Upper Cervical Spine Trauma

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Upper Cervical Spine Trauma

- Epidemiology
- Anatomy
- Radiographic Evaluation
- Common Injuries
- Special Considerations

Epidemiology

- 717 cervical spine fractures (657 patients over 13 years)
- C2 fractures most common
- Younger patients: C1 and C2 Hangman's fractures more common
- Odontoid fractures evenly distributed
  - Younger patients have higher energy injuries

Ryan and Henderson Injury 1992

Upper Cervical Anatomy

Upper Cervical Anatomy

- Biomechanically specialized
  - Support of "large" cranial mass
  - Large range of motion
    - Flexion/extension
    - Axial rotation
    - 50% of cervical spine motion localized to Occ-C1-C2 articulations

France JC, Bono CM, Vaccaro AR. Initial radiographic evaluation of the spine after trauma: when, what, where, and how to image the acutely traumatized spine. J orthop trauma. 2005 ;19:640-9.

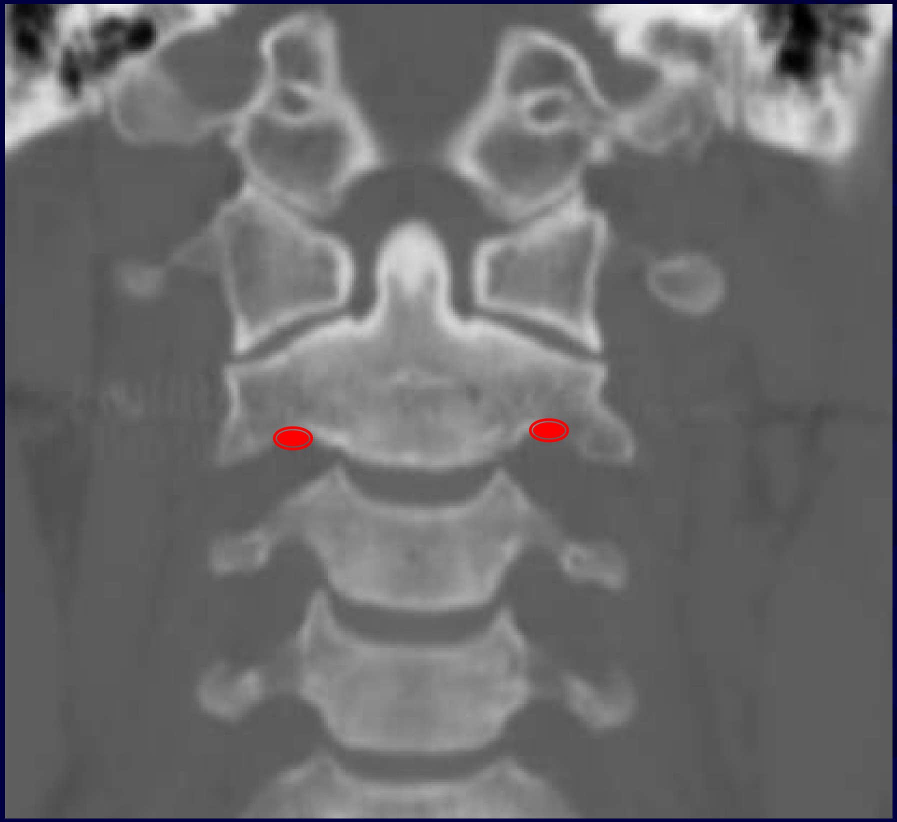
Vertebral Artery Course

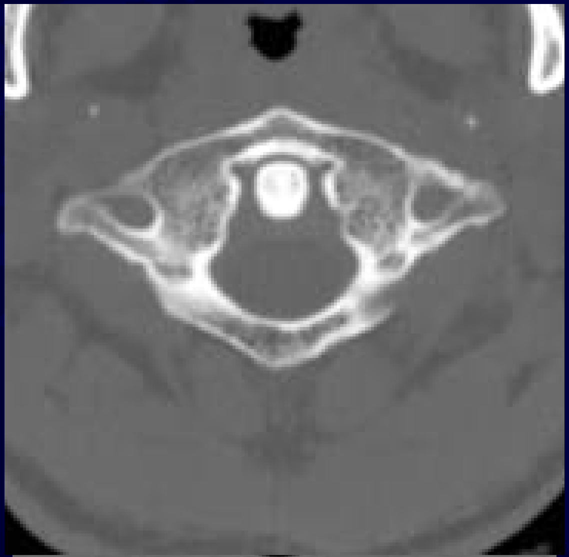
- Course through C1/C2 determine potential for screw placement for fixation
  - C1 lateral mass screws
  - C1-2 transarticular screws
  - C2 pedicle/pars screws

- Special attention to be paid for enlarged or aberrant foramina with low threshold for **CTA/MRA** for complete evaluation

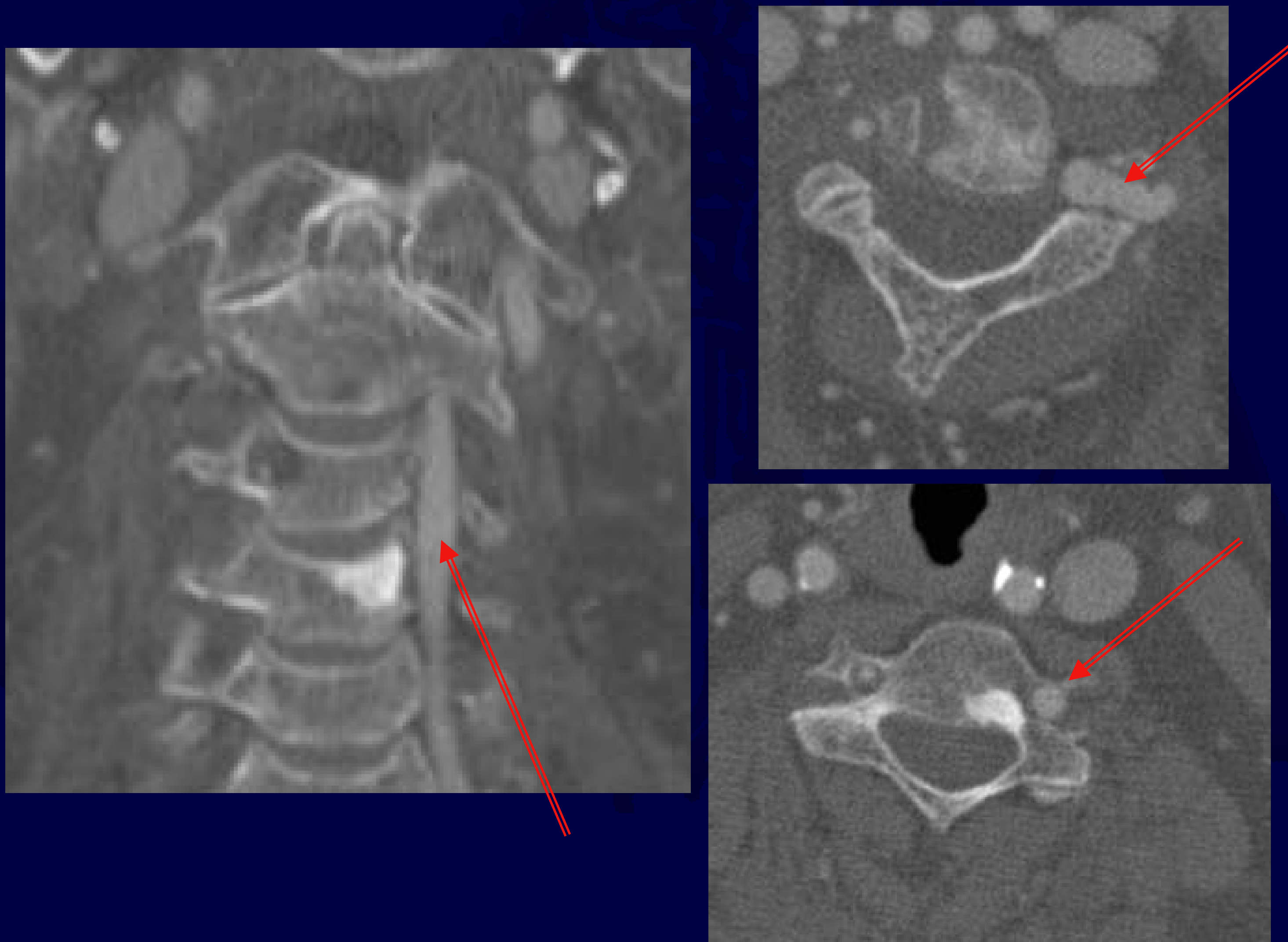
Harty JA, Sparkes J, McCormack D, Walsh MG. Recognition of progressive atlanto-occipital dislocation (by a changing neurologic status and clinical deformity). J orthop trauma. 2003 1;17:299-302.

Normal Vertebral Artery



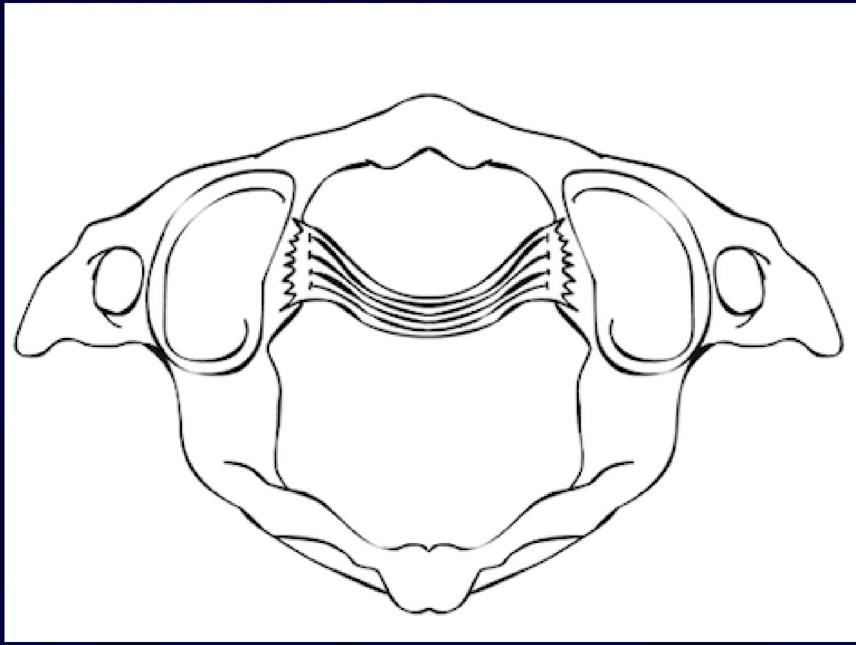


Tortuous Vertebral Artery



C1 - Atlas

- Transition between cranium and c-spine
  - Occ-C1: flexion-extension
- No body (C2 dens)
- Vertebral artery foramen
- 2 arches
  - Anterior
  - Posterior
    - Vertebral artery groove

