarged and abnormally shaped foramen transversarium are seen in axial CT scans (D and E).

Other Options

J Neurosurg (3 Suppl Pediatrics) 104:181–187, 2006

Multilevel cervical disconnection syndrome: initial description, embryogenesis, and management

Report of two cases

PAUL KLIMO JR., M.D., M.P.H., RICHARD C. E. ANDERSON, M.D., AND DOUGLAS L. BROCKMEYER, M.D.

Department of Neurosurgery, and Division of Pediatric Neurosurgery, University of Utah, Primary Children's Medical Center, Salt Lake City, Utah

✓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

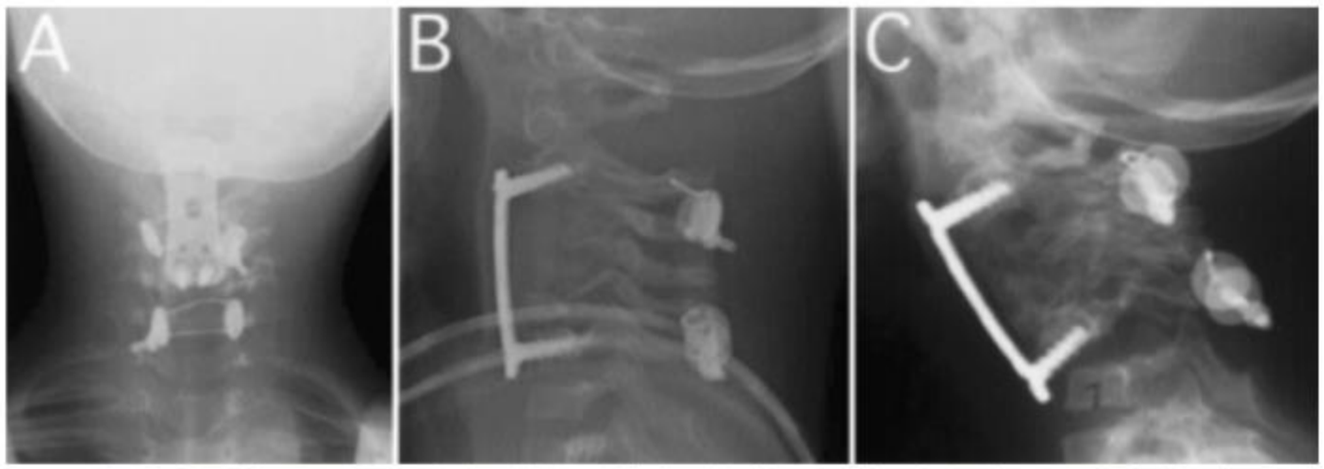


FIG. 5. Case 2. Anteroposterior (A), lateral (B), and flexion (C) plain x-ray films obtained postoperatively. Note the instability that developed at the C6–7 level with flexion; the lateral masses almost become perched. This required an extension of the posterior construct.

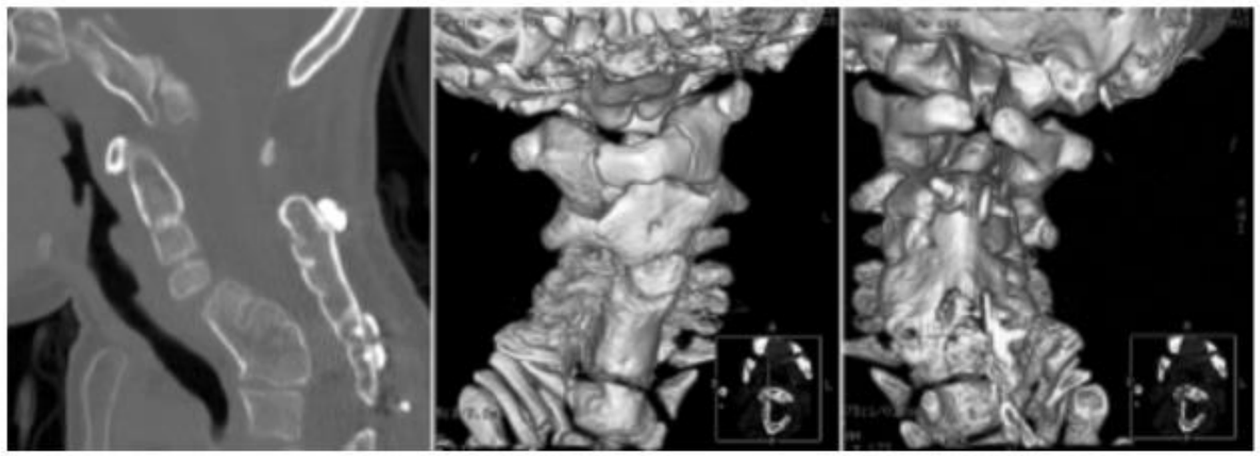


FIG. 3. Case 1. Postoperative sagittal CT reconstruction *(left)* and three-dimensional models (*center* and *right*) demonstrating solid anterior and posterior fusion constructs. *Right:* Note the posterior wire and titanium disc construct.

