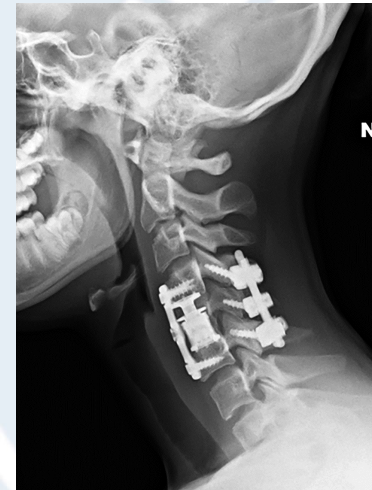
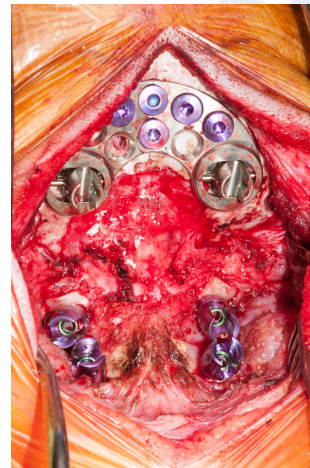
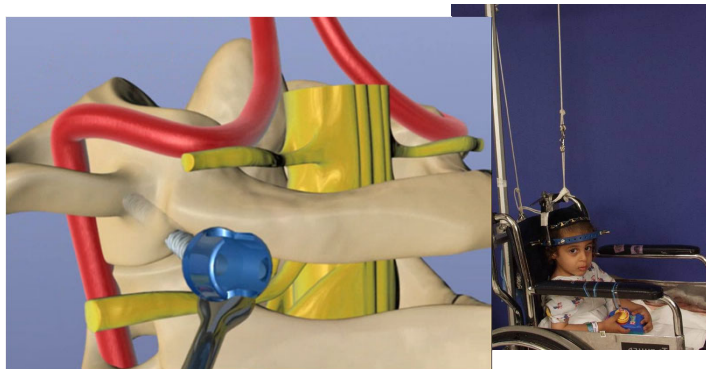


# Instrumentation of the Pediatric Cervical Spine

Daniel Hedequist MD  
Childrens Hospital/Harvard Medical School

**ICEOS MEETING, 2016**

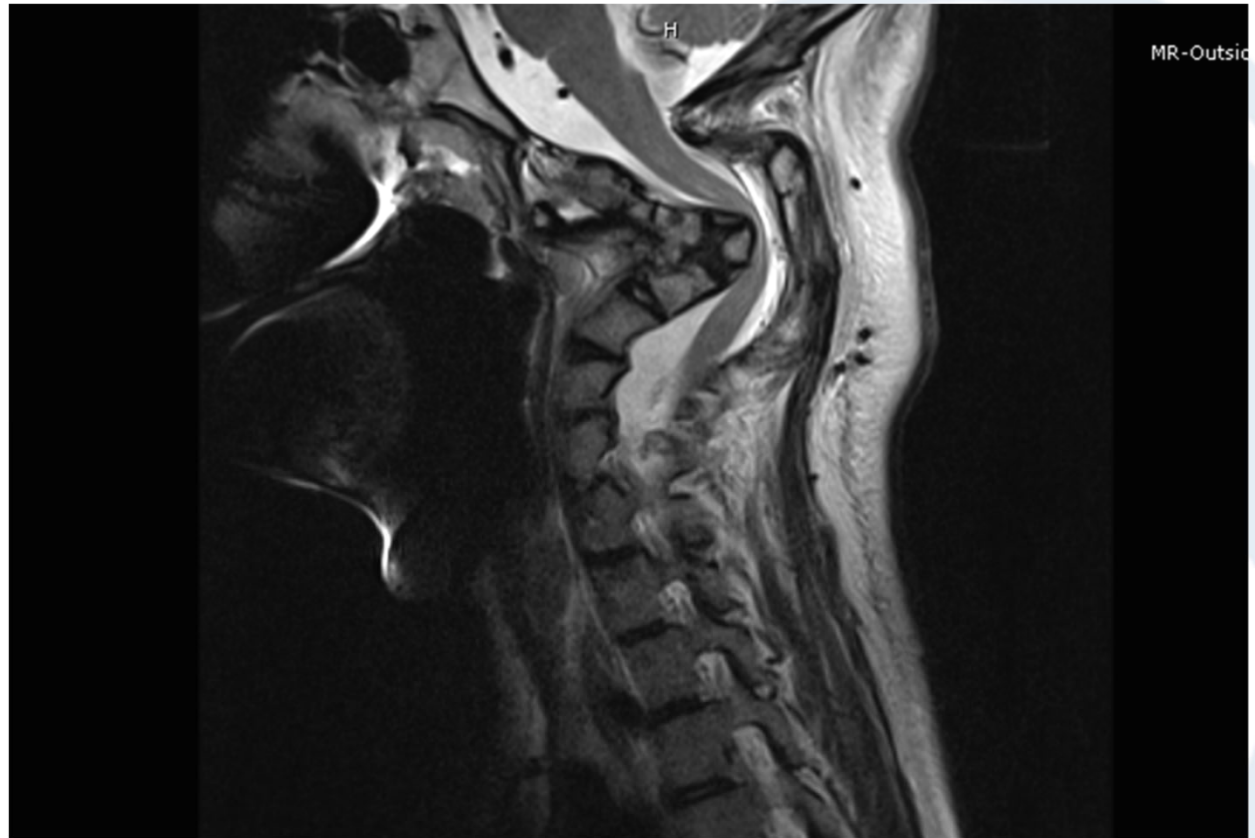


# Pediatric C-Spine

Biology  
Anatomy  
Deformity  
Age  
Size  
Myelopathy



Decompression  
Reduction  
Stabilization  
Fusion



# Myelopathy and Deformity





# TOOLS

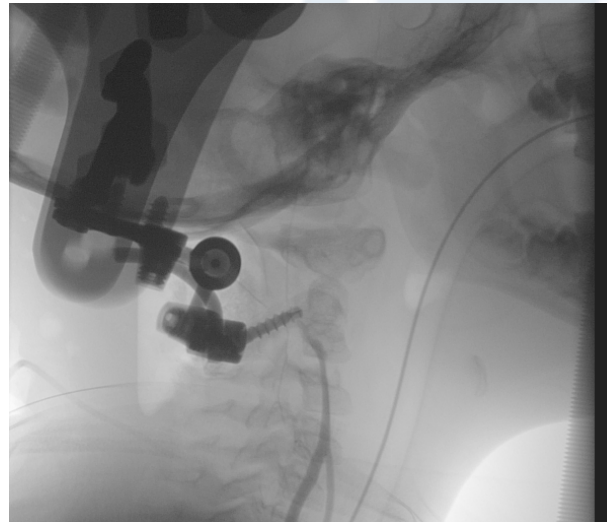
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- **Knowledge of the Vertebral Artery Anatomy**
- **Computed Tomography Scans**
- **Knowledge of the Anatomy**
- **Anatomical Dissection**