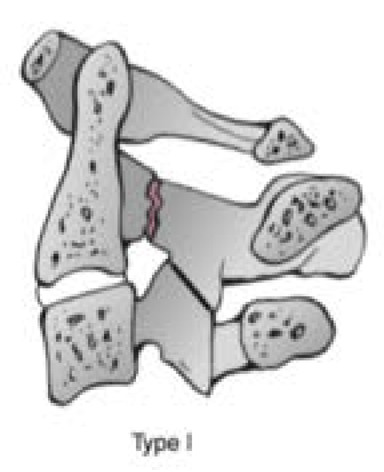


C2 Anatomy

- Dens
  - Embryological C1 body
  - Base = watershed (poorly vascularized)
  - Osteoporotic
- Flat C1-2 joints: rotation
- Vertebral artery foramen
  - Inferomedial to superolateral

Anatomy – The Axis

- Important transition point for forces within the c-spine
- Important anatomical points
  - Superior and inferior articular processes are “offset” in the AP direction- due to different functions at each articulation
  - Pars interarticularis- due to this transition is a frequent fracture site
  - Odontoid process- the “pivot” for rotation

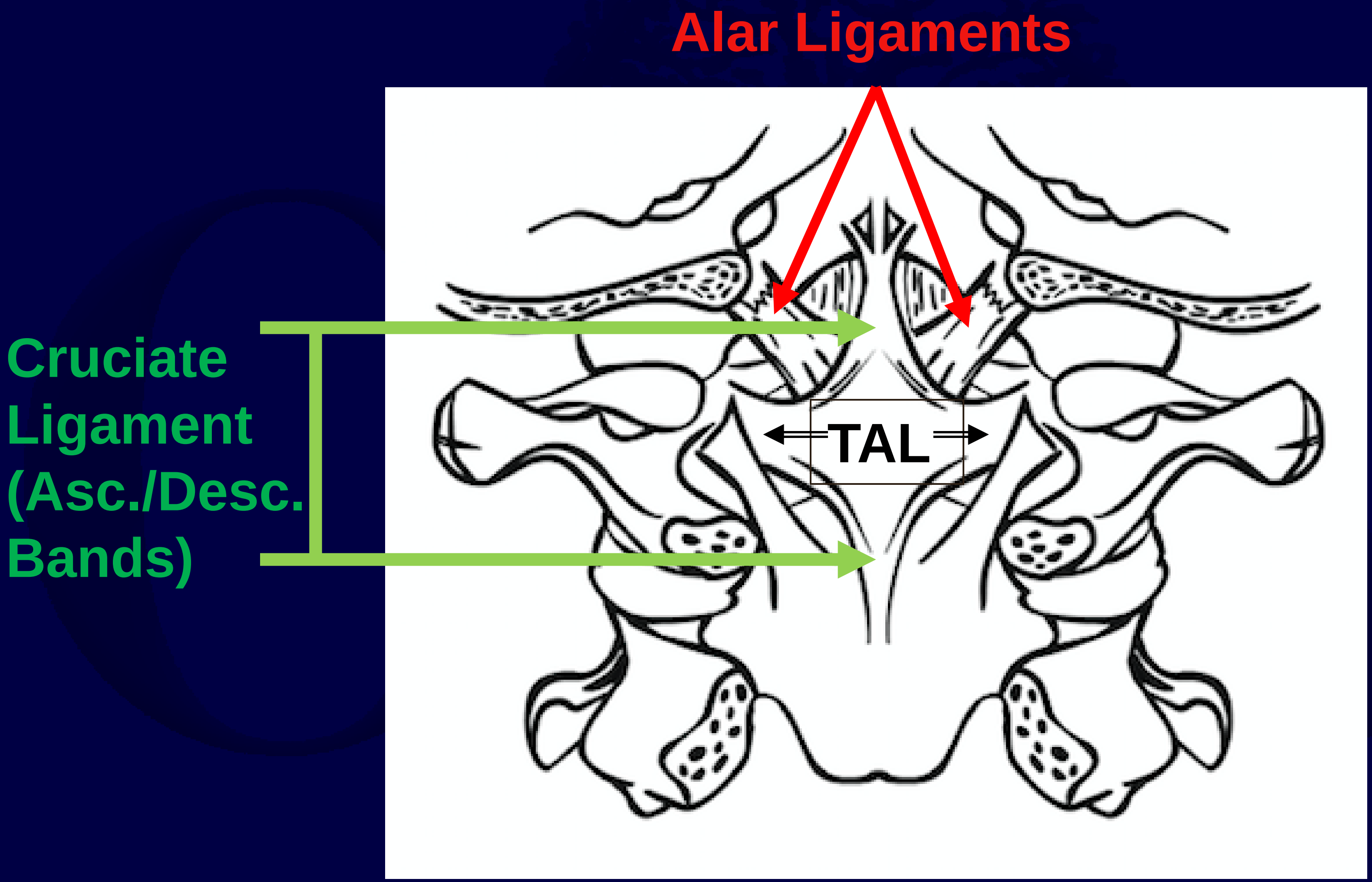


Rockwood and Green’s Fractures in Adults Eighth Edition Figure 44-43 p. 1729

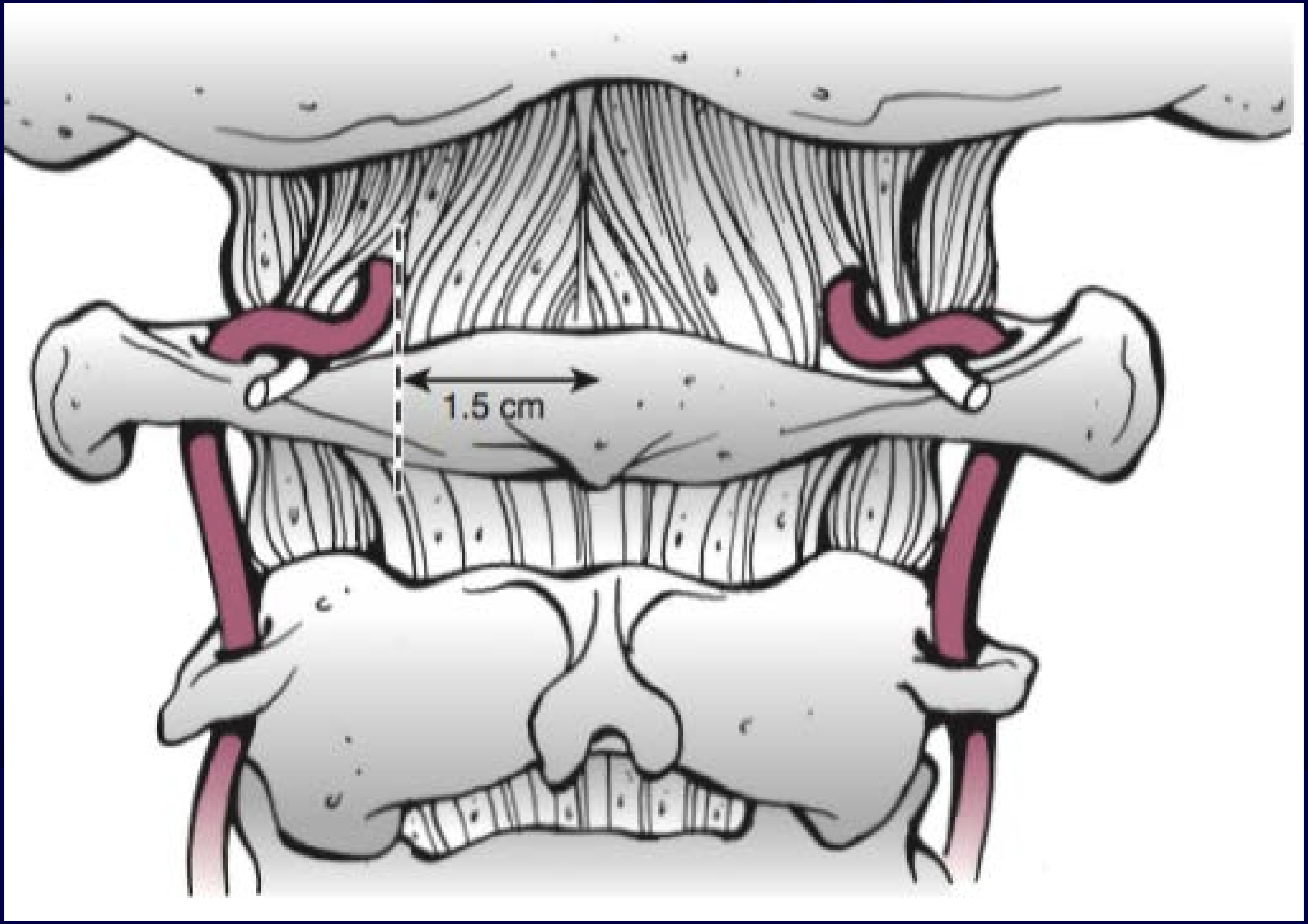
Ligamentous Anatomy

- Provide restraint for mobile upper cervical spine (check-rein function)
- Classified according to location with respect to vertebral canal
  - Internal:
    - Tectorial membrane
    - **Cruciate ligament – including transverse ligament**
    - **Alar and apical ligaments**
  - External
    - Anterior and posterior atlanto-occipital membranes
    - Anterior and posterior atlanto-axial membranes
    - Articular capsules and ligamentum nuchae

Atlanto-Axial Anatomy



Vertebral Artery



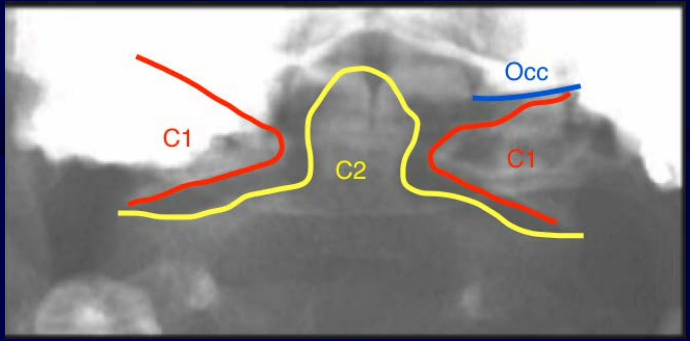
Rockwood and Green's Fractures in Adults Eighth Edition Figure 44-17 p. 1692