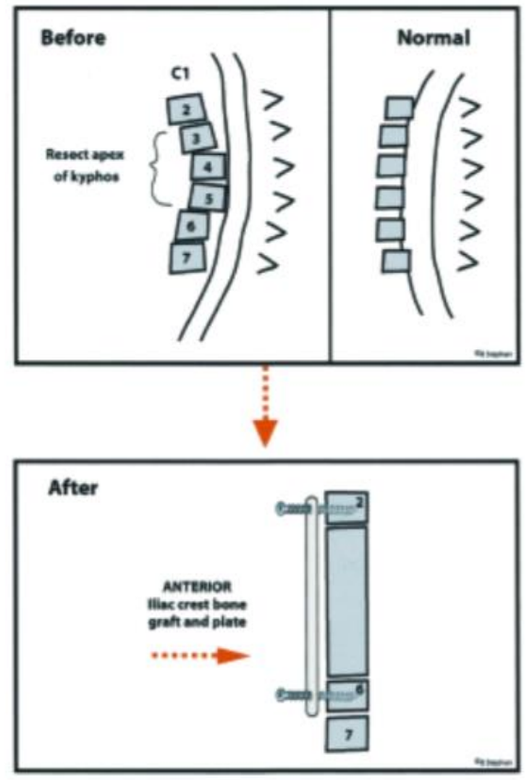


FIG. 7. Diagrams depicting the reduction, decompression, and reconstruction of the anterior column as performed in our patients. Resection of the kyphos apex is followed by reduction of the deformity *(upper)* and placement of an interbody graft and fixation devices *(lower)*.