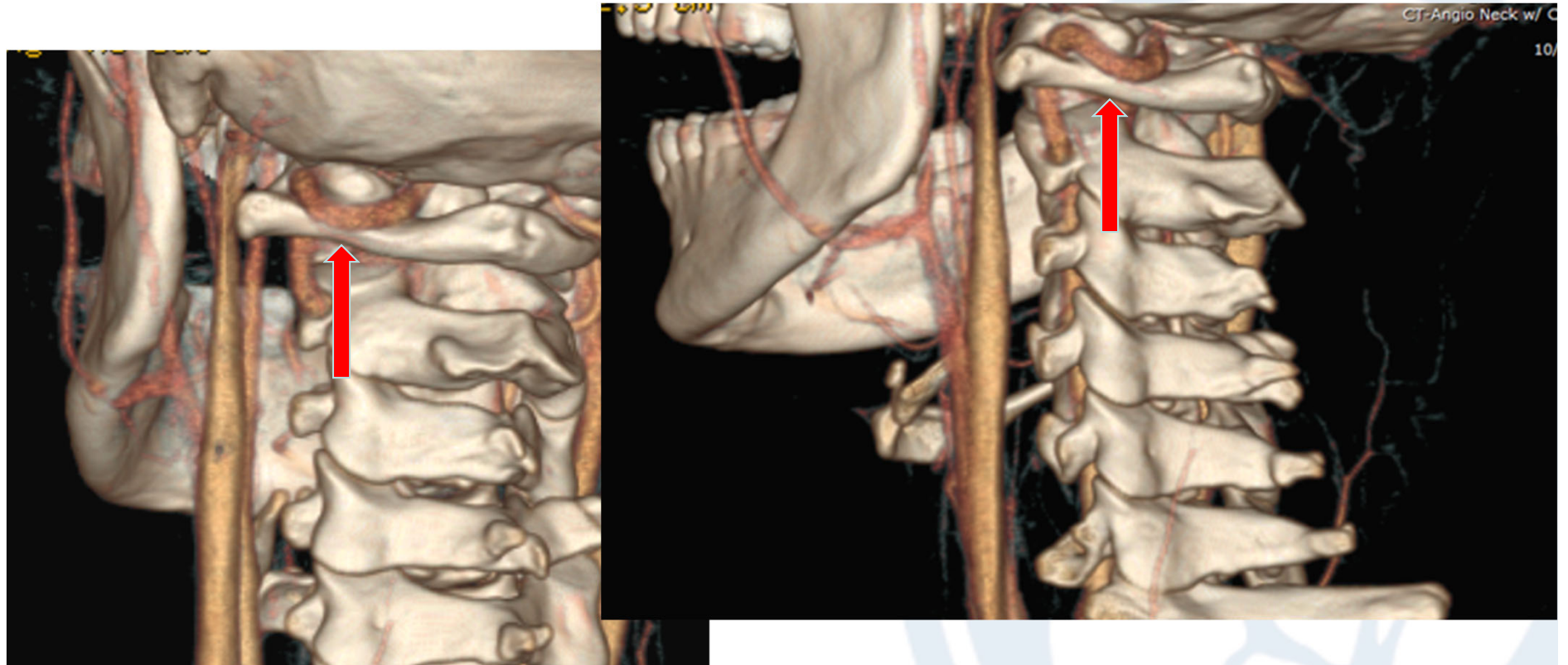


# Anatomy in Children--Dissection

- Location of the vertebral artery at C1 in children: how far out laterally can one safely dissect? Goldstein RY, Sunde CD, Assaad P, Grimm J, Skaggs DL, Andras L.J Bone Joint Surg Am. 2014 Sep 17;96(18):1552-6.
  - Looked at distance from vertebral groove to midline in CT 549 patients
  - Younger the patient (<8 yrs) the nearer the vertebral artery to the midline
  - 97% were at least 1 cm lateral to midline
  - Greater than age 8 the average is as adults



# Stay Below the Ring Laterally!



# CT EVALUATION

- **CT scan:1-mm fine cut with multi-planar reformatts**
  - Evaluates anomalous bony anatomy
  - Evaluates if adequate bony channel available
  - Evaluates position of foramen transversarium
    - Selection of a rigid internal fixation construct for stabilization at the craniovertebral junction in pediatric patients. Anderson RC, Ragel BT, Mocco J, Bohman LE, Brockmeyer DL. J Neurosurg. 2007 Jul;107(1 Suppl):36-42.
      - » 25% anomalous course of VA



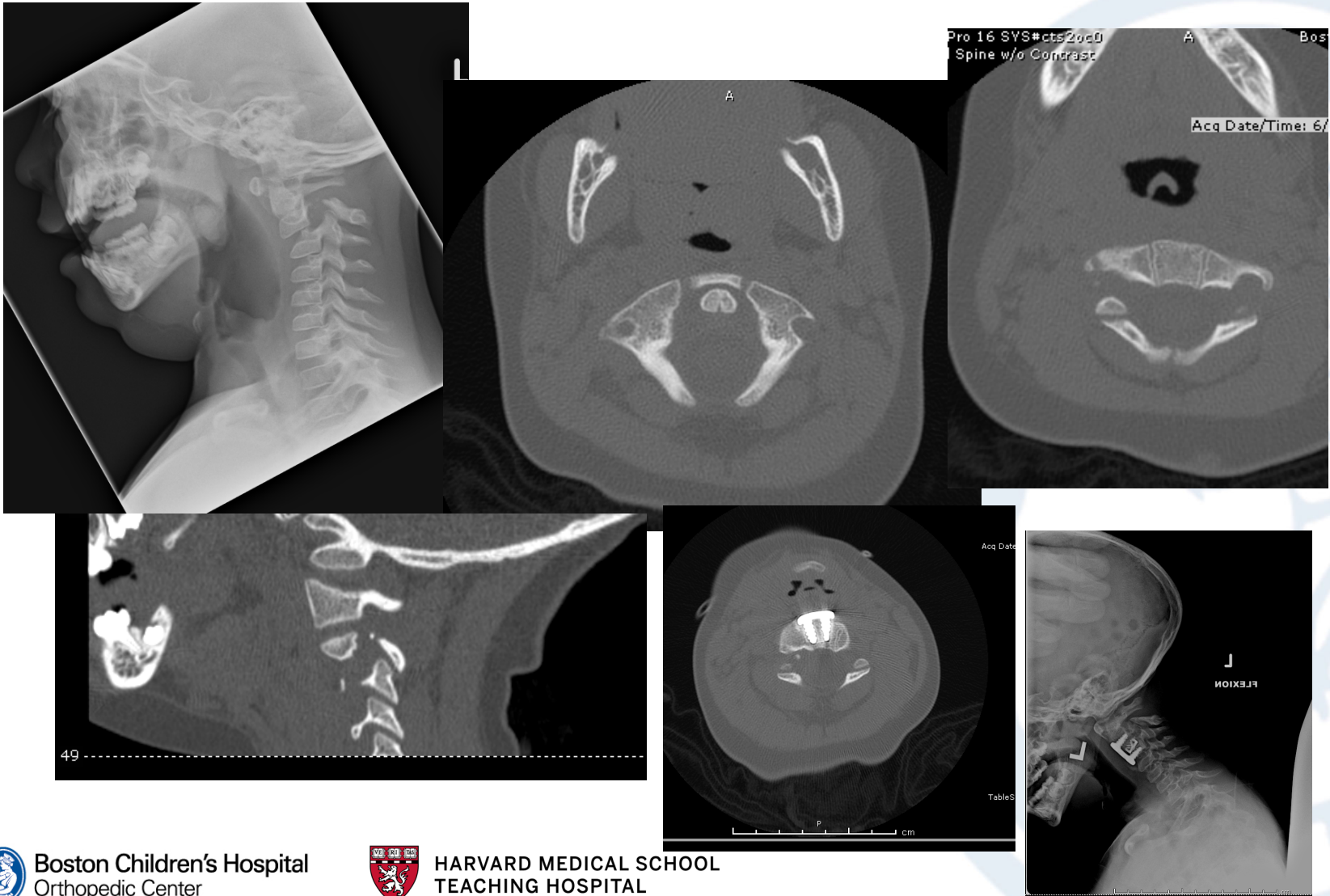


# Evaluating CT Scan--Anatomy





# CT Scan--Size



# Background

- **Benefits of modern instrumentation:**

- Rigid fixation
- Diminished immobilization
- Improved fusion rates
- Reduction capacity



- Lateral mass screw fixation in children. Hedequist D, Proctor M, Hresko T.J Child Orthop. 2010 Jun;4(3):197-201
- Single stage reduction and stabilization of basilar invagination after failed prior fusion surgery in children with Down's syndrome. Hedequist D, Bekelis K, Emans J, Proctor MR.Spine (Phila Pa 1976). 2010 Feb 15;35(4):E128-33
- Modern cervical spine instrumentation in children. Hedequist D, Hresko T, Proctor M.Spine (Phila Pa 1976). 2008 Feb 15;33(4):379-83.
- Screw fixation to C2 in children: a case series and technical report. Hedequist D, Proctor M.J Pediatr Orthop. 2009 Jan-Feb;29(1):21-5