Radiographic Evaluation

Plain Radiographic Evaluation

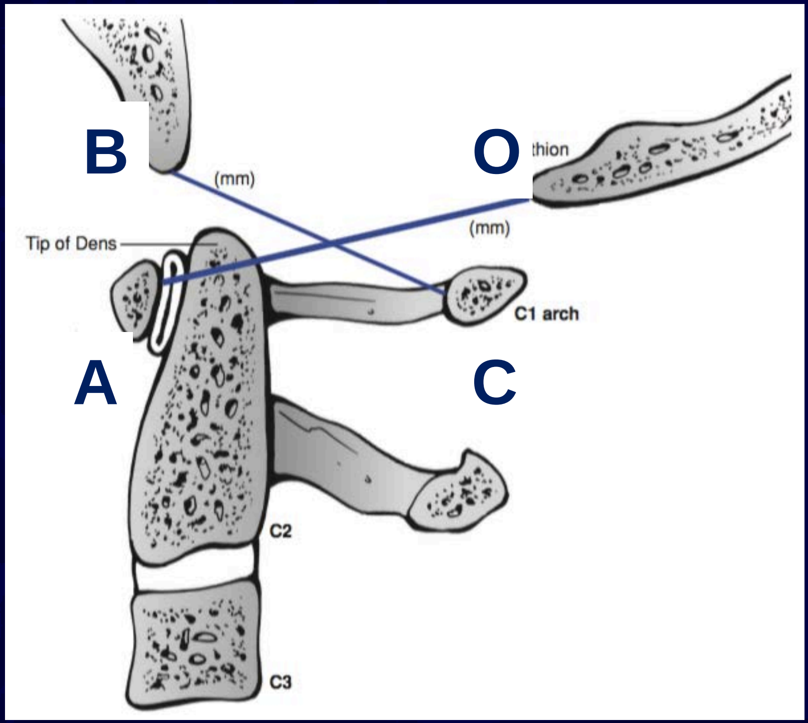
- Lateral View
  - Prevertebral Swelling
    - Soft Tissue Shadow
      - <6mm at C2
      - Concave/Flat
  - Pre-dental space ≤ 3mm
  - Atlanto-Occipital Joint Congruence
  - *Radiographic Lines (Harris Line/Powers Ratio)

- Open Mouth AP
  - Distraction
  - C1-2 Symmetry



Powers' Ratio

- BC/OA
  - >1 considered abnormal
- Limited Usefulness
- Positive only in Anterior Translational injuries
- False Negative with pure distraction



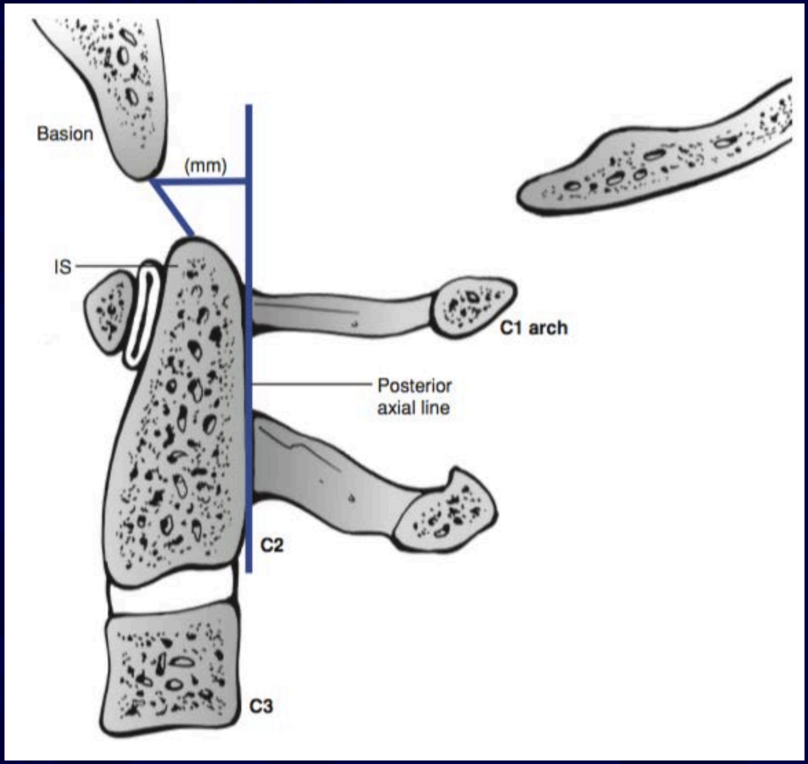
Rockwood and Green's Fractures in Adults
Eighth Edition Figure 44-1 p. 1691

Powers et al, Neurosurgery, 1979

Harris' Lines

- Basion-Dental Interval (BDI)
  - Basion to Tip of Dens
    - <12 mm in 95%
    - >12 mm ABNORMAL
- Basion-Axial Interval (BAI)
  - Basion to Posterior Dens
    - -4-12 mm in 98%
    - >12 mm Anterior Subluxation
    - >4 mm Posterior Subluxation

***>12 mm BAI/BDI abnormal



Rockwood and Green's Fractures in Adults Eighth Edition Figure 44-1 p. 1683

Harris et al, Am J Radiol, 1994

Radiographic Diagnosis

MRI

- Increased Signal Intensity in :
  - C0-C1 Joint
  - C1-2 Joint
  - Spinal Cord
  - Cranio-cervical ligaments
  - Pre-vertebral soft tissues

Dickman et al, J Neurosurg, 1991

Warner et al, Emerg Radiol, 1996

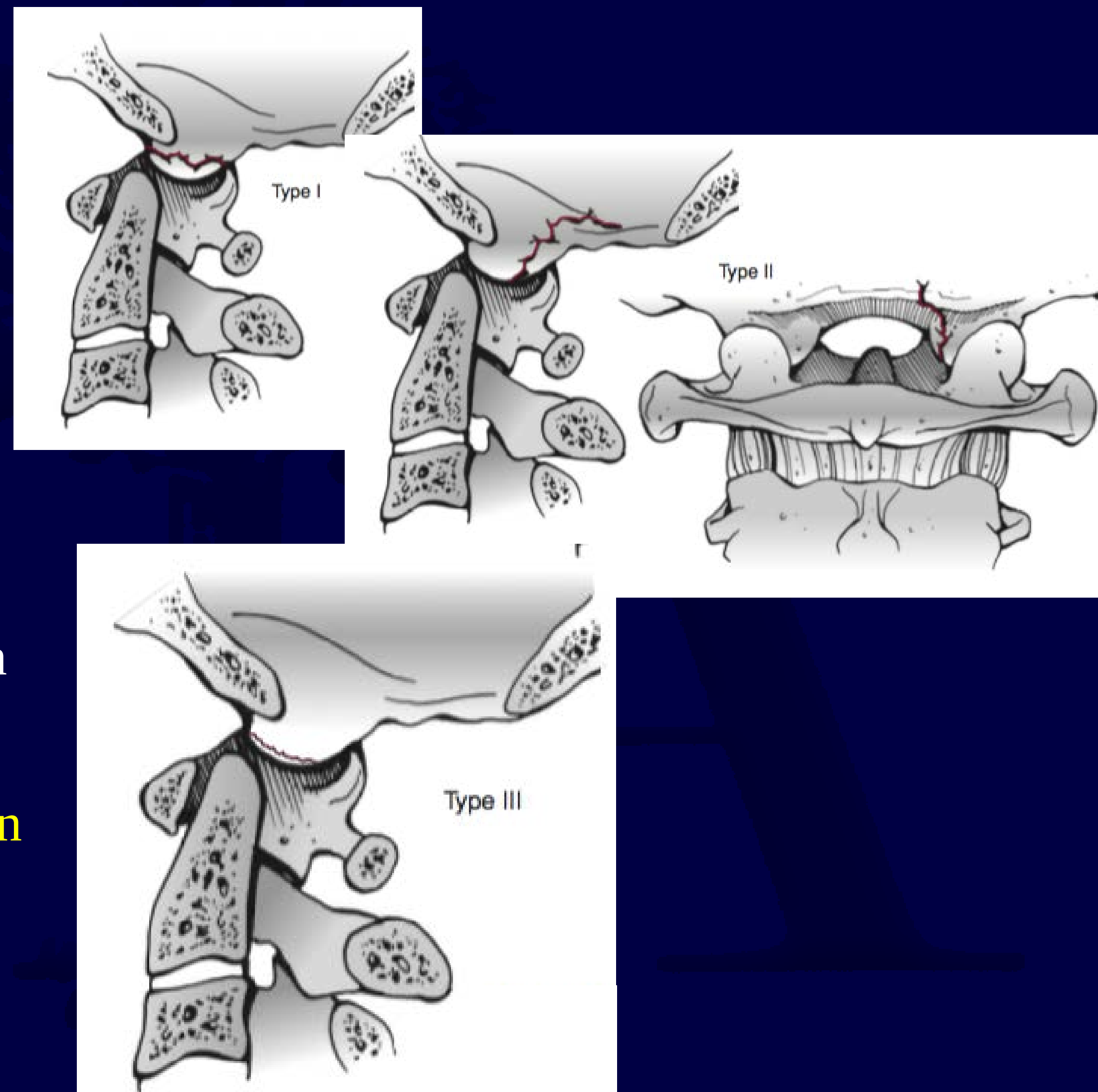
Upper Cervical Spine Fractures

- Common Injuries
  - Occipital Condyle Fracture
  - Craniocervical sprain?
  - C1 ring injuries
  - Odontoid Fracture
  - Hangman’s Fracture
- Uncommon Injuries
  - Craniocervical Dislocation
  - Rotatory subluxation

Occipital Condyle Fracture

- Type I
  - Impaction Fracture
- Type II
  - Extension of basilar skull fracture
- Type III
  - ALAR ligament Avulsion
  - *Must evaluate for craniocervical dissociation

Anderson/Montesano, Spine 1988
Tuli et al., Neurosurgery 1997



Rockwood and Green's Fractures in Adults
Eighth Edition Figure 44-38 p. 1716

Craniocervical Dissociation

- Antlanto-Occipital Joint
- Occipito-Cervical Joint
- Cranio-cervical Joint
- Atlanto-Axial Joint

