# Craniocervical Junction
## Anatomy Made Easy!

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COLLEGE *of* MEDICINE

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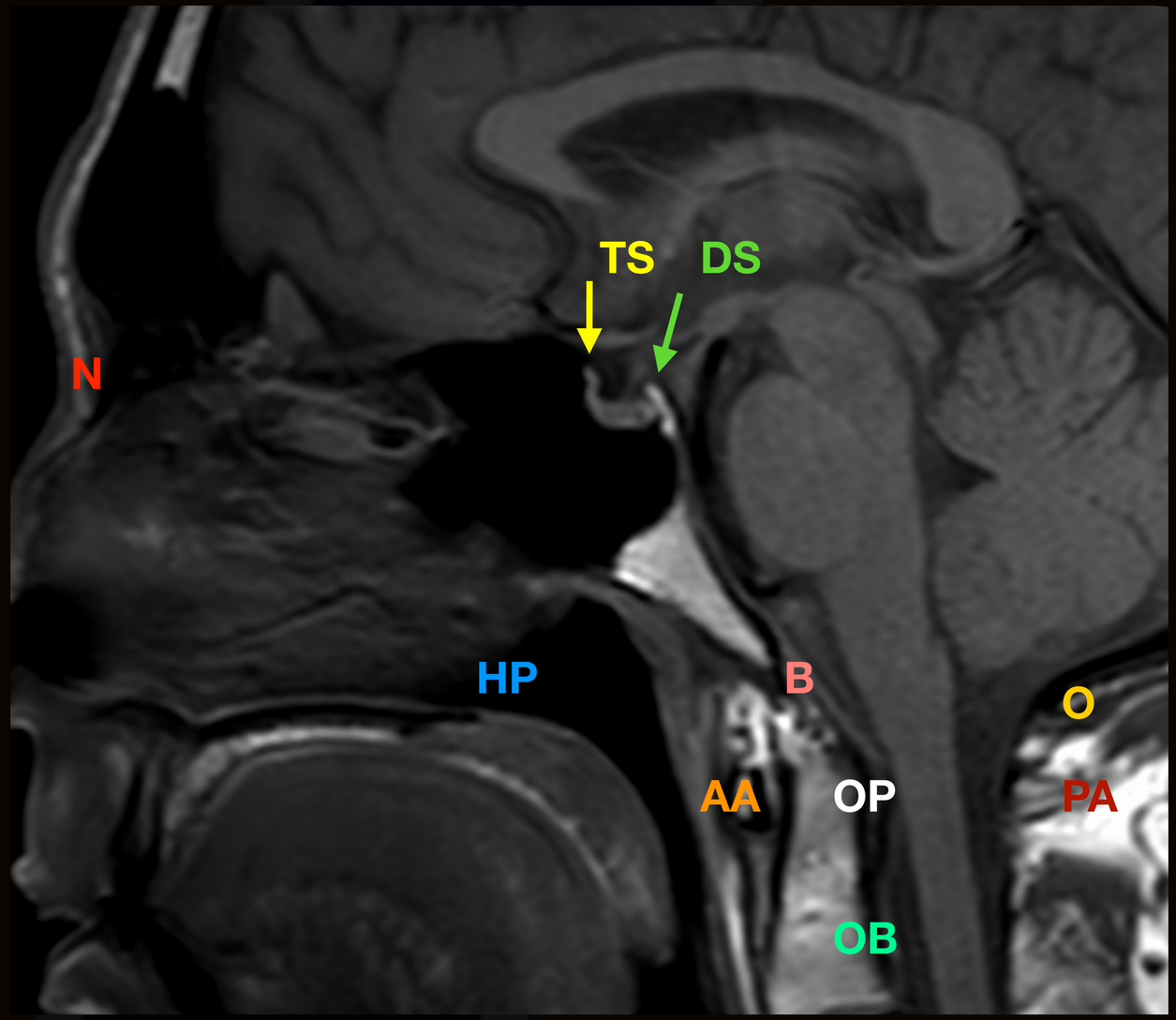
# Educational Objectives

- Review craniovertebral junction (CVJ) anatomy and craniometry.
- Review basilar “invagination” terminology.
- Cover a broad range of CVJ anomalies / pathologies, as well as some associated presenting symptomatology; accentuated by illustrative example cases.
- Provide head and neck radiologists with a quick-go-to reference for key points related to CVJ pathology.

# Sagittal Craniovertebral Junction Anatomy

- N = Nasion
- TS = Tuberculum Sella
- DS = Dorsum Sella
- HP = Hard Palate
- B = Basion

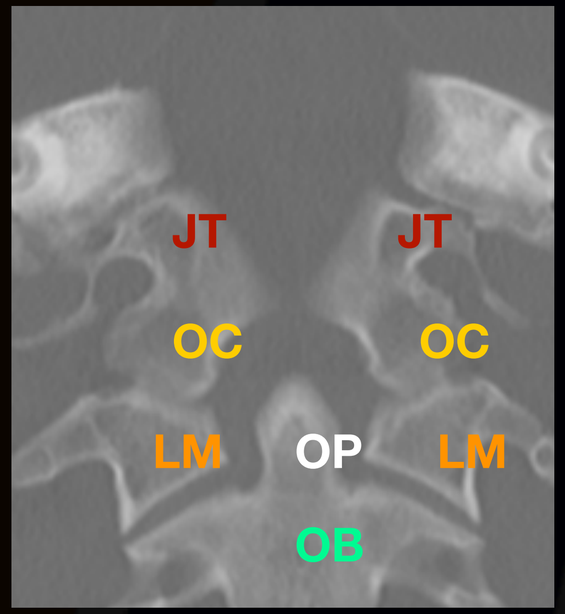



- AA = Anterior Arch of C1
- OP = Odontoid Process
- OB = Odontoid Body
- O = Opisthion
- PA = Posterior Arch of C1