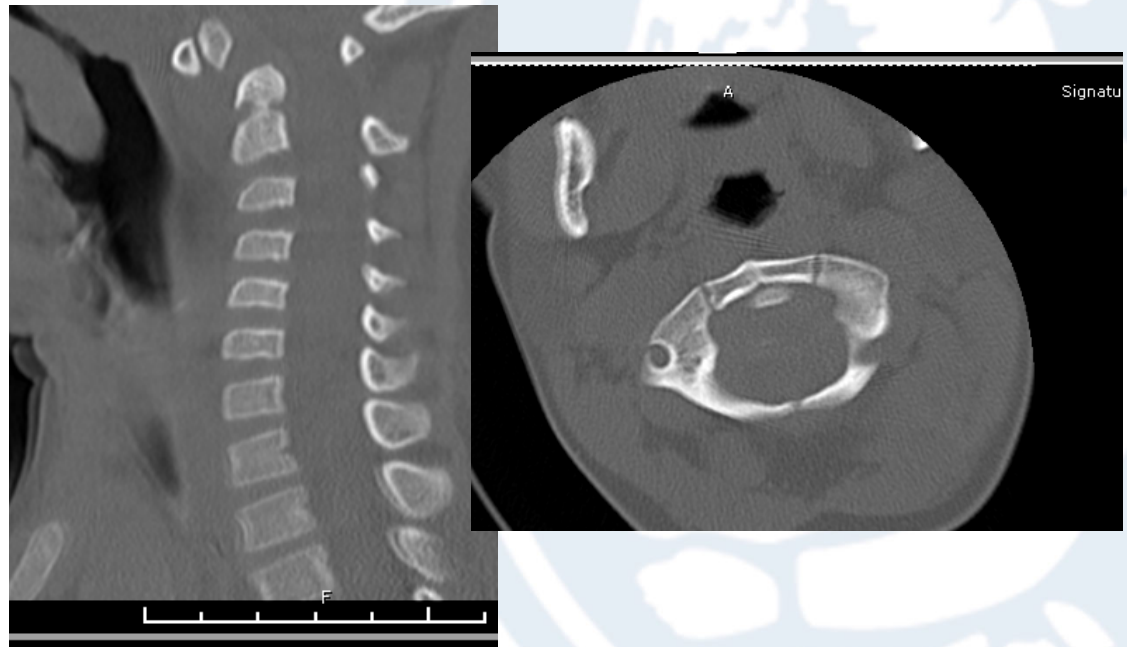
# Upper Cervical Fixation

- **Prefer C1 lateral mass screws coupled with C2 screws rather than transarticular**
  - Less technically problematic
  - Can be easily coupled above or below
  - Overcomes the inherent anatomical challenges of C2
    - High riding Vert
    - Smaller pars



# Case Against Transarticular Screws

Difficult to tell if joint perfectly reduced  
-Instability, rotary subluxation



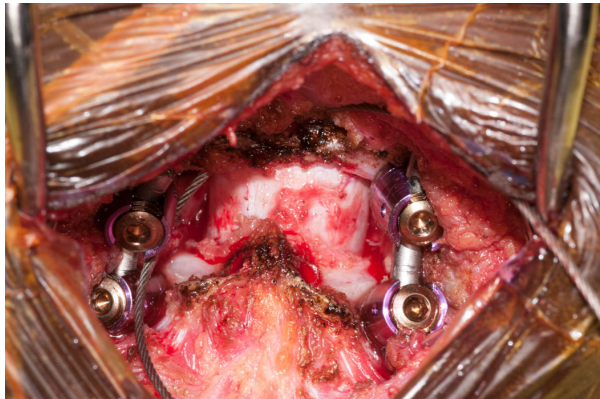
# C1-2 Screw Construct

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- **C1-C2 Joint does not need to be reduced**
- **Avoid small C1 landing area**
- **Multiple options for screws at C2**

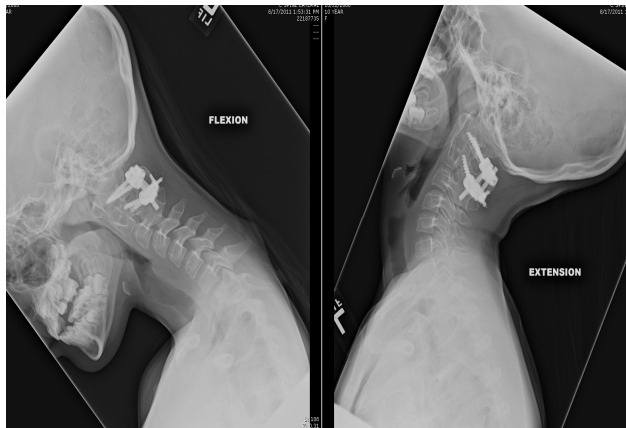


# C1 Lateral Mass Screws



- **Ideal when coupled to C2 screws—”Harms”**
  - Posterior C1-C2 fusion with polyaxial screw and rod fixation. Harms J, Melcher RP. Spine (Phila Pa 1976). 2001 Nov 15;26(22):2467-71.

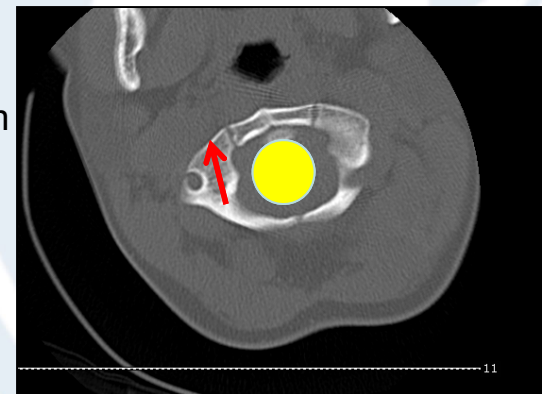
- **Placement completely dependent on adequate exposure**
- **Biomechanically strong**





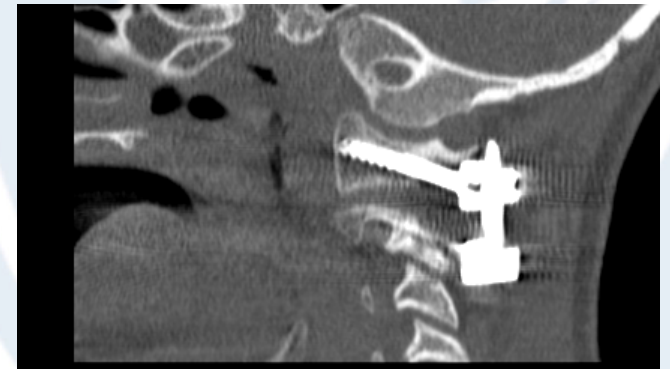
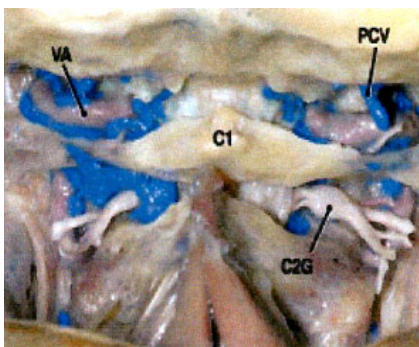
# C1 LM Anatomy in Children

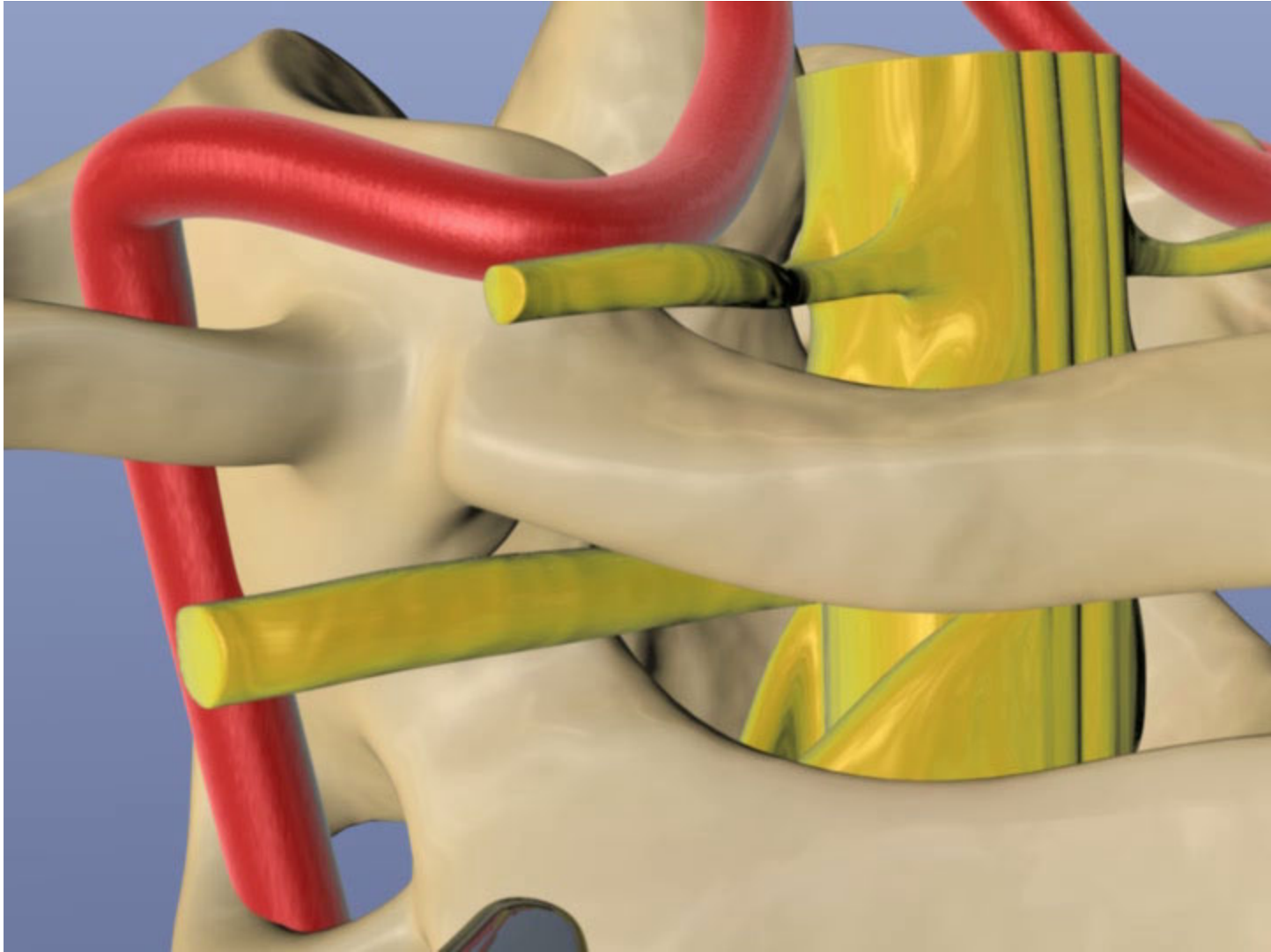
- **Computed tomography morphometric analysis for C-1 lateral mass screw placement in children. Clinical article. Chamoun RB, Whitehead WE, Curry DJ, Luerssen TG, Jea A.J Neurosurg Pediatr. 2009 Jan;3(1):20-3.**
  - CT analysis of 76 patients looking at potential screw feasibility
  - 151/152 lateral masses deemed acceptable for screw placement
- **Feasibility of Rigid Upper Cervical Instrumentation in Children: Tomographic Analysis of Children Aged 2 to 6. Geck MJ, Truumees E, Hawthorne D, Singh D, Stokes JK, Flynn A.J Spinal Disord Tech. 2013 Apr 3.**
  - CT scan analysis 50 patients ages 2-6 years of age
  - Mean length and width of C1 lateral mass 15 mm and 8 mm
  - Feasible in all patients