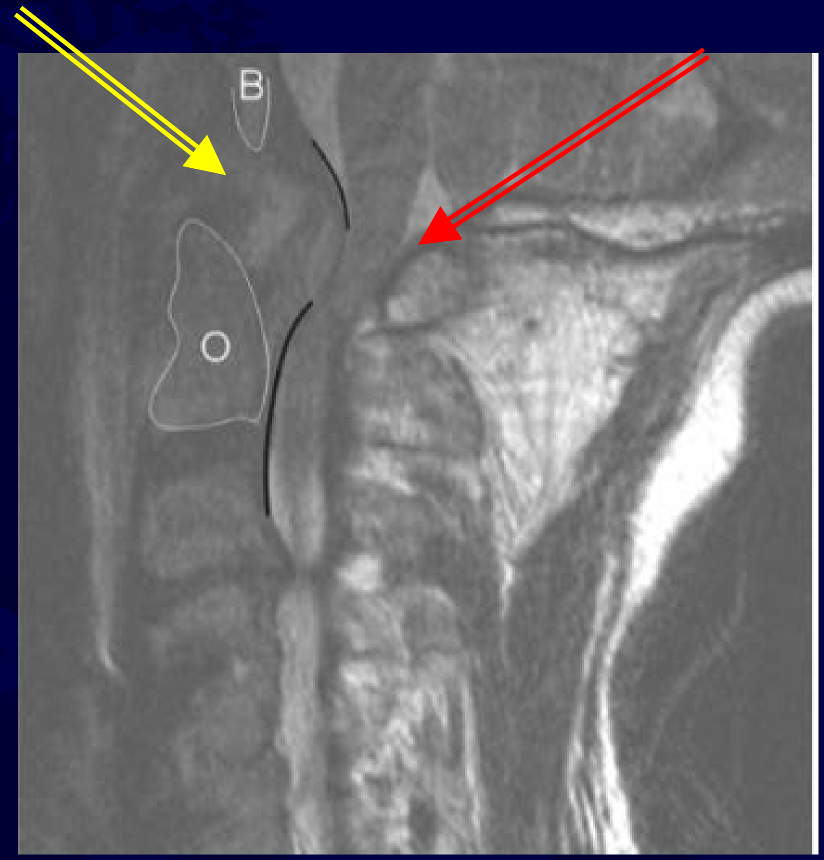
Craniocervical Dissocation

- High energy typically required to cause this injury pattern
- Commonly Fatal
  - Present 6-20% of post mortem studies
  - Alker et al, 1978
  - Bucholz & Burkhead,1979
  - Adams et al, 1992
- 50% missed injury rate
  - **1/3 Neurological Worsening**
  - Davis et al, 1993

Symptoms/Findings

- Lower Cranial nerve deficits (V, IV, VII, XII)
- Horner's syndrome
- Cerebellar ataxia

- Often associated with Wallenberg syndrome

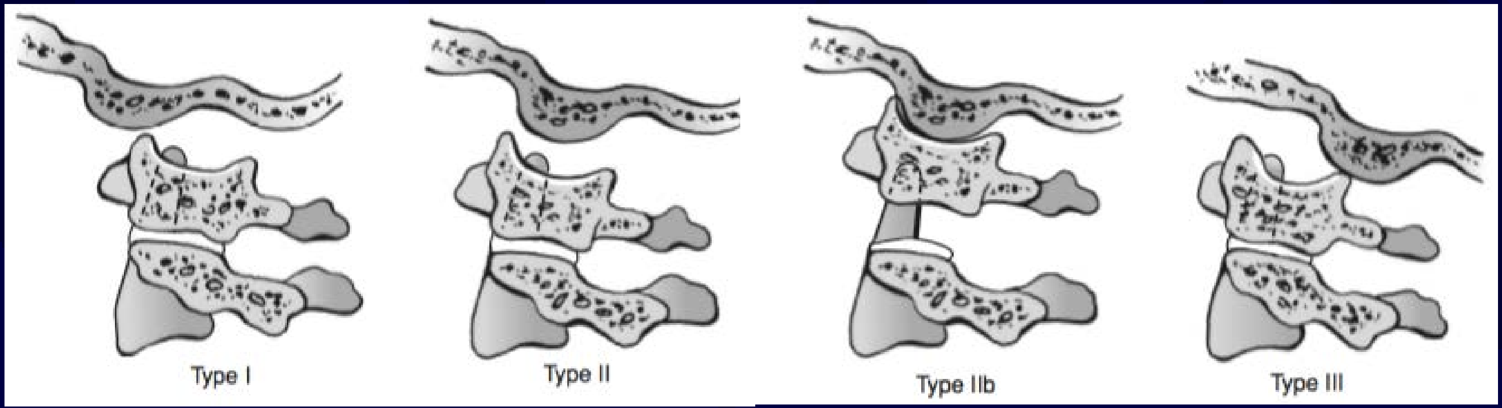


Wallenberg Syndrome

- Involving occlusion of posterior inferior cerebellar artery (PICA)
- Nystagmus
- CN X nerve palsy (dysphagia)
- Cerebellar ataxia
- Ipsilateral Horner's syndrome
- Ipsilateral pain/temperature deficit over upper half of face
- Contralateral pain/temperature deficit over body
- Hiccups

Traynelis Classification

- Direction based classification
  - I- Anterior dislocation
  - II – Longitudinal dislocation
  - IIb – Atlantoaxial dislocation
  - III – posterior dislocation



Rockwood and Green's Fractures in Adults Eighth Edition Figure 44-34 p. 1711

Traynelis et al. J Neurosurgery 1986

Harborview classification

Stage	Injury Descriptor
1	MRI evidence of injury to craniocervical osseoligamentous stabilizers; craniocervical alignment within 2 mm of normal, **distraction of <2 mm on provocative traction**
2	MRI evidence of injury to craniocervical osseoligamentous stabilizers; craniocervical alignment within 2 mm of normal, **distraction of >2 mm on provocative traction**
3	Craniocervical malalignment of >2 mm on static radiographs

- Cranio-cervical sprain (stage 1) may be treated non-operatively

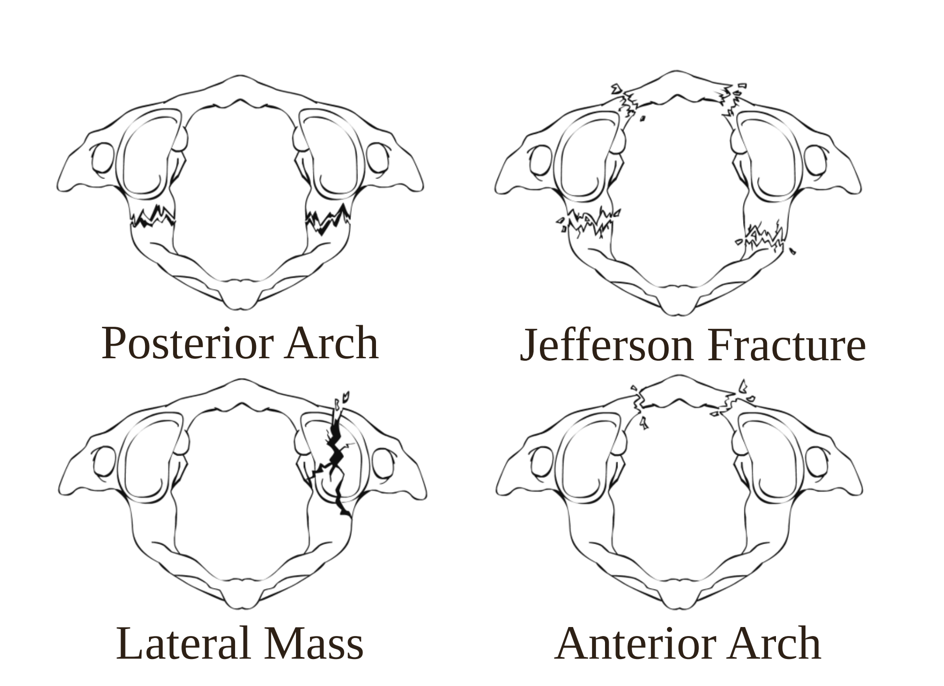
Bellabarba et al. Spine 2006

Craniocervical Dissociation

- Treatment
  - Emergency Room
    - Collar/sandbag/tape
    - Halo vest
    - Minimize transfers!
    - Keep cranium on cervical spine
- Definitive
  - Posterior occipitocervical fusion
  - ALWAYS include C1 and C2

Atlas Fractures

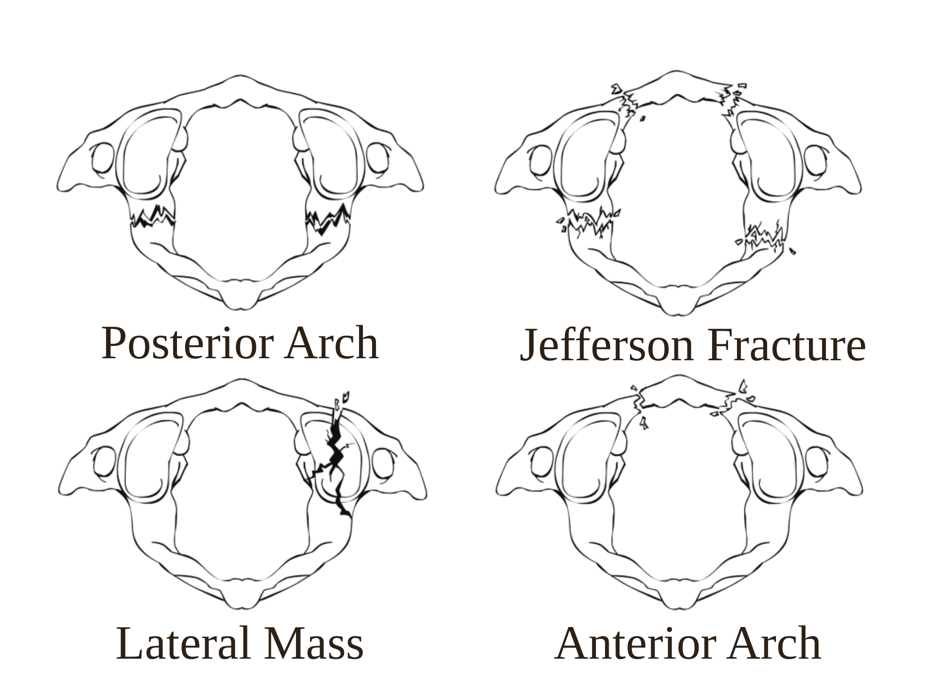
- Anterior Arch
- Posterior Arch
- Jefferson (Displaced vs. Nondisplaced)
- Lateral Mass Fracture
- *Transverse Ligament injury



Atlas Fractures - Treatment

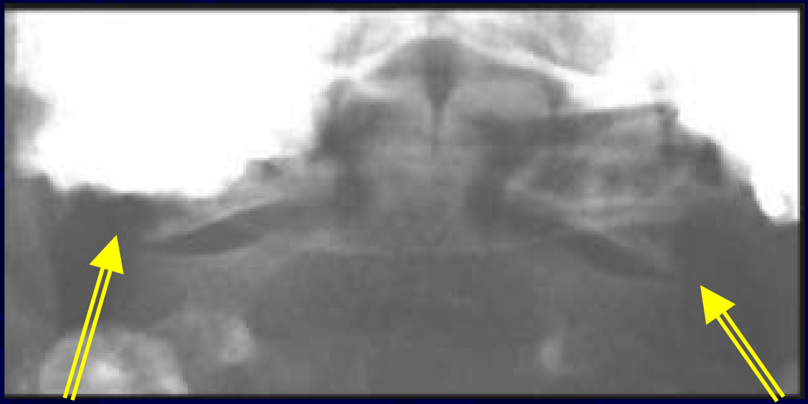
Collar

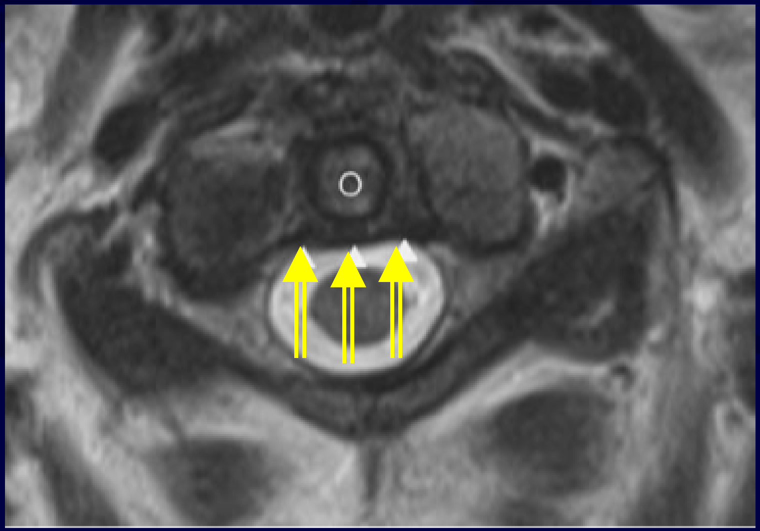
1. Isolated anterior arch
2. Isolated posterior arch
3. Non-displaced Jefferson fracture