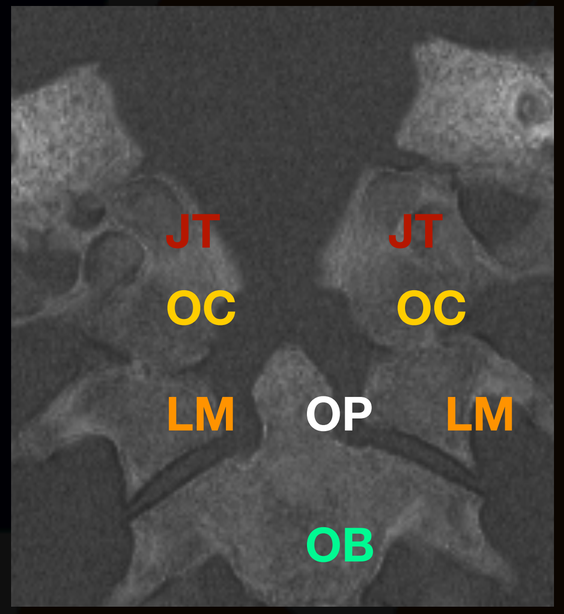
Adapted from Smoker. RadioGraphics 1994: 255-277

# Coronal CVJ Anatomy

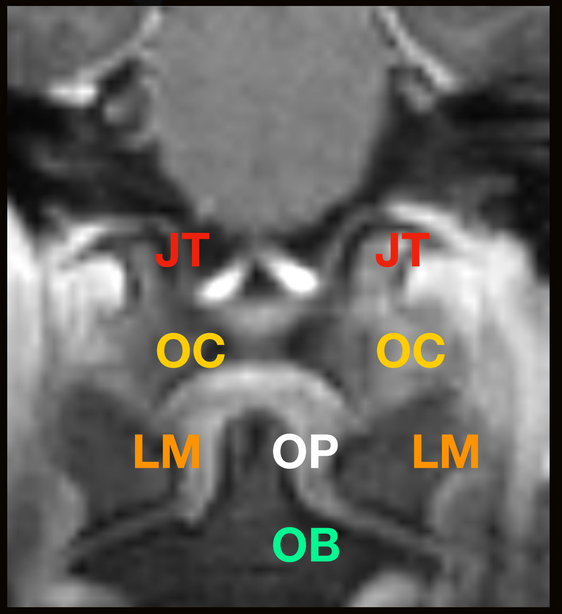
- JT = Jugular Tubercles
- LM = Lateral Masses of C1
- OP = Odontoid Process
- OB = Odontoid Body
- OC = Occipital Condyles