# C1 screw placement

- **Adequate visualization of starting point critical for screw placement**
- **Epidural veins can be problematic**
- **C2 ganglionectomy beneficial**
  - Routine sectioning of the C2 nerve root and ganglion for C1 lateral mass screw placement in children: surgical and functional outcomes. Patel AJ, Gressot LV, Boatey J, Hwang SW, Brayton A, Jea A. Childs Nerv Syst. 2013 Jan;29(1):93-7. doi: 10.1007/s00381-012-1899-1. Epub 2012 Sep 27.





Boston Children's Hospital  
Orthopedic Center



HARVARD MEDICAL SCHOOL  
TEACHING HOSPITAL

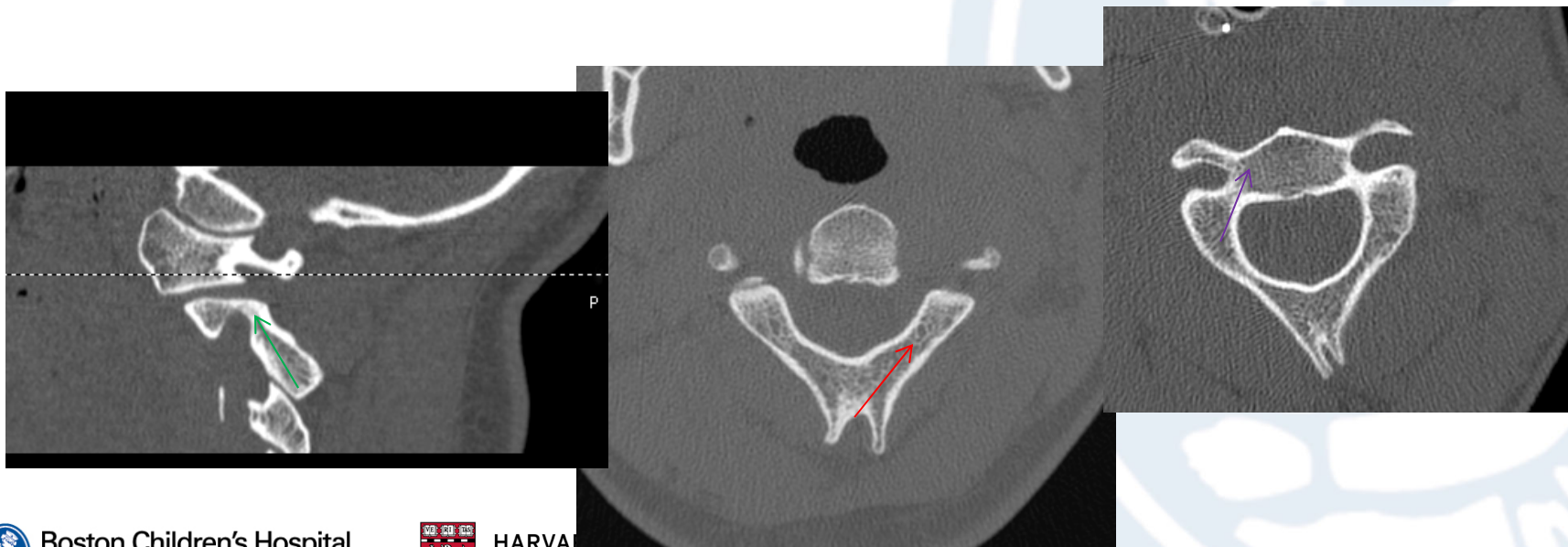
# Clinical series-Feasibility

- **C-1 lateral mass screw fixation in children with atlantoaxial instability: case series and technical report.** Desai R, Stevenson CB, Crawford AH, Durrani AA, Mangano FT. *J Spinal Disord Tech.* 2010 Oct;23(7):474-9.
- **Screw fixation of the upper cervical spine in the pediatric population. Clinical article.** Haque A, Price AV, Sklar FH, Swift DM, Weprin BE, Sacco DJ. *J Neurosurg Pediatr.* 2009 Jun;3(6):529-33.
- **Incorporation of C-1 lateral mass screws in occipitocervical and atlantoaxial fusions for children 8 years of age or younger. Technical note.** Jea A, Taylor MD, Dirks PB, Kulkarni AV, Rutka JT, Drake JM. *J Neurosurg.* 2007 Aug;107(2 Suppl):178-83.
  - No screw related complications
  - Complete screw containment
  - No screw revisions



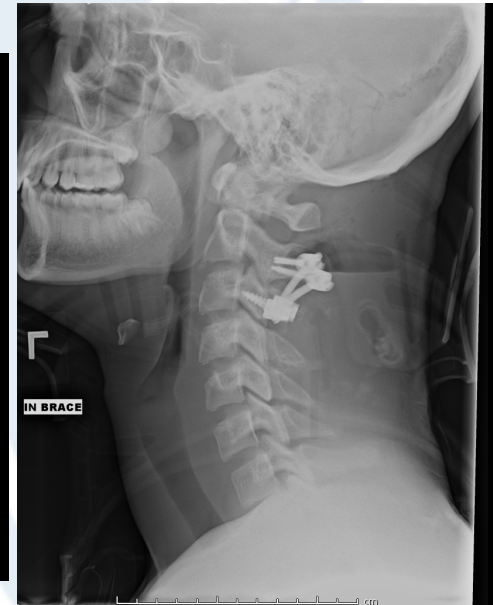
# C2 Screw options

- **C2 pars screws** **STRONG**
- **C2 translaminar screws** **STRONGER**
- **C2 pedicle screws** **STRONGEST**



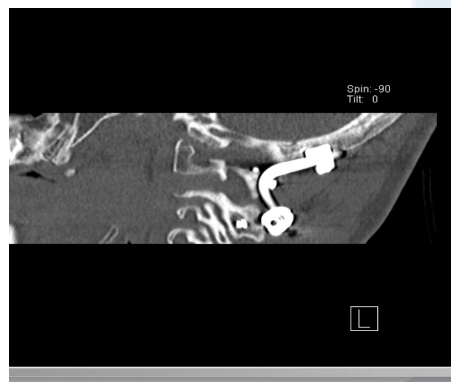
# Anatomical evaluation of C2

- **Feasibility of Rigid Upper Cervical Instrumentation in Children: Tomographic Analysis of Children Aged 2 to 6.** Geck MJ, Truumees E, Hawthorne D, Singh D, Stokes JK, Flynn A.J *Spinal Disord Tech.* 2013 Apr 3
  - CT morphometric study
  - C2 translaminar suitable >90 % lamina
  - C2 pedicle screws in 50%