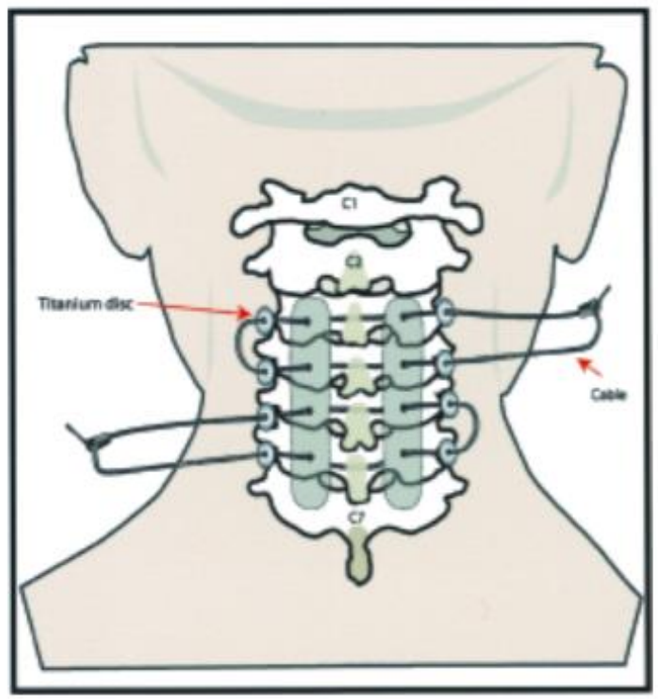
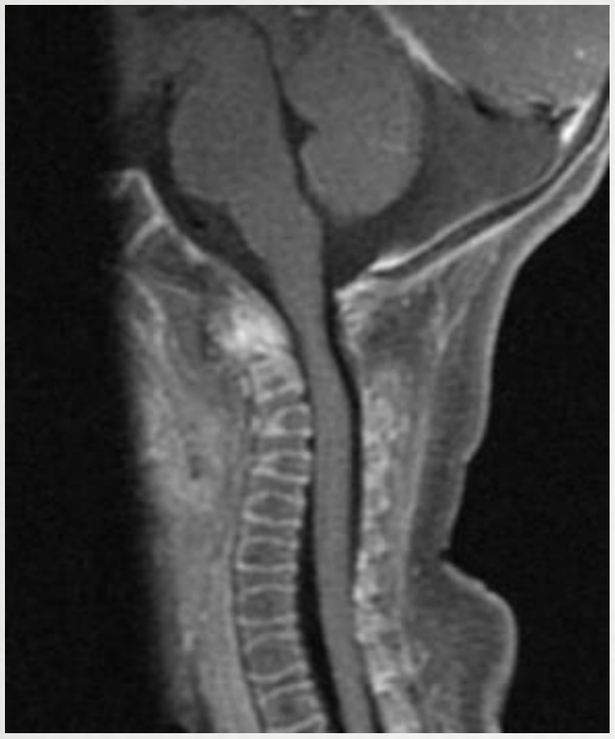
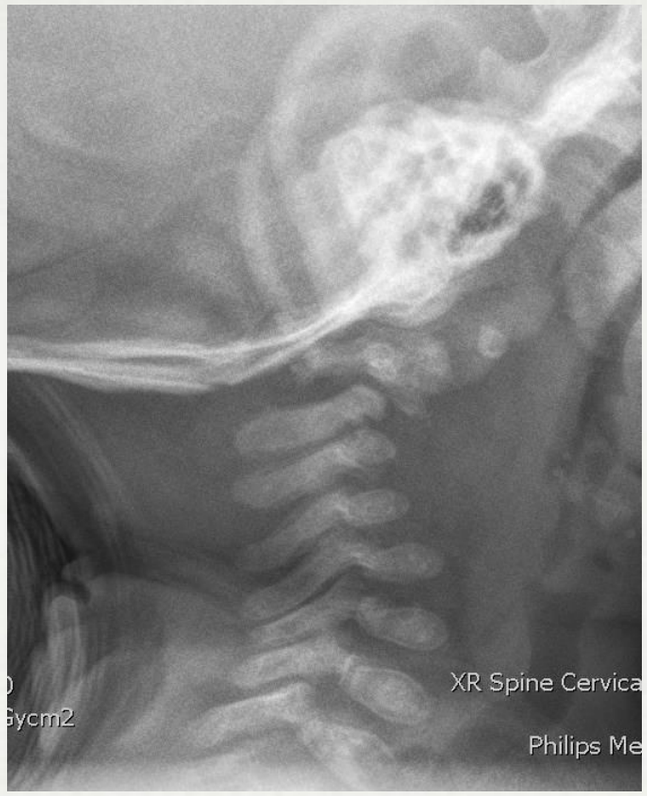
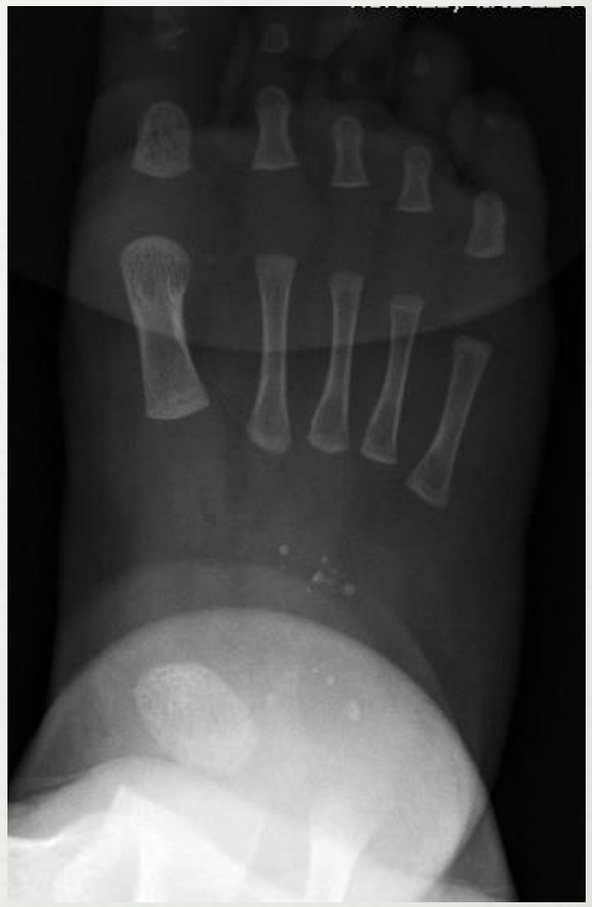