CT MPR at 2.5 mm




CT Volumetric Rendering Technique at 20 mm




T1 Post-Contrast MPRAGE

Adapted from Smoker. RadioGraphics 1994: 255-277

Childs Nerv Syst
DOI 10.1007/s00381-008-0601-0

SPECIAL ANNUAL ISSUE

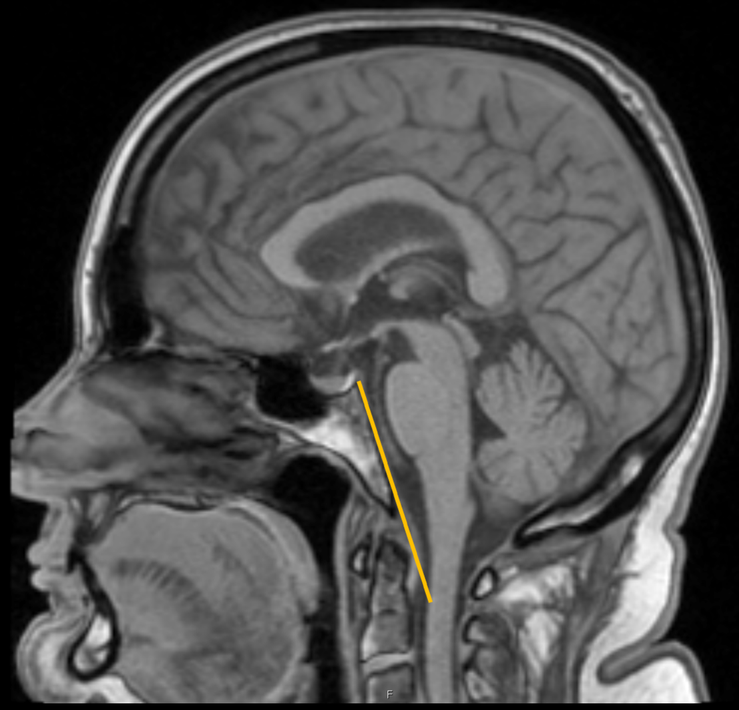
# Imaging the craniocervical junction

**Wendy R. K. Smoker · Gheetika Khanna**

| Lines and angles | Location | Remarks |
|---|---|---|
| Chamberlain's line | Posterior margin of hard palate to opisthion | Tip of the odontoid should be no more than 5 mm above this line; anterior arch of C1 typically lies below |
| McGregor's line | Posterior margin of hard palate to undersurface of occipital squamosal surface | Tip of the odontoid should be no more than 7 mm above this line; anterior arch of C1 typically lies below |
| Wackenheim's clivus baseline | Line extrapolated along dorsal surface of the clivus | Line should fall tangent to, or intersect, the posterior one third of the odontoid |
| Clivus-canal angle | Angle formed at junction of Wackenheim's line and posterior vertebral body line | Range=150° in flexion to 180° in extension <150° considered abnormal |
| Basal angle | Angle subtended by the junction of the nasion–tuberculum and tuberculum–basion tangents | Average=134–135°<br>Minimum=121°<br>Maximum=148–149°<br>Platybasia if >150° |
| Atlanto-occipital joint axis angle | Angle formed at the junction of lines traversing the atlanto-occipital joints | Average=124–127°<br>May approach 180° in severe occipital condyle hypoplasia |

# Basic Craniometry Measurements

## Wackenheim´s Line



**Wackenheim´s Clivus Baseline:**

Line extending along dorsal surface of the clivus.

Dens should be tangential or anterior to this line.

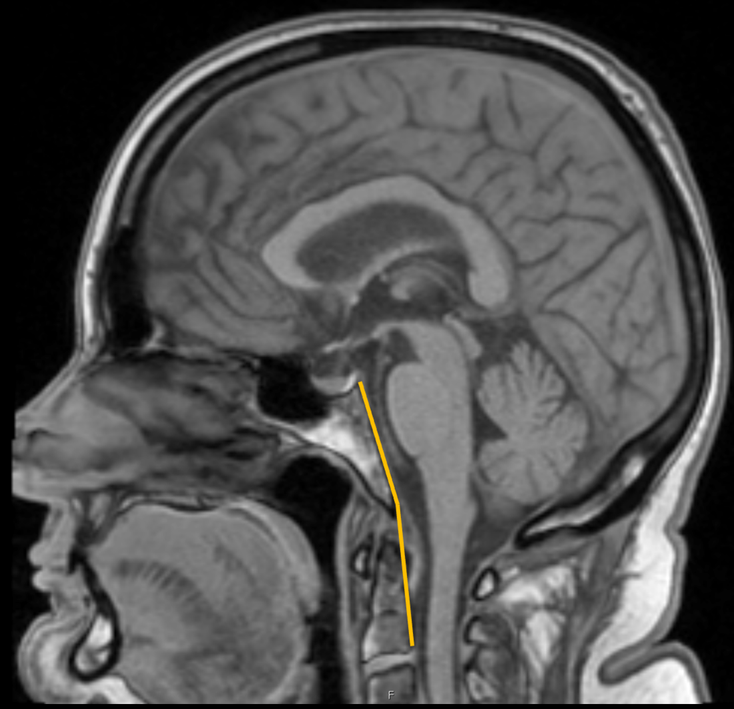
## Welcher Basal Angle

**Welcher basal angle:**

Angle formed by intersection of the nasion-tuberculum line and tuberculum-basion line.

It averages 132° and should remain below 140°.

## Clival Canal Angle



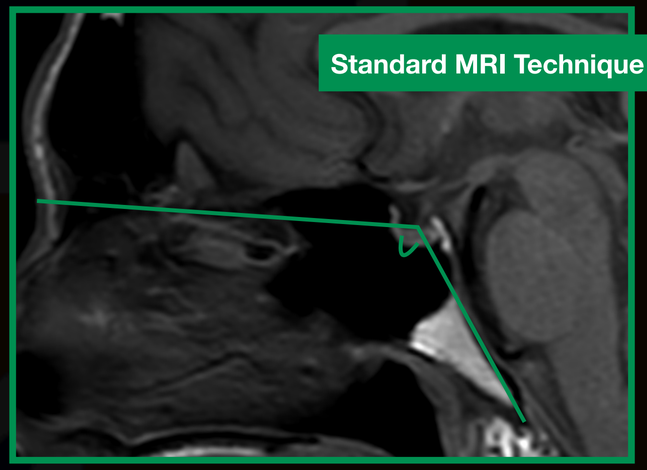
**Clival-Canal angle:**

Angle formed at the intersection of the Wackenheim Line with a line constructed along posterior surface of axis body and dens.

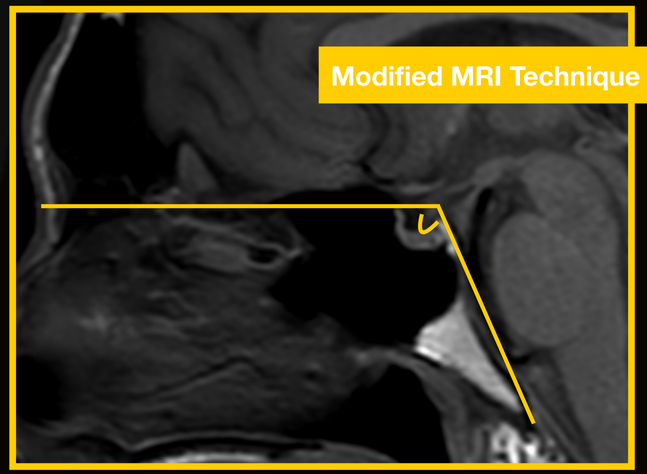
Normal: 160-170° ventral cord compression:< 150°.