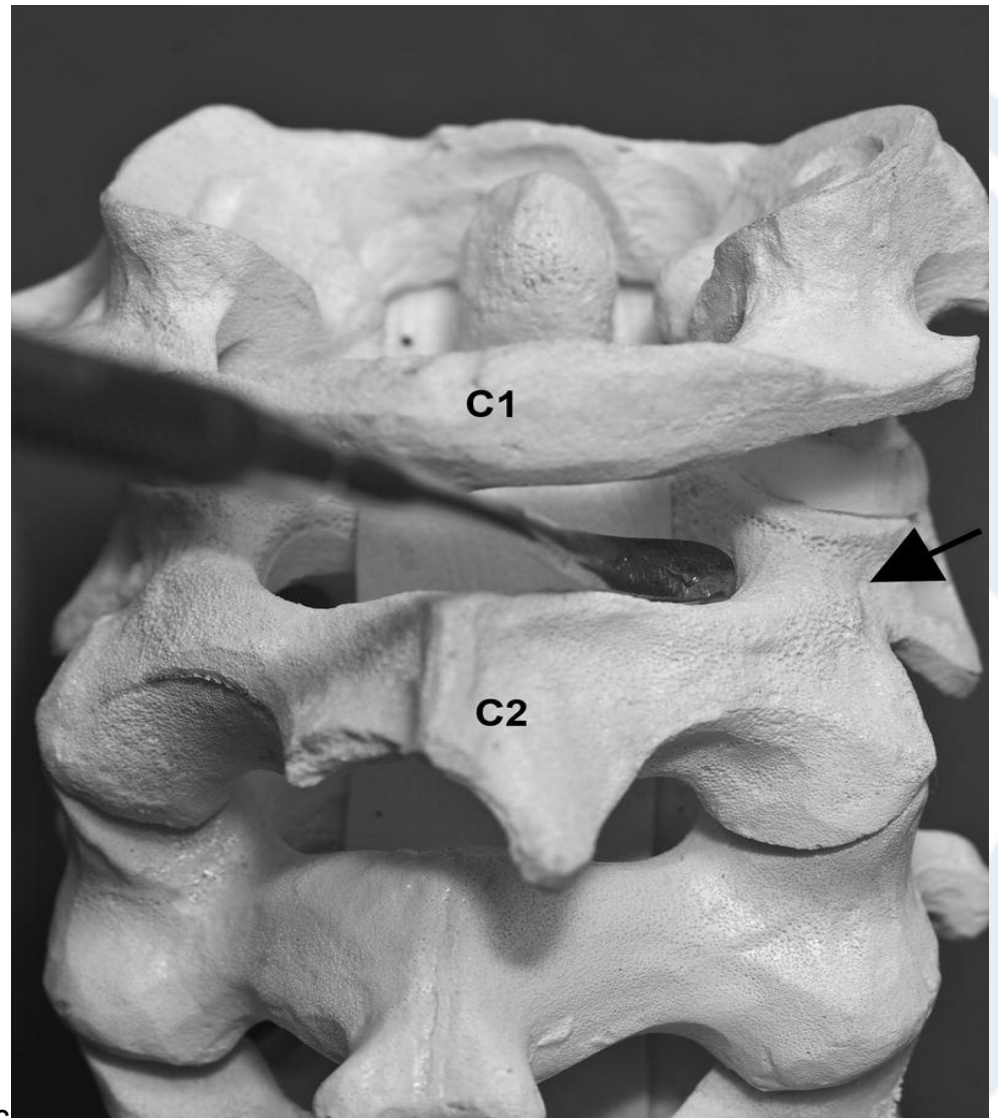
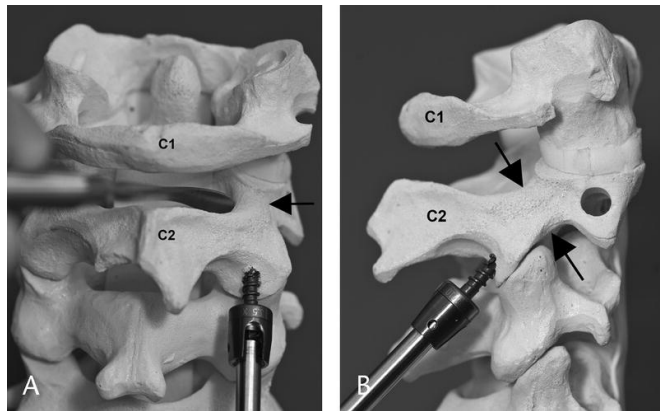
# Clinical results C2 fixation

- **Screw fixation to C2 in children: a case series and technical report.**Hedequist D, Proctor M.J *Pediatr Orthop.* 2009 Jan-Feb;29(1):21-5
- **Screw fixation of the upper cervical spine in the pediatric population.** Clinical article.Haque A, Price AV, Sklar FH, Swift DM, Weprin BE, Sacco DJ.*J Neurosurg Pediatr.* 2009 Jun;3(6):529-33
- **Treatment of pediatric atlantoaxial instability with traditional and modified Goel-Harms fusion constructs.**Heuer GG, Hardesty DA, Bhowmick DA, Bailey R, Magge SN, Storm PB.*Eur Spine J.* 2009 Jun;18(6):884-92