Transverse Ligament Injury

- Represented by combined lateral mass overhang of >6.9 mm
  - Spence et al. JBJS 1970
- Lateral mass overhang of >8.1 mm when assessed by radiographs secondary to magnification error
  - Heller et al. JSDT 1993
- Normal imaging to the right

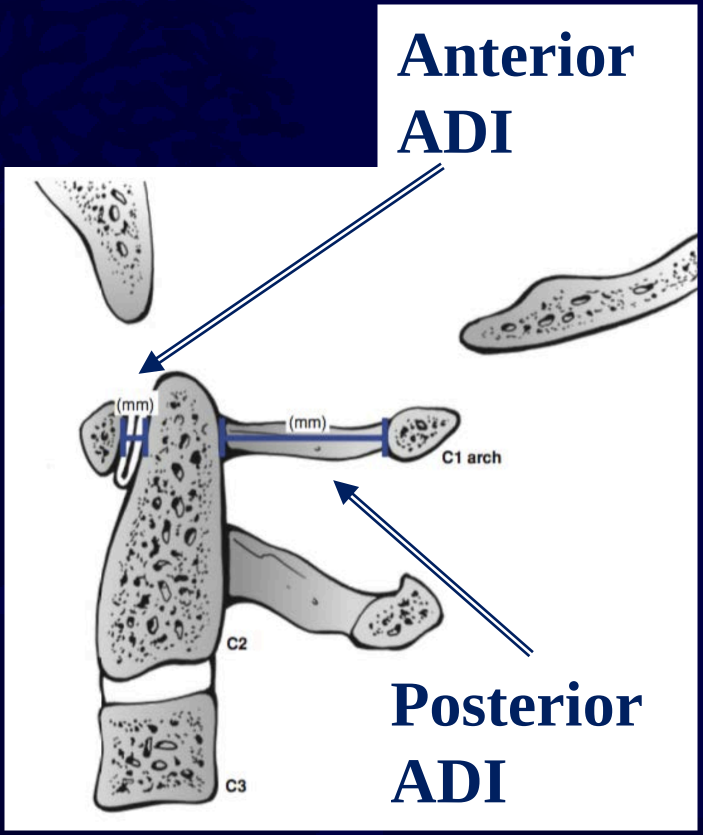




Rockwood and Green's Fractures in Adults
Eighth Edition Figure 43-6 p. 1661/1690

Atlas Fractures - Treatment

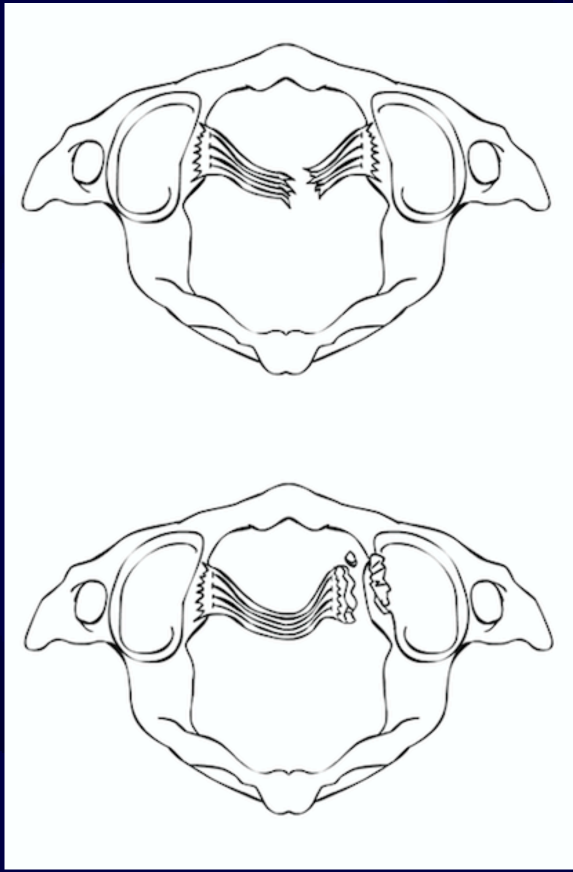
- Displaced <6.9 mm/8.1 mm
  - Halo vest for 3 months
- Displaced >6.9 mm/8.1 mm
  - Halo traction (reduction) * several weeks followed by halo vest
  - Immediate halo vest
  - Posterior C1-2 fusion (unable to tolerate halo)
- After brace treatment complete confirm C1-2 stability
  - Flexion/extension films
  - **C1-2 fusion for AADI > 5mm**



Rockwood and Green's Fractures in Adults Eighth Edition Figure 44-3 p. 1684

- Halo falling out of favor for collar with non-operative treatment…

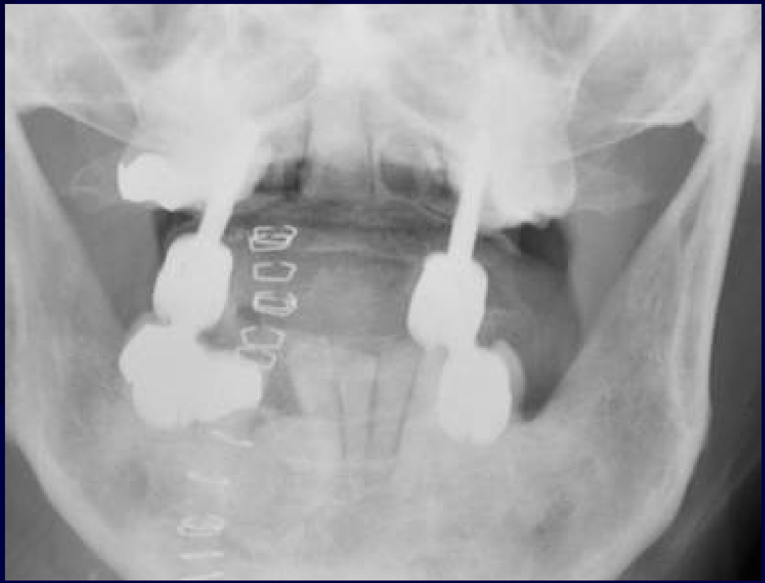
Transverse ligament avulsion



- Bony avulsions may heal with nonoperative management
- TAL rupture (ligamentous) does not heal with non-operative management and requires C1-C2 arthrodesis

Atlas Fractures - Techniques

- Fusion options
  - Gallie (spinous process wiring)
    - **Post-op halo**
  - Brooks/Jenkins (sublaminar/spinous process wiring)
  - C1/C2 Transarticular Screws
    - most dependent on vertebral artery anatomy
  - C1 lateral mass/C2 pars-pedicle screws
  - Direct Osteosynthesis of C1



Odontoid Fractures

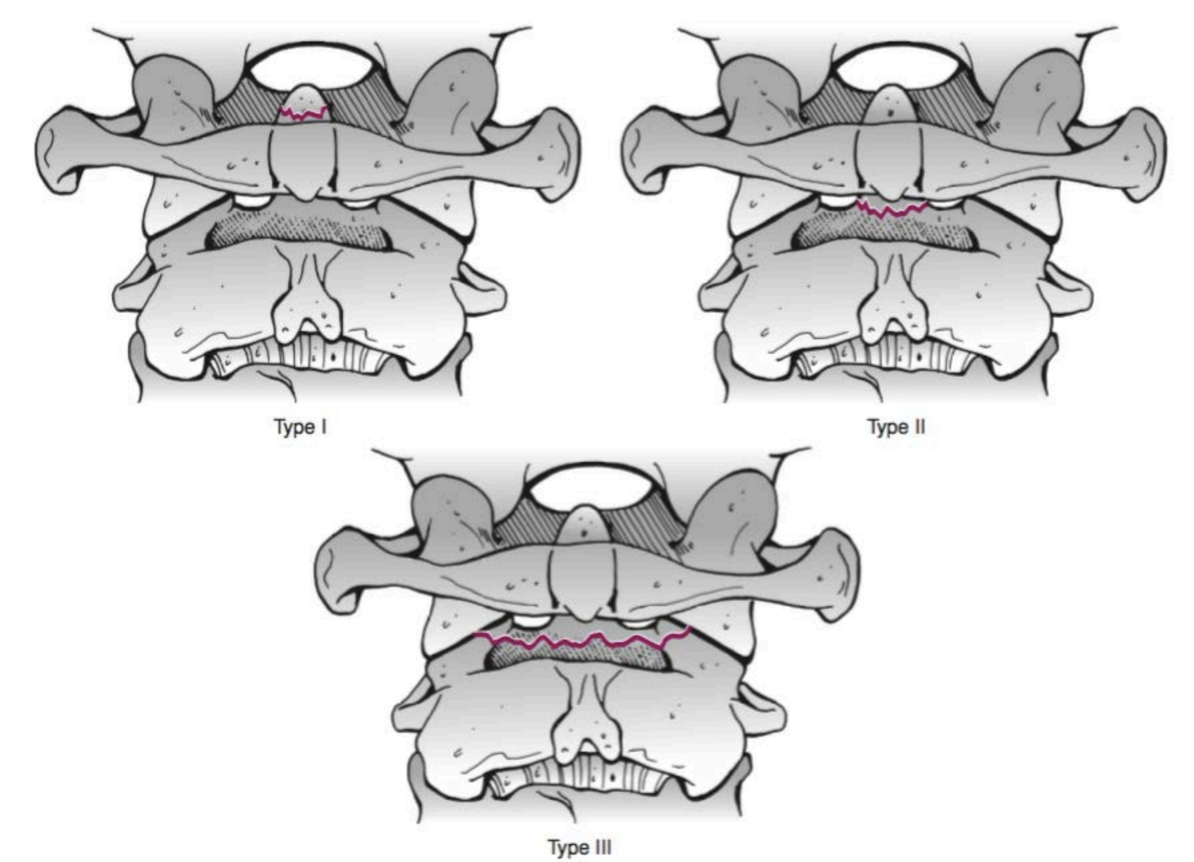
- Most common fracture of Axis
  - (nearly 2/3 of all C2 Fxs)
- 10 – 20 % of all cervical fractures
- Bimodal distribution
  - Young - high energy, multi-trauma
  - Elderly - low energy, isolated injury
    - Most common C-spine fracture elderly