# Skull Base Angle

- Also known as basal angle; used to diagnose platybasia or basilar kyphosis.
- Platybasia refers to abnormal flattening of the skull base
  - Platybasia alone is usually asymptomatic unless there is coexistent basilar invagination or impression.
- Basilar kyphosis
- Multiple ways to measure; however, MRI measurements have supplanted measurements related to other imaging modalities.
- Standard MRI Technique
  - Obtained by measuring the angle formed by the following two lines:
    1. Line extending from the Nasion to the center of the pituitary fossa.
    2. Line extending from the center of the pituitary fossa to the ventral border of the foramen of magnum.
- Modified MRI Technique
  - Obtained by measuring the angle formed by the following two lines:
    1. Line extending anterior cranial fossa floor to the tip of the dorsum sellae.
    2. Line from dorsum sellae tip extending inferiorly along the dorsal clivus.




**Normal: 125 to 143 degrees**
**Platybasia: >143 degrees**
**Basilar kyphosis: < 125 degrees**

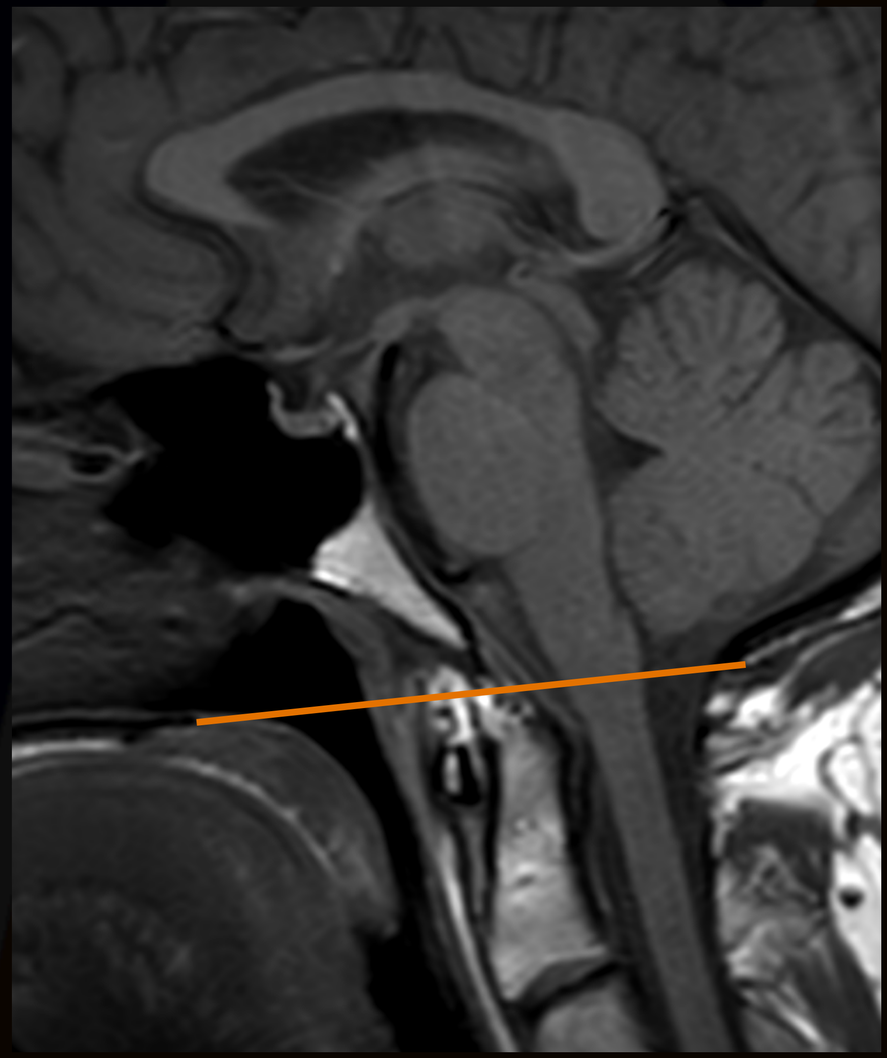



**Children: 114 +/- 5 degrees**
**Adults: 117 +/- 6 degrees**
**Greater angle = platybasia**
**Smaller angle = basilar kyphosis**

# Chamberlain's Line

Chamberlain's Line (CL): Line extending from the hard palate to the opisthion.

A "Vliolation" of CL occurs when the tip of the dens is greater than 3 mm above CL in adults; 5 mm above in children.