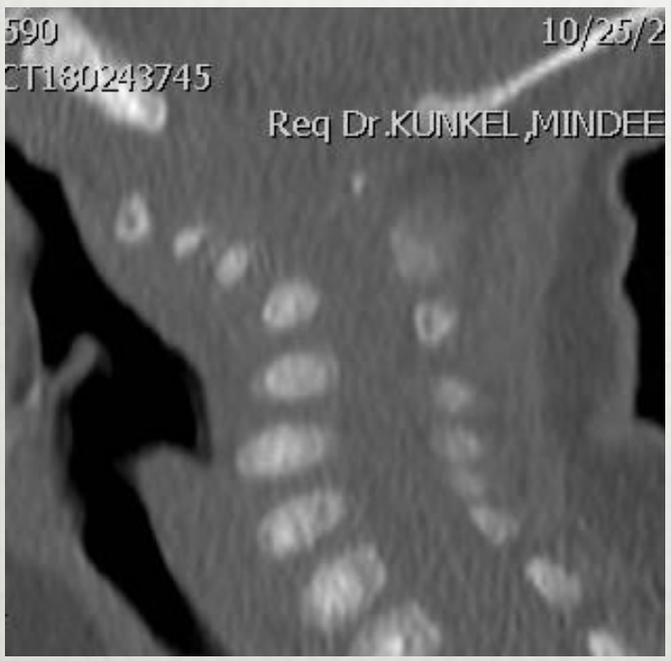
FIG. 8. Drawing depicting our multilevel posterior wiring technique using autologous rib grafts and cables with titanium discs.

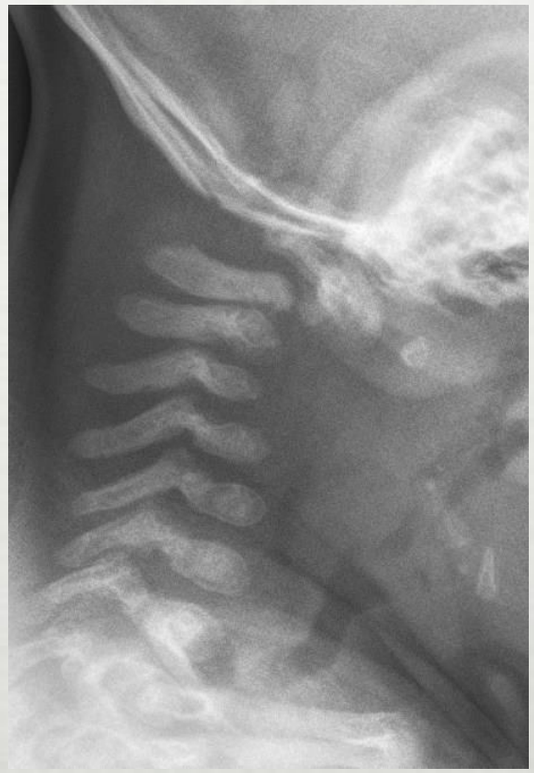
3 m/o M with short limbs, dyspnea











Chondrodysplasia Punctata

Long-term Growth

JNS PEDIATRICS

CLINICAL ARTICLE

J Neurosurg Pediatr 17:94–102, 2016

Long-term growth and alignment after occipitocervical and atlantoaxial fusion with rigid internal fixation in young children

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[1]Department of Neurological Surgery, Columbia University, New York, New York; [2]Department of Neurological Surgery, University of Pittsburgh, Pennsylvania; [3]Department of Neurological Surgery, University of Florida, Gainesville, Florida; [4]Department of Neurological Surgery, Wake Forest University Baptist Medical Center, Winston-Salem, North Carolina; [5]Division of Pediatric Neurosurgery, Texas Children's Hospital, Houston, Texas; [6]Department of Neurological Surgery, Ohio State University, Columbus, Ohio; [7]Department of Neurological Surgery, Medical College of Wisconsin/Children's Hospital of Wisconsin, Milwaukee, Wisconsin; [8]Department of Neurological Surgery, All Children's Hospital, St. Petersburg, Florida; [9]Department of Neurological Surgery, Yale University School of Medicine, New Haven, Connecticut; and [10]Department of Neurological Surgery, University of Utah, Salt Lake City, Utah

OBJECTIVE The long-term consequences of atlantoaxial (AA) and occipitocervical (OC) fusion and instrumentation in young children are unknown. Anecdotal reports have raised concerns regarding altered growth and alignment of the cervical spine after surgical intervention. The purpose of this study was to determine the long-term effects of these surgeries on the growth and alignment of the maturing spine.

METHODS A multiinstitutional retrospective chart review was conducted for patients less than or equal to 6 years of age who underwent OC or AA fusion with rigid instrumentation at 9 participating centers. All patients had at least 3 years of clinical and radiographic follow-up data and radiographically confirmed fusion. Preoperative, immediate postoperative, and most recent follow-up radiographs and/or CT scans were evaluated to assess changes in spinal growth and alignment.