Elderly and the Odontoid

- Platzer Studies
  - Elderly increased pseudarthrosis rate (12% v. 8%)
  - Elderly tolerated pseudarthosis well (1/5)
  - Elderly tolerated halo well
  - 10% mortality (4/41)
  - 22% complication rate
- Chapman studies
  - Elderly did not heal the odontoid fracture (4/17)
  - Elderly tolerated halo well (7/8)
  - 15% mortality (3/20)
- Harrop and Vaccaro
  - 9/10 "union"
  - 5/10 postop halo
  - 1/10 perioperative death
- Multiple series of high mortality rates

- Platzer et al. Spine 2007
- Platzer et al. Neurosurgery 2007
- Platzer et al. Spine 2008
- Kuntz et al./Chapman Neurosurg Focus 2000
- Harrop et al. Neurosurg Focus 2000

Anderson and D'Alonzo Fracture Classification

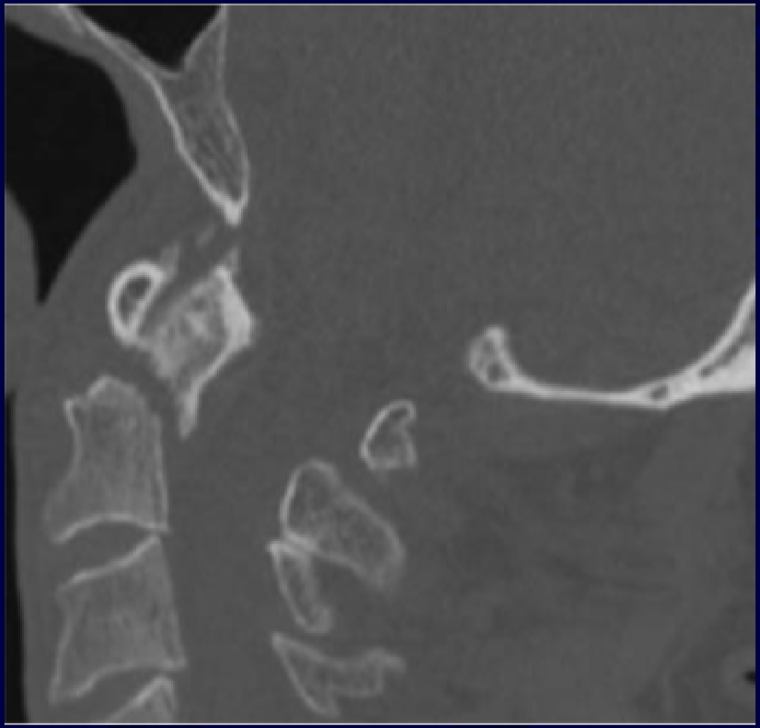


Rockwood and Green's Fractures in Adults Eighth Edition Figure 44-41 p. 1723

Type	Frequency
Type I	2% (2/49)
Type II	50-75% (32/49)
Type III	15-25% (15/49)

Anderson/D'Alonzo JBJS 1974

Acute Management

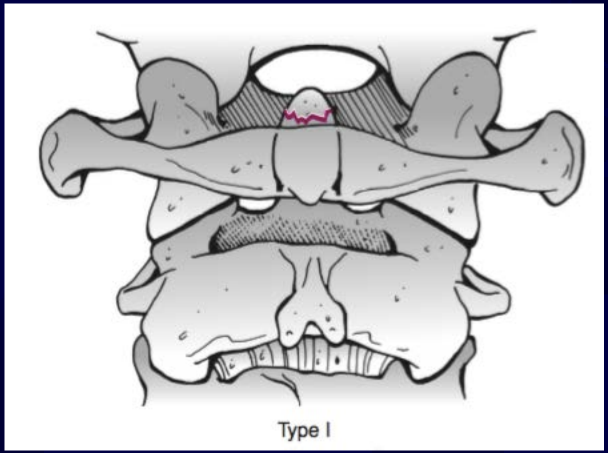


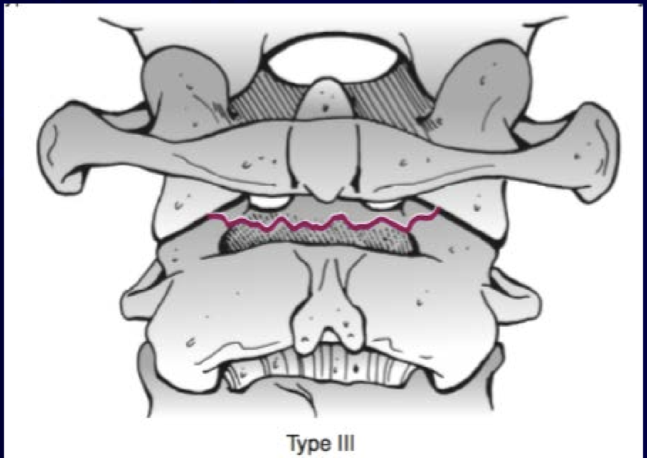
- Spinal cord injury rare (17/226)
- Airway compromise
  - 0/8 nondisplaced
  - 1/21 anterior displacement
  - 13/32 posterior displacement (2 deaths)

Don't do flexion reductions!

Harrop et al. Neurosurg Focus 2000
Przybylski et al. Neurosurg Focus 2000

Definitive Treatment Options





Type 1

- C-Collar
- Beware of unrecognized craniocervical dissociation

Type 3

- C-Collar (10-15% nonunion)
- SOMI brace
- Halo vest

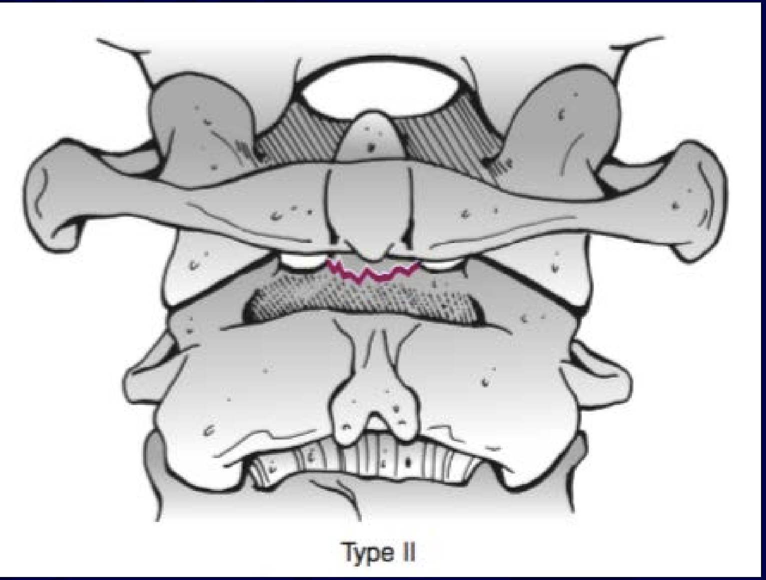
Traynelis et al. Neurosurg Focus 2000

Rockwood and Green's Fractures in Adults Eighth Edition Figure 44-41 p. 1723

Treatment Options

Type 2

- C-Collar
- SOMI / Minerva
- Halo Vest
- Odontoid Screw
- C1-2 posterior fusion



Rockwood and Green's Fractures in Adults
Eighth Edition Figure 44-41 p. 1723

Risk factors for nonunion in Type II odontoid fractures

- Secondary to watershed blood supply
- Higher ratio of cortical to cancellous bone
- Displacement > 6mm (assoc. w/ >50% nonunion rate)
- Age > 50 y
- Fx Comminution
- Angulation >10 degrees
- Treatment delay > 4 days

Koivikko et al. JBJS Br 2004

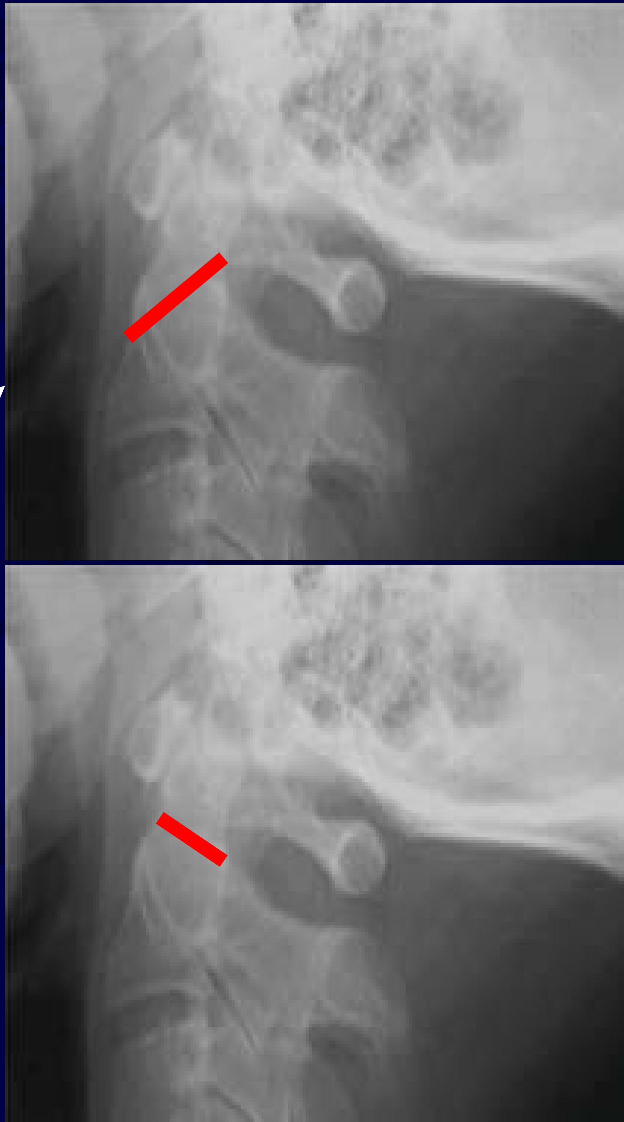
Anterior Odontoid Screw Fixation

Indications

- Displaced Type II, Shallow Type III
- Polytrauma patient
- Unable to tolerate halo-vest
- Early displacement despite halo-vest
- (Reduces in extension)

Contraindications

- Non-reducible odontoid fracture
- (Reduces in flexion)
- Body habitus (Barrel chest)
- Associated TAL injury
- Subacute injury (> 6 months)
- Reverse oblique
- (elderly)



France JC, Bono CM, Vaccaro AR. Initial radiographic evaluation of the spine after trauma: when, what, where, and how to image the acutely traumatized spine. Jorthop trauma. 2005;19:640-9.