**Chamberlain's Line without violation**

Adapted from Smoker. RadioGraphics 1994: 255-277

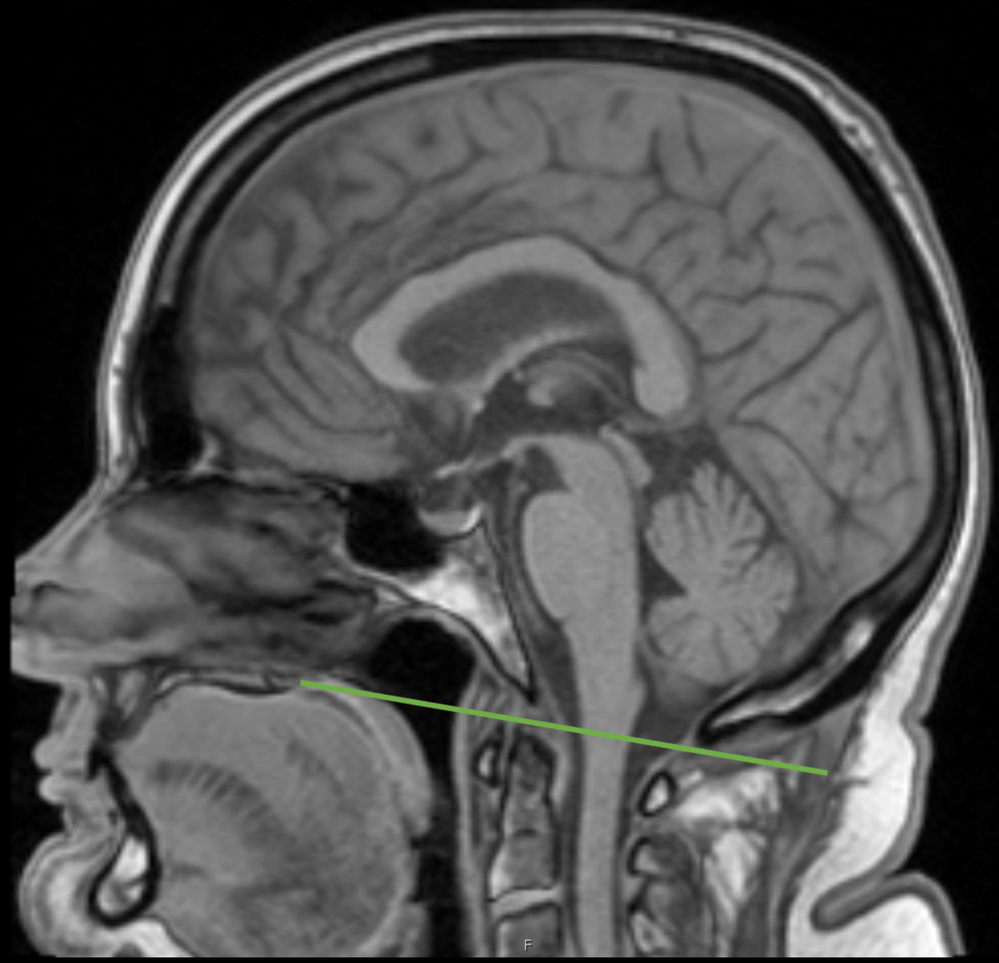
# McGregor´s Line

McGregor's line: Line extending from the posterior margin of the hard palate to undersurface of occipital squamosal surface.

- Modification of CL used in basilar invagination evaluation.

- Tip of the odontoid should be no more than 4.5 mm above this line; anterior arch of C1 typically lies bellow.

- Greater than 4.5 mm indicates basilar invagination/Impression.