RESULTS Forty children (9 who underwent AA fusion and 31 who underwent OC fusion) were included in the study (mean follow-up duration 56 months). The mean vertical growth over the fused levels in the AA fusion patients represented 30% of the growth of the cervical spine (range 10%–50%). Three different vertical growth patterns of the fusion construct developed among the 31 OC fusion patients during the follow-up period: 1) 16 patients had substantial growth (13%–46% of the total growth of the cervical spine); 2) 9 patients had no meaningful growth; and 3) 6 patients, most of whom presented with a distracted atlantooccipital dislocation, had a decrease in the height of the fused levels (range 7–23 mm). Regarding spinal alignment, 85% (34/40) of the patients had good alignment at follow-up, with straight or mildly lordotic cervical curvatures. In 1 AA fusion patient (11%) and 5 OC fusion patients (16%), we observed new hyperlordosis (range 43°–62°). There were no cases of new kyphosis or swan-neck deformity, evidence of subaxial instability, or unintended subaxial fusion. No preoperative predictors of these growth patterns or alignment were evident.

CONCLUSIONS These results demonstrate that most young children undergoing AA and OC fusion with rigid internal fixation continue to have good cervical alignment and continued growth within the fused levels during a prolonged follow-up period. However, some variability in vertical growth and alignment exists, highlighting the need to continue close long-term follow-up.

http://thejns.org/doi/abs/10.3171/2015.5.PEDS14728

KEY WORDS occipitocervical; craniocervical; atlantoaxial; fixation; fusion; spine

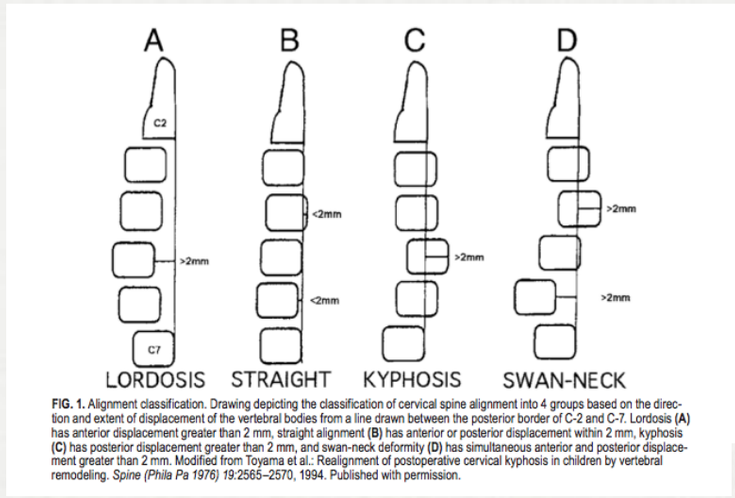
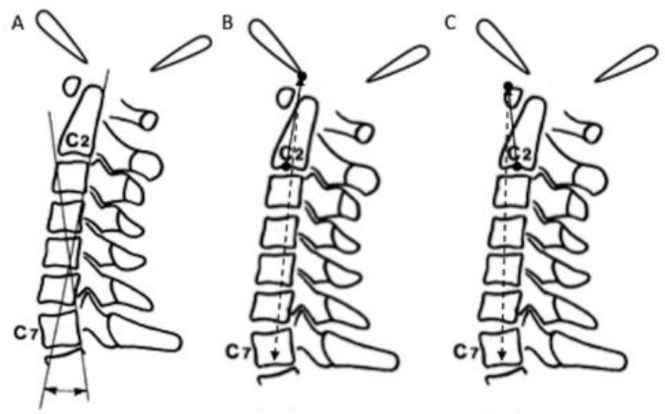


FIG. 1. Alignment classification. Drawing depicting the classification of cervical spine alignment into 4 groups based on the direction and extent of displacement of the vertebral bodies from a line drawn between the posterior border of C-2 and C-7. Lordosis **(A)** has anterior displacement greater than 2 mm, straight alignment **(B)** has anterior or posterior displacement within 2 mm, kyphosis **(C)** has posterior displacement greater than 2 mm, and swan-neck deformity **(D)** has simultaneous anterior and posterior displacement greater than 2 mm. Modified from Toyama et al.: Realignment of postoperative cervical kyphosis in children by vertebral remodeling. *Spine (Phila Pa 1976)* 19:2565–2570, 1994. Published with permission.



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:

<u>Occipitocervical options:</u>

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

+/- Halo

<u>Subaxial options:</u>

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

+/- Halo

Thank You