Anterior Odontoid Screw

Advantages

- Direct fracture osteosynthesis
- Maintenance of C1-C2 motion
- Minimal EBL
- Decreased wound issues vs. posterior approach
- More useful for young patient

Vaccaro et al. JBJS 2013
Subach et al. Neurosurgery 1999
Rushton et al. JSDT 1997
Chiba et al. JSDT 1996

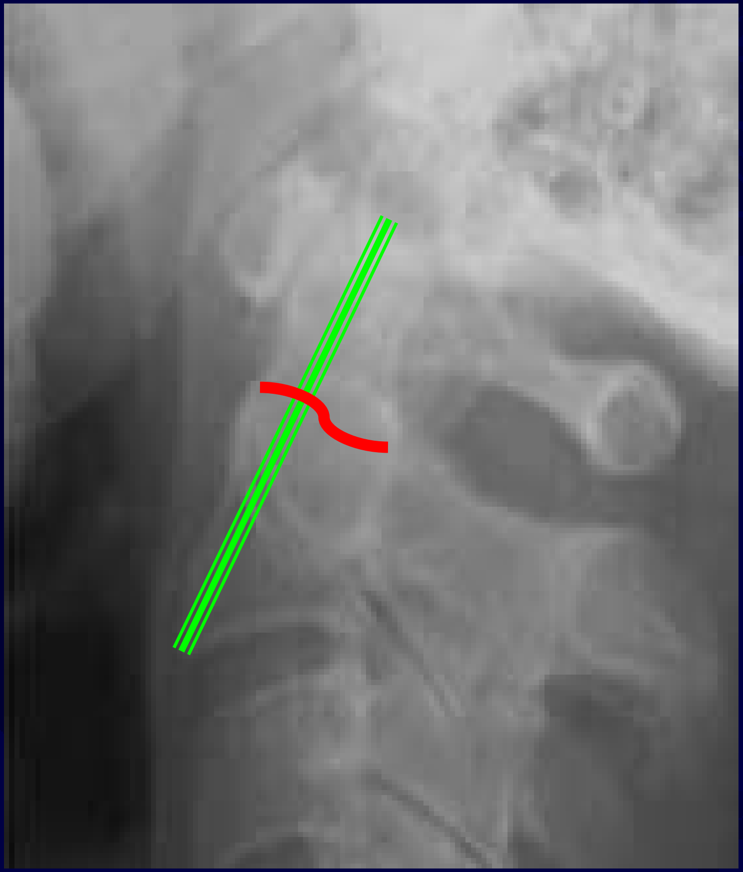
Disadvantages

- Requires favorable patient anatomy
  - Must not have:
    - Barrel chest
    - Congenital cervical fusion
    - Thoracic kyphosis
    - Cervical stenosis
- Reverse obliquity/comminution
- Irreducible fracture
- Requires intact transverse ligament
- Higher incidence of dysphagia in elderly
- Higher failure rate in osteoporotic Bone

Anterior Screw Technique

- Smith Robinson approach (Skin incision at C5)
- Neck in slight extension
- Wine cork/bite block for open mouth views
- Biplanar fluoroscopy
- Need to enter body caudal portion of promontory
  - Partial C2/3 discectomy
- Midline for single screw placement

Anterior Screw Technique



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- Critical to cross rostral cortex
- Critical to use lag screw technique
- Limited evidence for second screw

One or Two Screws?

- No significant difference biomechanically
  - Sasso et al. Spine 1993
  - Graziano et al. Spine 1993
- No difference clinically
  - Apfelbaum et al. J Neurosurg 2000
  - Jenkins et al. J Neurosurg 1998

Apfelbaum Clinical Outcomes

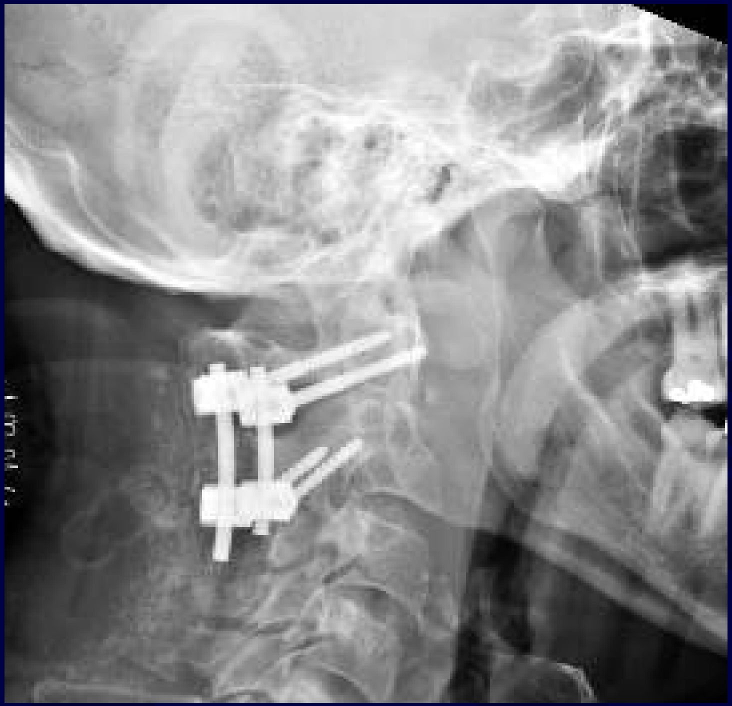
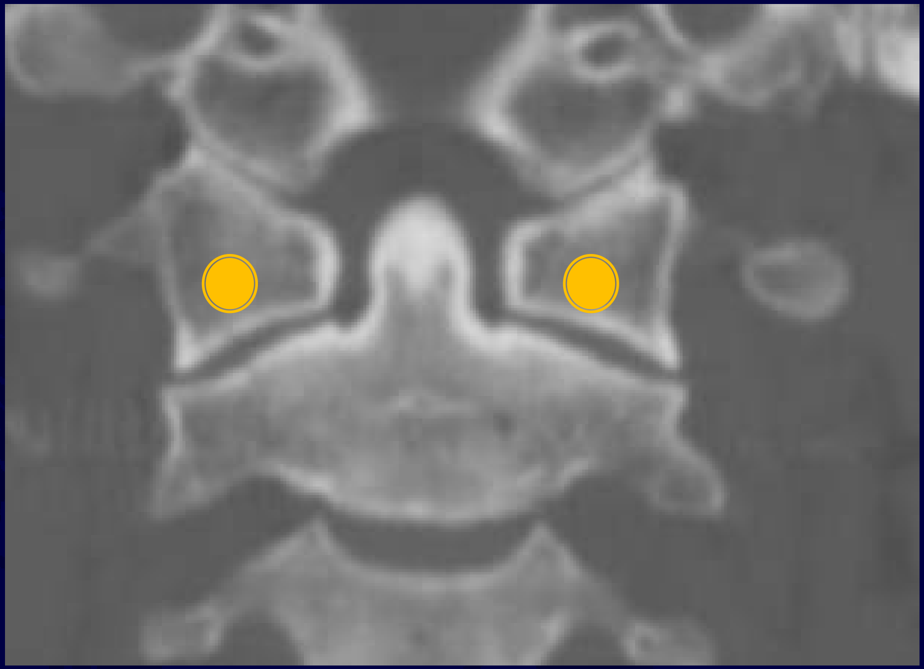
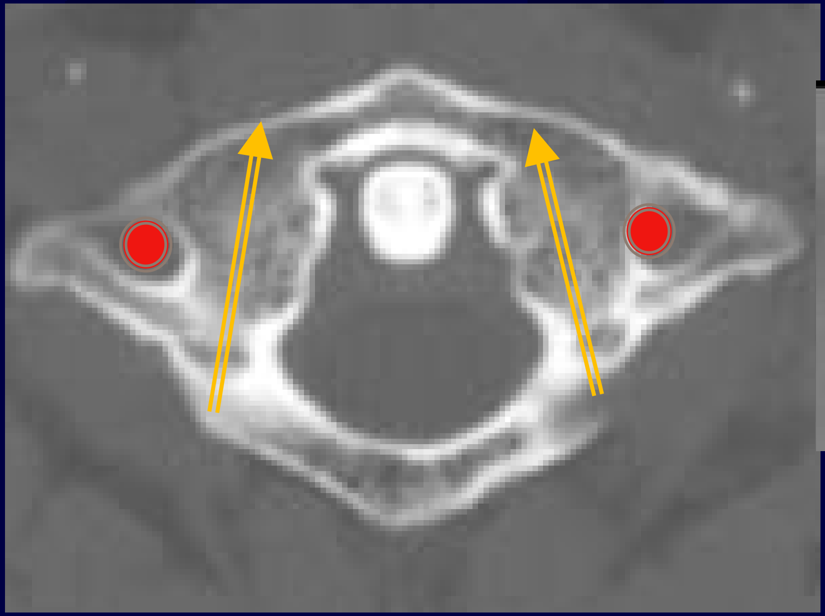
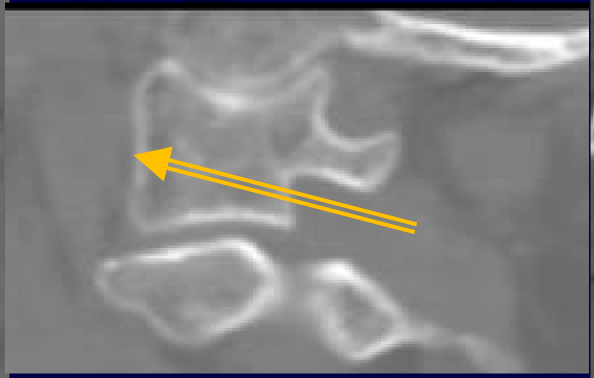
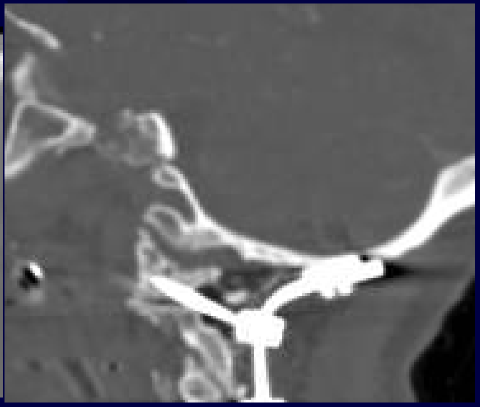
- 147 patients
  - 129 (117) <6 months
  - 18 > 6 months
- 88% fusion rate
  - Recent fractures
  - Horizontal and posterior oblique
  - No difference between one or two screws
- 25% fusion rate in remote fractures
- 10% implant complication
  - Screw pullout of C2 body
- 1% perioperative mortality
  - 6% within 30 days