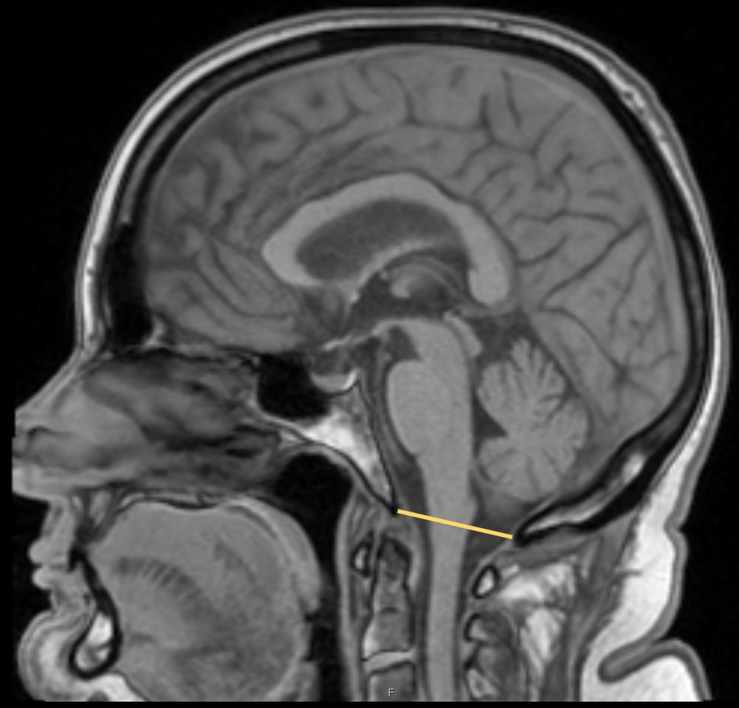


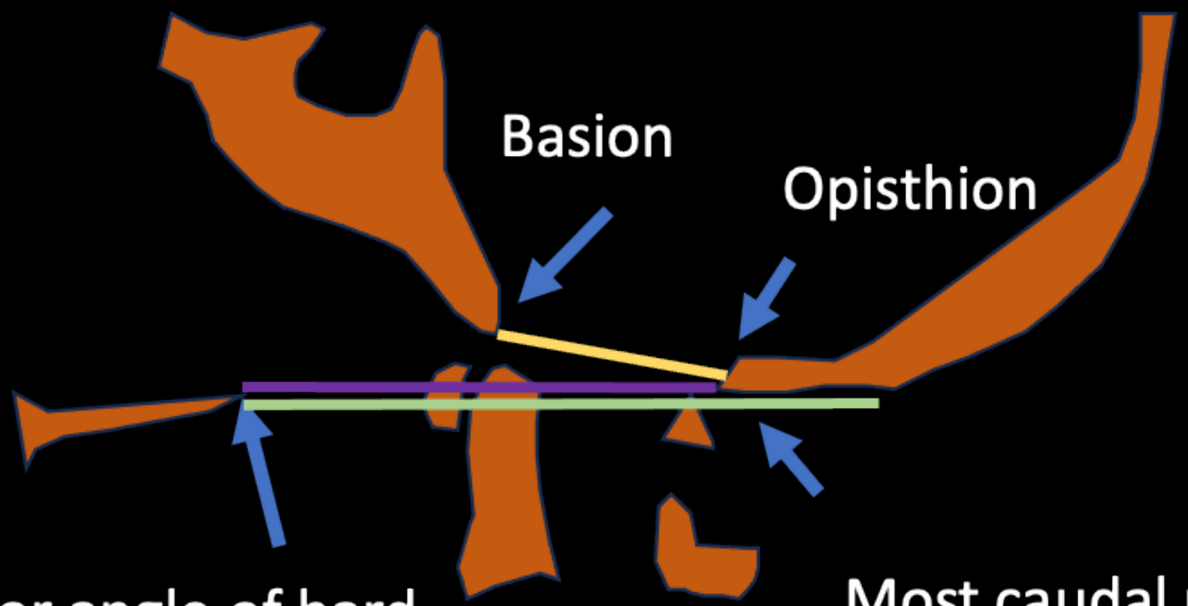
# Mc Rae Line

McRae line: Line that connects the anterior and posterior margins of the foramen magnum (basion to opisthion).

- The tip of the odontoid process is normally 5 mm below this line; basilar invagination is diagnosed when the tip crosses this line.

- helps to measure the cerebellar tonsillar position: normal is above the foramen magnum.