# Screw fixation at C2

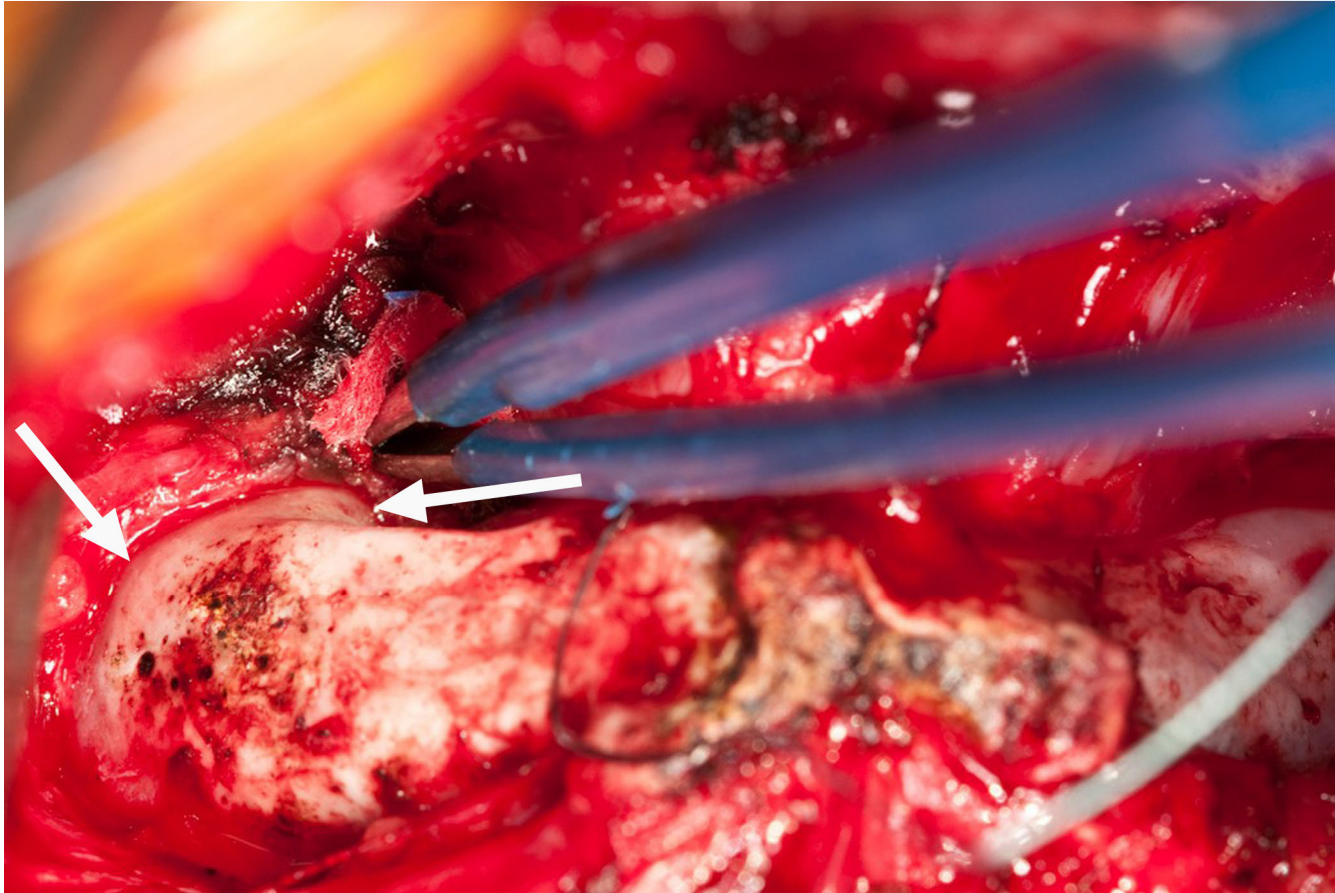
- Planning
- Exposure
- Palpation





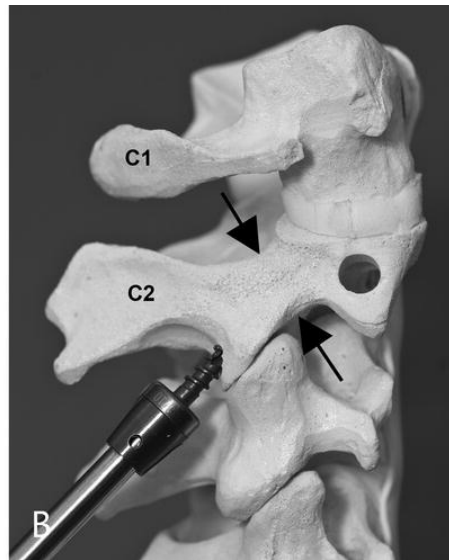
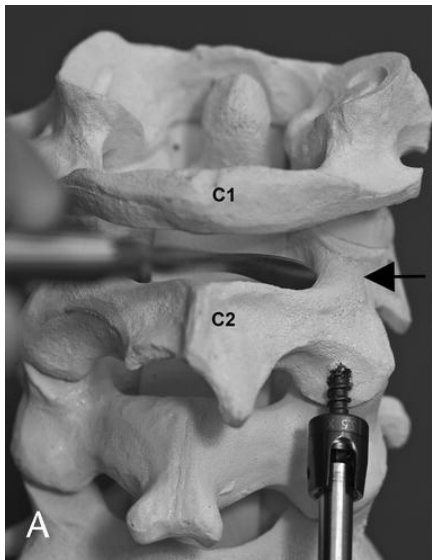
# USE THE BIPOLAR!

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# C2 Pars Screws

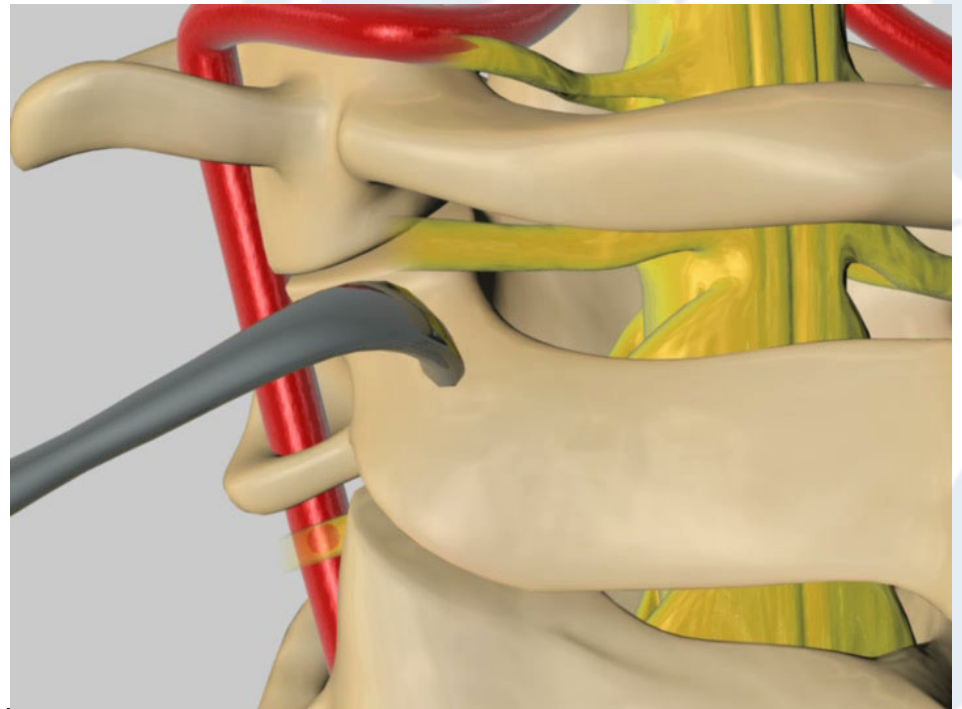
- **Technically easy**
- **Fits in line with subaxial screws and occipital fixation**
- **Pull-out strength adequate for most cases**



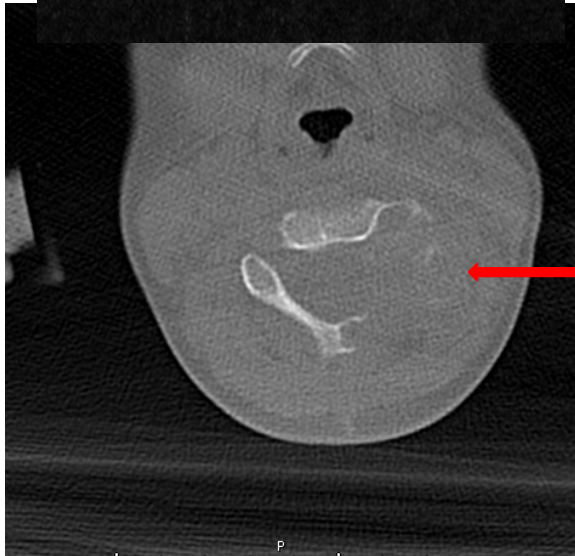
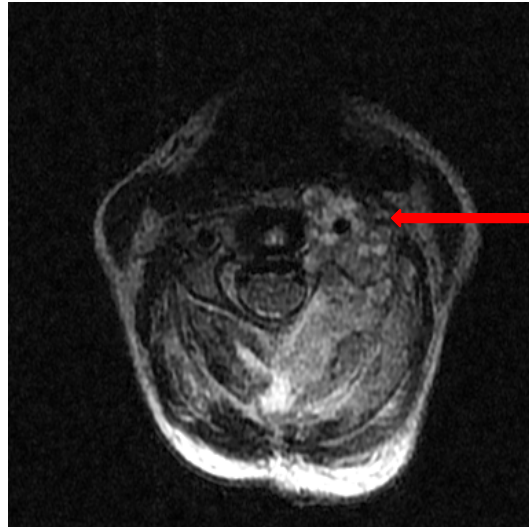
# C2 Pars Screw

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- **Lateral mass equivalent**
- **Dissection of pars is the key for medial-lateral direction**
- **Fluoroscopy is key for rostral direction**