Apfelbaum et al. J Neurosurg 2000

Posterior Odontoid Stabilization

- Options
  - Posterior wiring
    - Up to 25% pseudoarthrosis
    - Halo vest necessary Dickman JNS 1996, Grob Spine 1992
    - Largely falling out of favor due to C1/C2 screw techniques which do not require intact posterior arch in addition to postop immobilization
  - Transarticular screw fixation
    - Magerl and Steeman Cerv Spine 1987
    - Reilly et al JSD 2003
    - Cannot perform with aberrant vascular anatomy
    - Requires reduction prior to screw placement
  - C1 lateral mass - C2 pars/pedicle/lamina screw
    - First described by Laheri/Goel; modified by Harms/Melcher for use with screw rod construct

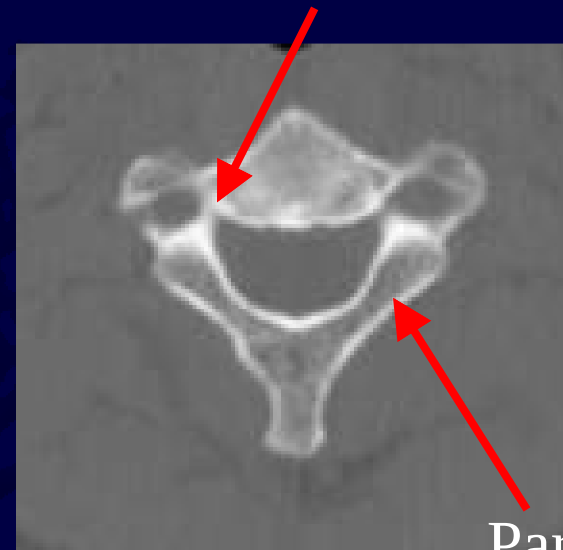
C1 LATERAL MASS SCREWS

C2 SCREW PLACEMENT

Trans-articular

C2 pars/pedicle



Posterior Fusion Summary

- Catastrophic failures reported for trans-articular screws alone
- Trans-articular screws with wired bone graft is stiffest construct
  - Requires intact C1 lamina
  - Requires reducible C1-2 facets
  - Requires favorable anatomy
- Gallie wiring is inadequate without two supplemental screws
- No advantage of either wiring construct with two transarticular screws
- Harm’s technique is most flexible

Harms and Melcher Spine 2001

Hott et al. J Neurosurg Spine 2005

Aryan et al. J Neurosurg Spine 2008

Traumatic Spondylolisthesis Axis (Hangman's Fracture)

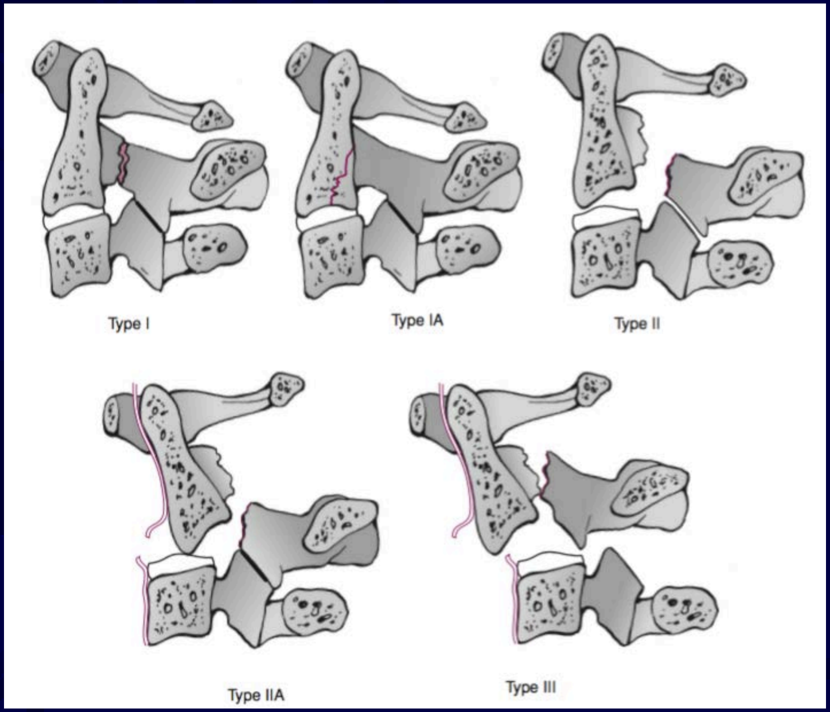
- Second most common fracture of axis
  - 25% of C2 injuries
- Most common mechanism of injury is MVA

Hangman's Fracture

- Younger age group (Avg. 38 yrs)
- Usually due to hyperextension-axial compression forces (windshield strike)
- Neurologic injury seen in only 5-10 %
  (acutely decompresses canal)
- Traditional treatment has been Halo vest
- Collar adequate if < 6 mm displaced
  - Coric et al JNS 1996

Hangman's Fracture

- Border of craniocervical and subaxial spine
- Intact disk defines Type I
- Halo treatment difficult with torn disk (types II and III)
- Avoid traction in type IIa



Rockwood and Green's Fractures in Adults Eighth Edition Figure 44-43 p. 1729

Hangman's Fracture Treatment

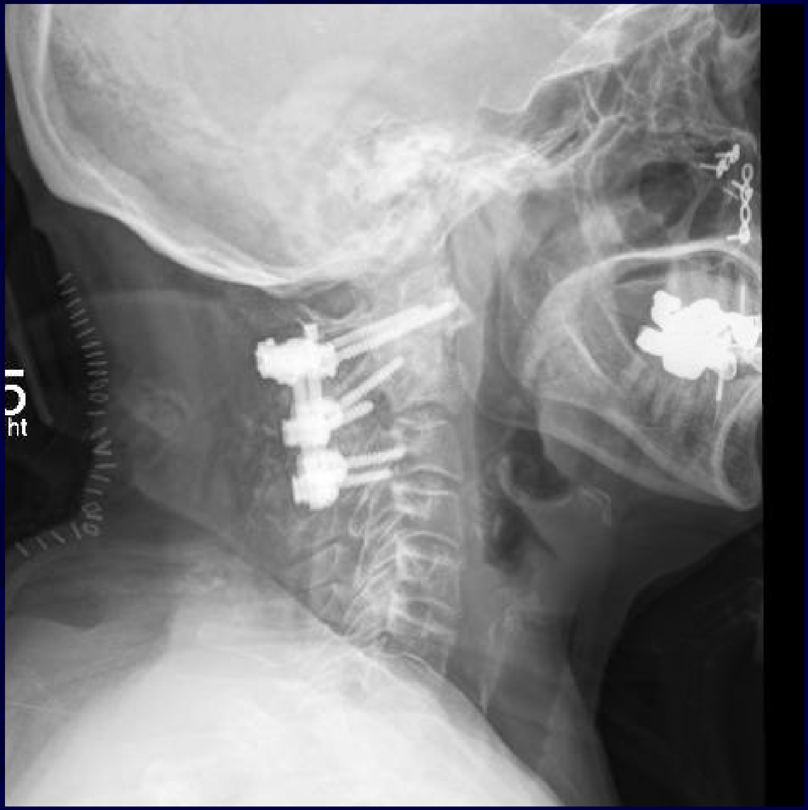
Types II and III

Posterior

- Open reduction and C1-C3 fusion
- Direct pars repair and C2-C3 fusion

Anterior

- C2/C3 ACDF with instrumentation



Atlanto-axial Rotatory Subluxation

	Odontoid Pivot	Anterior Displacement with One Lateral Articular Process Pivot		Posterior Displacement
Fielding	Type 1	Type 2 (3-5 mm)	Type 3 (>5 mm)	Type 4

- Rare injury
- More commonly seen in pediatric population
- Treatment dependent on timing of subluxation
- Evaluate with careful patient history and use of rotatory CT

Fielding and Hawkins JBJS 1977

Atlanto-axial Rotatory Subluxation

	Odontoid Pivot	Anterior Displacement with One Lateral Articular Process Pivot		Posterior Displacement
Fielding	Type 1	Type 2 (3-5 mm)	Type 3 (>5 mm)	Type 4

<u>Treatment Options</u>

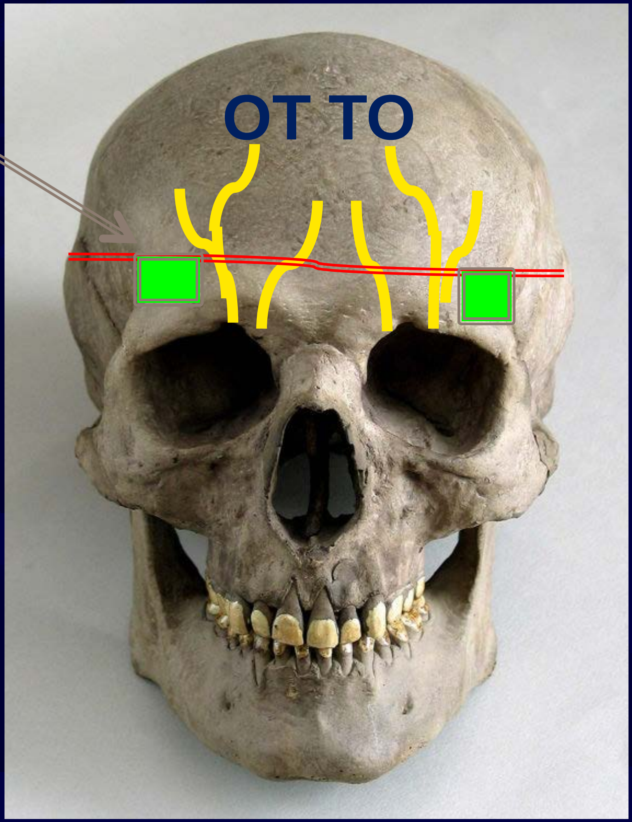
- Traction/halo
- Posterior fusion
- Lateral facetectomy, reduction, fusion
- Transoral facetectomy, reduction, fusion

Fielding and Hawkins JBJS 1977

Halo Immobilization

Pin Placement

- Pin placement below **equator** of skull
- Anterior Placement just over lateral 1/3rd of eyebrow
  - Too lateral forces insertion into thin lateral bone
  - Too medial risks injury to supraOrbital nerve and supraTrochlear nerve [OT TO]
- Posterior pin placement above pinnae (below equator of skull)



Bono JAAOS 2007

Halo in Elderly

- Tashijan et al J. Trauma 2006
  - 78 patients, age > 65yo
  - Type II or III odontoid fractures
  - Increased early morbidity and mortality
    - Compared with treatment using operative fixation or rigid collar
- Van Middendorp et al. JBJS 2009
  - 239 patients
  - All ages in halo
  - No increased risk of pneumonia or death in patients >65 years old

Beware of the halo in the elderly population!

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Return to Spine Index

Return to index