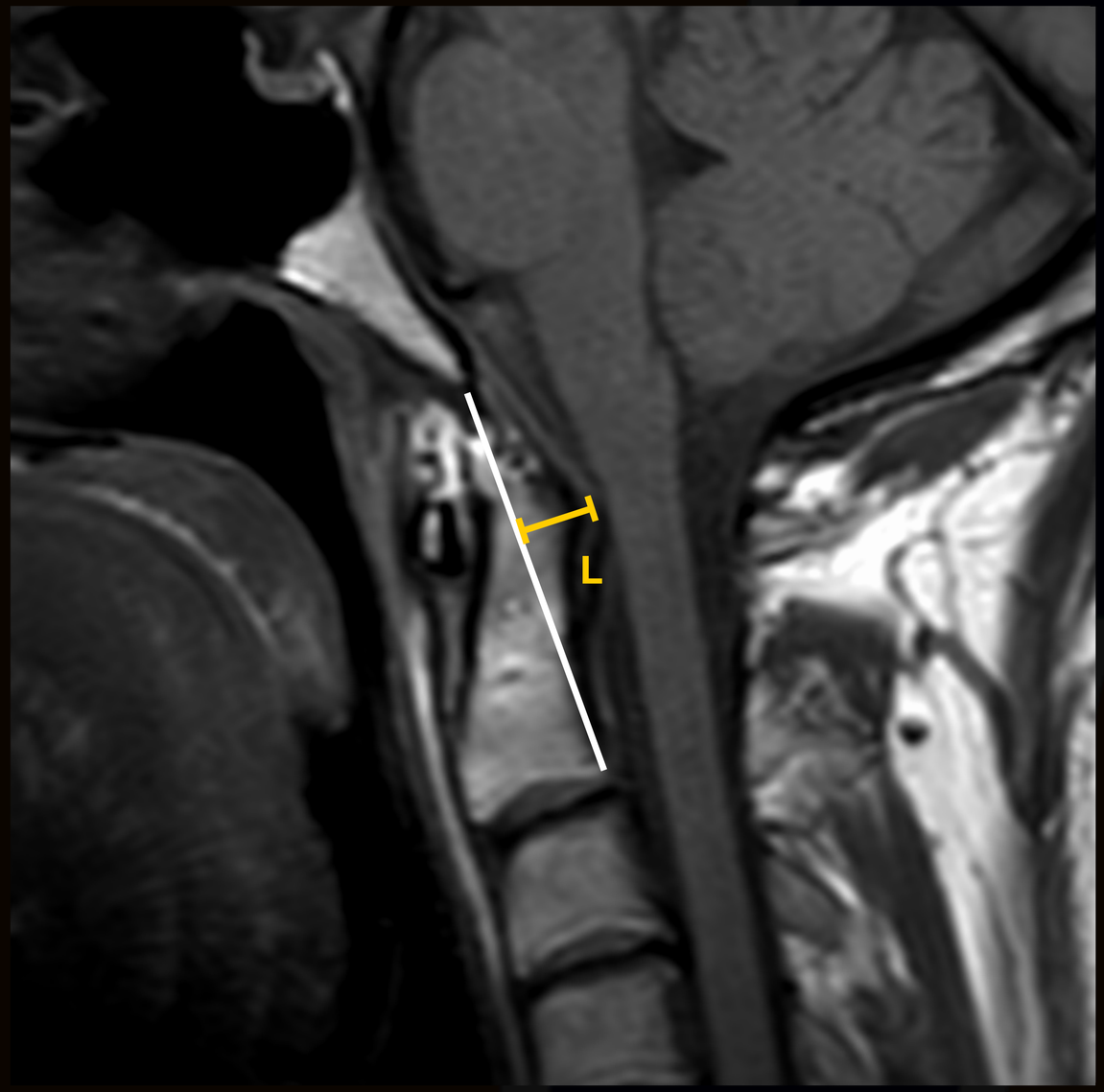



Mc Rae line

Chamberliain line

Mc Gregor line

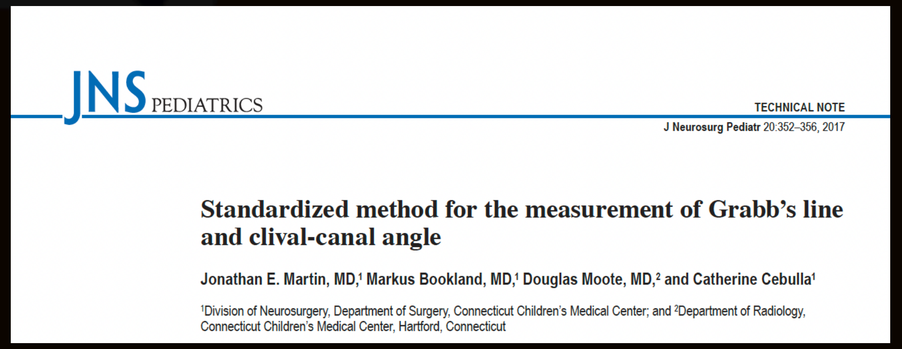
# Grabb-Oakes Measurement




Grabb-Oakes Measurement (GOM) is obtained by:

1. Drawing a line from the basion to the posterior margin of the C2 inferior endplate.
2. Draw a line perpendicular to the first line that extends to the dura.
3. The length (L) of the second line corresponds the GOM.

A GOM greater than 9 mm is at increased risk for ventral brainstem compression.



JNS PEDIATRICS

TECHNICAL NOTE

J Neurosurg Pediatr 20:352–356, 2017

**Standardized method for the measurement of Grabb's line and clival-canal angle**

Jonathan E. Martin, MD,[1] Markus Bookland, MD,[1] Douglas Moote, MD,[2] and Catherine Cebulla[1]

[1]Division of Neurosurgery, Department of Surgery, Connecticut Children's Medical Center; and [2]Department of Radiology, Connecticut Children's Medical Center, Hartford, Connecticut

# Symptomatology Related to CVJ Pathology

- Can present along a spectrum, ranging from entirely asymptomatic to severe progressive neurologic deficits
- Often vague, nonspecific symptoms at first. Slowly progressive.
- Symptomatology is based on the underlying neural and/or vascular structure(s) being compromised or the arterial territory involved
  - Can be ipsilateral or contralateral, depending of the compression relative to the level of decussation
  - The degree of compression is only loosely associated with the degree of symptomatology. That is, there can be severe compression without symptoms and vice versa
- May be a diagnosis of exclusion given the wide spectrum of symptoms associated with this entity. Thus, a full work-up is required to exclude other etiologies that may cause the same symptoms

| Motor Myelopathy |
| --- |
| Subtle and nonspecific |
| May present as lack of endurance |
| Paraparesis, hemiparesis, etc… |

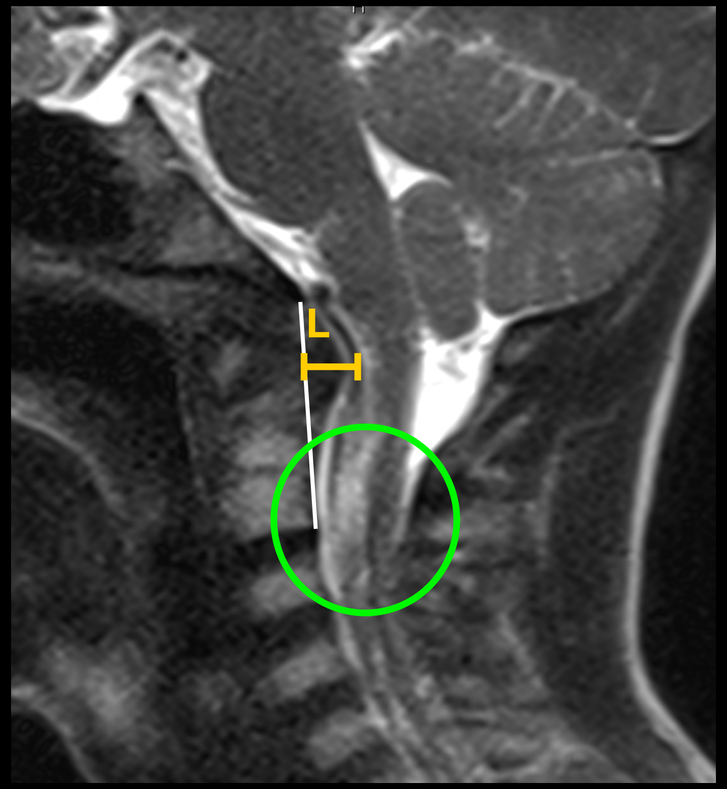
| Sensory Abnormalities |
| --- |
| Posterior Column Dysfunction |
| Spinothalamic Tract Dysfunction |
| Urinary Urgency or Hesitancy |