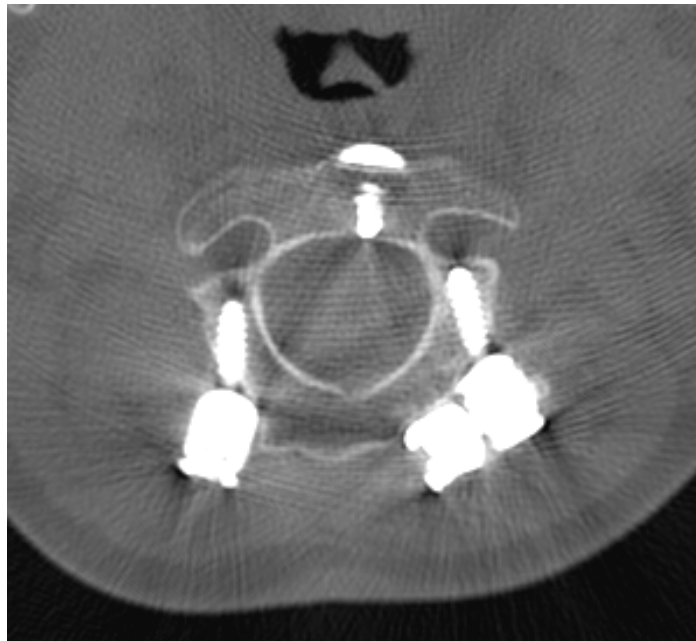


# C2 Example



CERVICAL CT  
3/13/2012 9:50:20 AM  
22347563  
\*\*\*\*  
LOC: -140.50  
THK: 2  
HFS





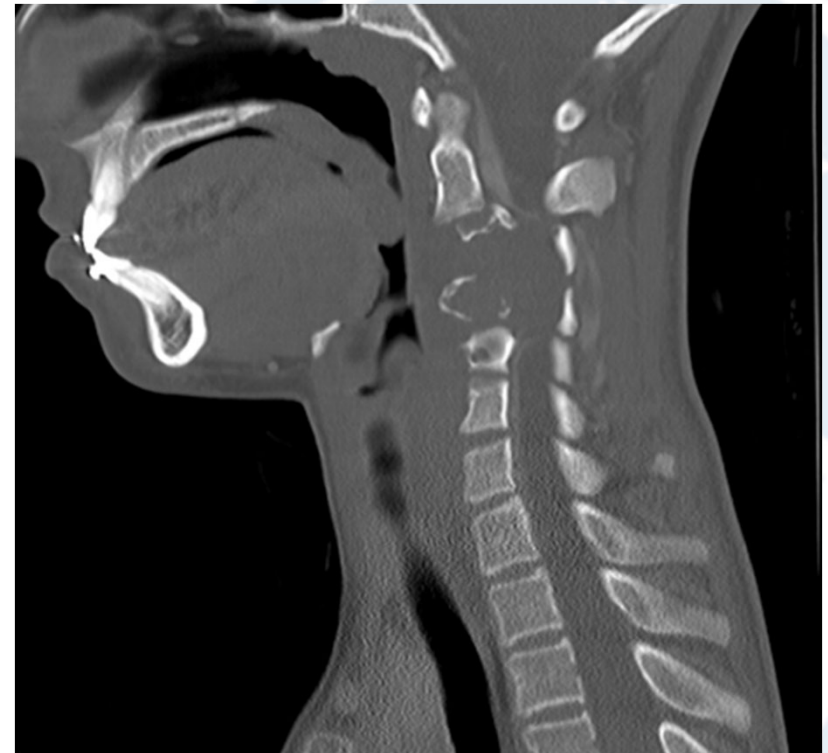
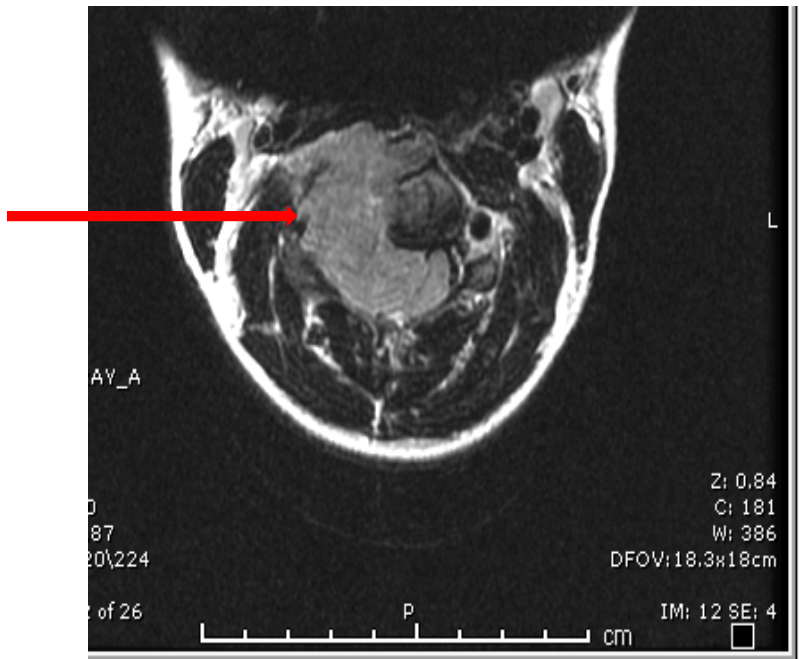
# Translaminar screws

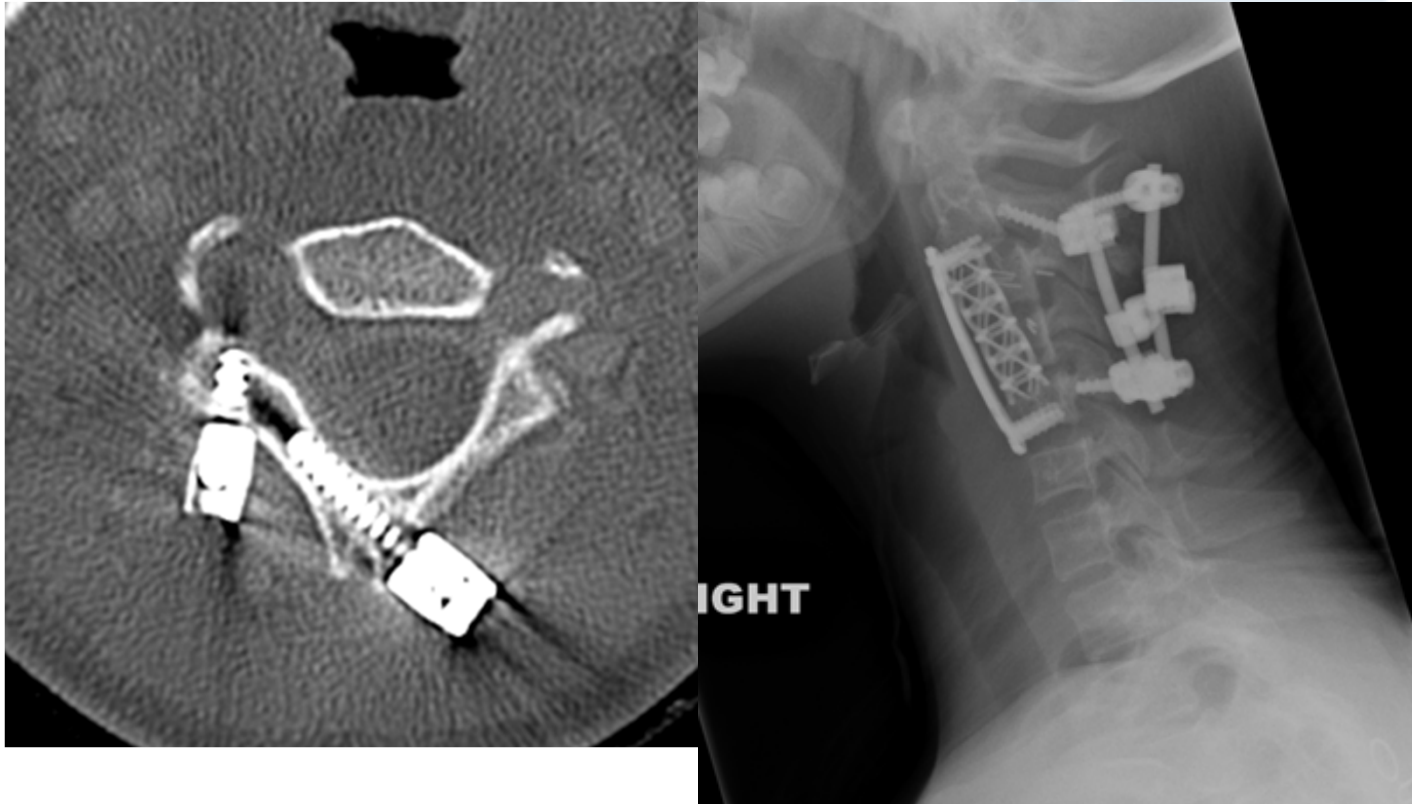
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- **Technically easy**
- **Watch starting points**
  - Crossing screws
- **Vert not at risk**
  - If vertebral artery damaged or sacrificed on other side then this is the optimal screw



# Translaminar screws

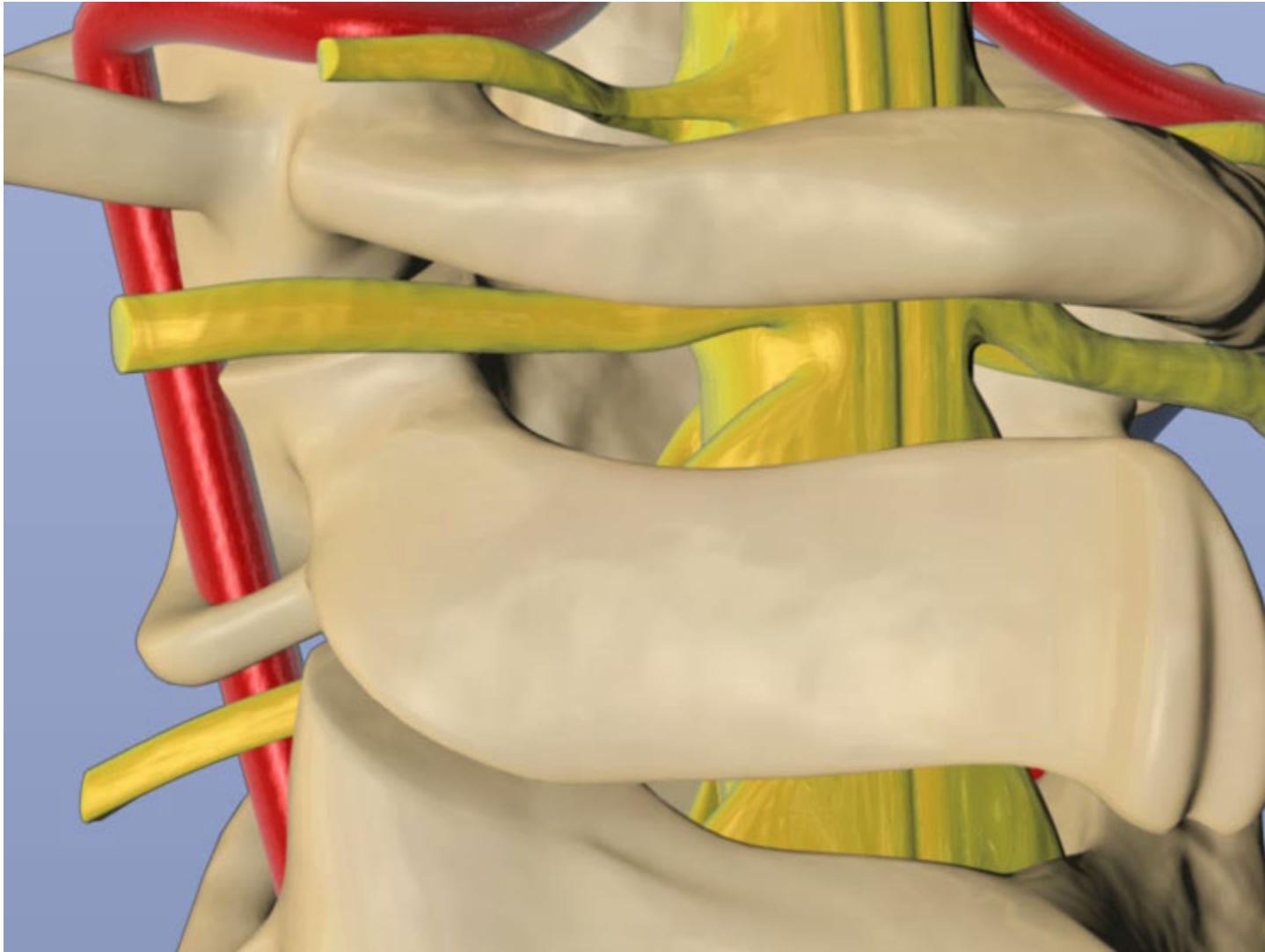




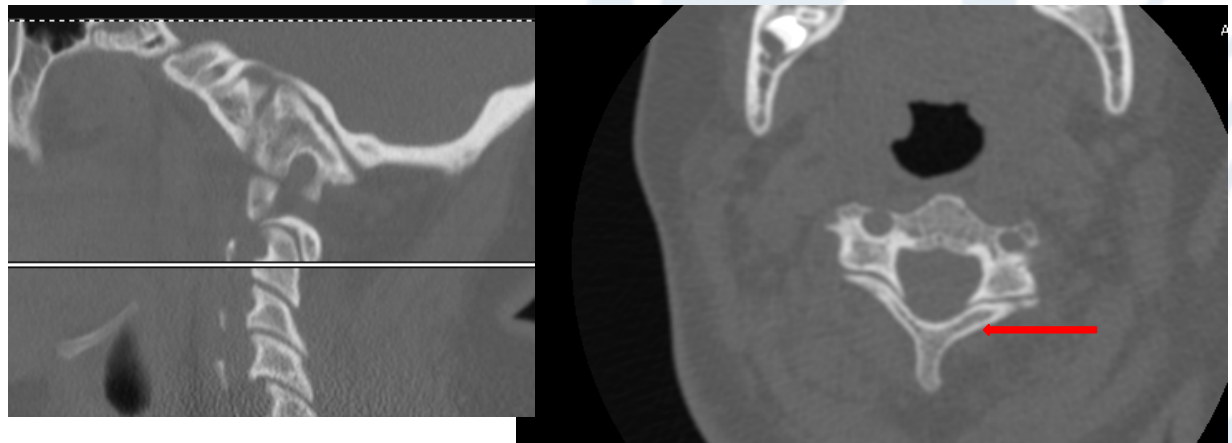
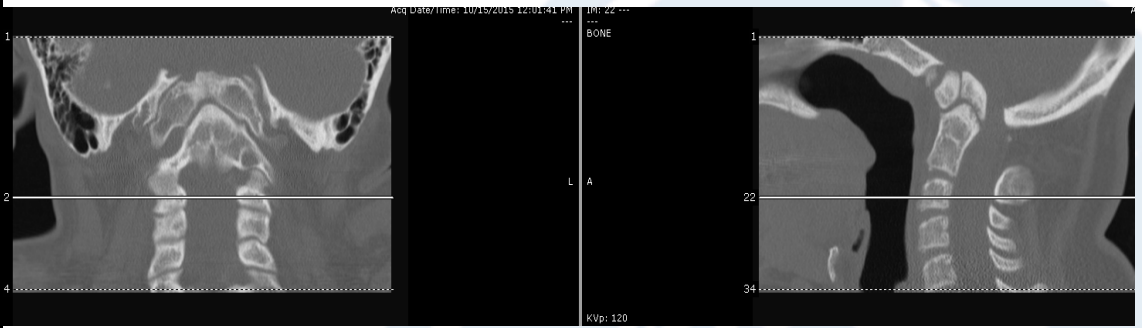


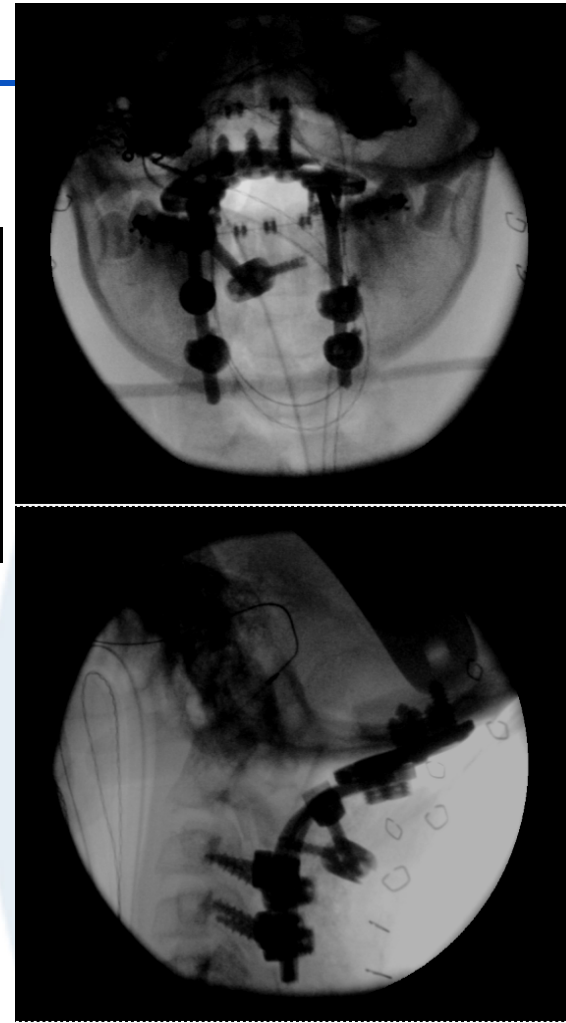
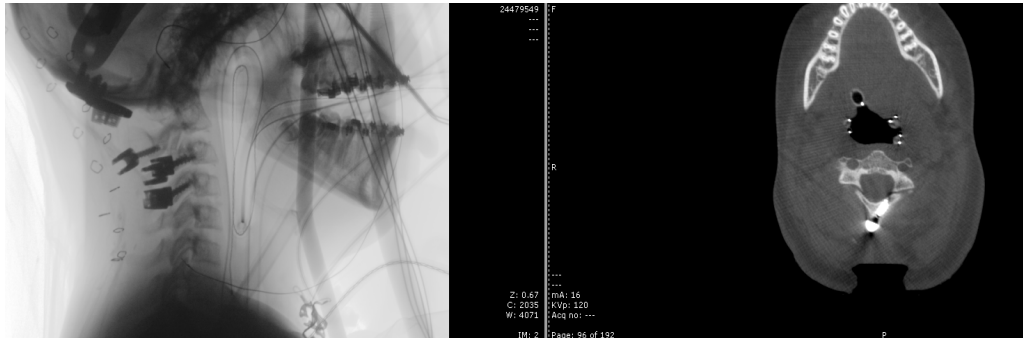
# Translaminar technique

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# Anomalous Anatomy





# Summary

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- **Rigid Instrumentation in children**

- Feasible in most patients
- CT most useful study
- Surgical dissection most important
- Halo still may be necessary
- Remember graft
  - Iliac crest mandatory at upper cervical/craniocervical junction



# Save the Date—November 8<sup>th</sup>, 2016

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- **Children's Hospital Boston Spine Symposium**
- **Honoring John Emans M.D.**
  - GRICE LECTURER 2016