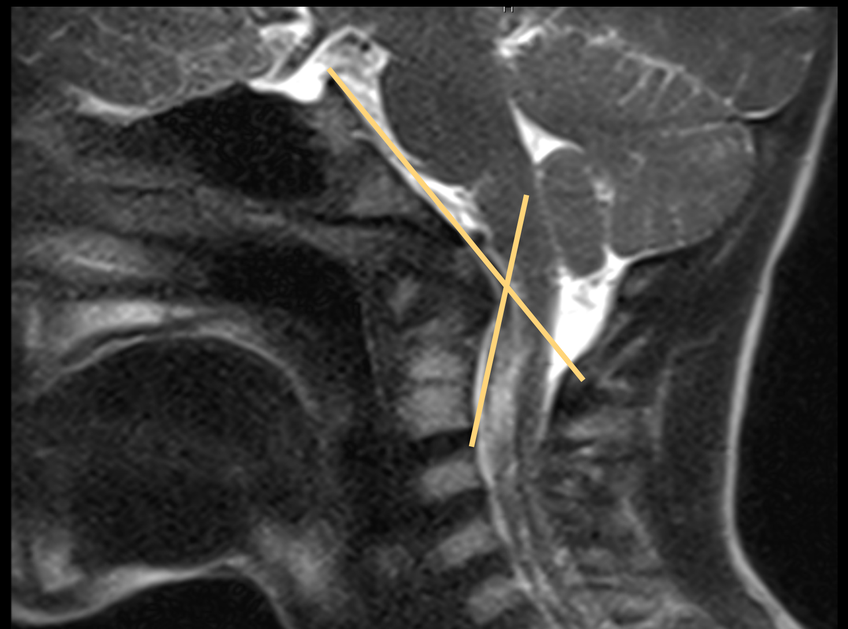
| Brainstem Dysfunction |
| --- |
| Nystagmus |
| Apnea |
| Bilateral facial paresis or paralysis |
| Loss of coordinated movements |

| Lower CN Dysfunction |
| --- |
| Dysarthria |
| Dysphagia (CN IX) |
| Tongue muscle atrophy |
| Dysphonia |

| Vascular Compromise |
| --- |
| Syncope |
| Vertigo |
| Transient Ischemic Attacks |

Smoker. RadioGraphics 1994 14:255-277



## Grabb-Oakes Measurement

Drawing a line from the basion to the posterior margin of the C2 inferior endplate.

A GOM greater than 9 mm is at increased risk for ventral brainstem compression.

**Clival-Canal angle:**

Angle formed at the intersection of the Wackenheim Line with a line constructed along posterior surface of axis body and dens.

Normal: 160-170° ventral cord compression:< 150º.

Kyphotic CCA < 150 degrees.

67 year old female with bilateral upper extremity weakness.

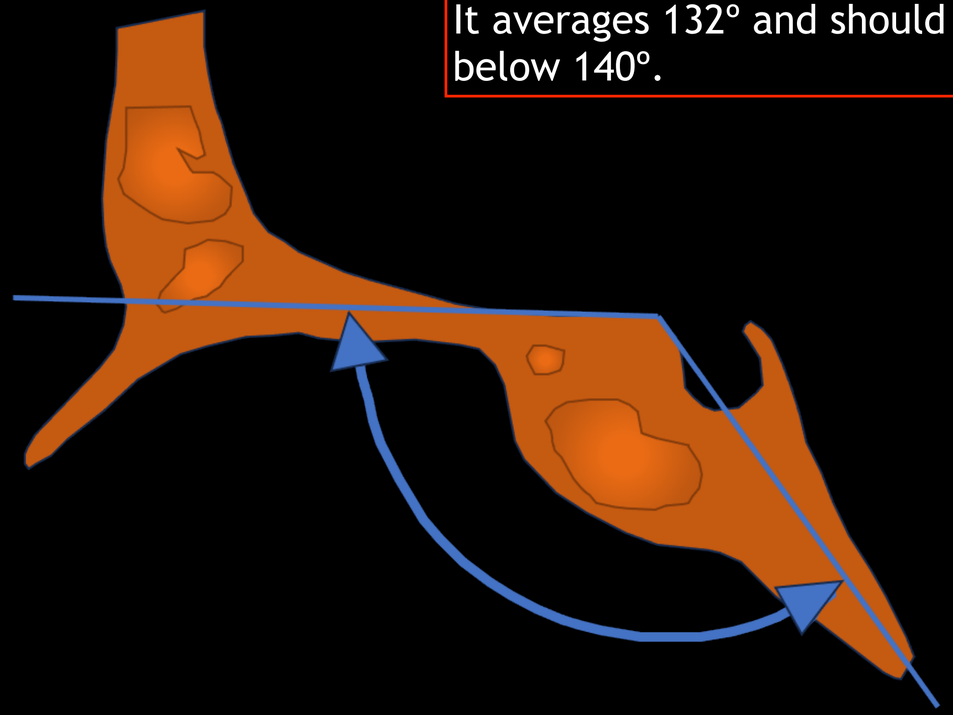
Clival canal Angle of 128º, **Grabb-Oakes Measurement 10 mm.** Upper cervical chord compression with T2 signal abnormality.

# Platybasia

**Welcher basal angle:**

Angle formed by intersection of the nasion-tuberculum line and tuberculum-basion line.

It averages 132° and should remain below 140º.



## Congenital

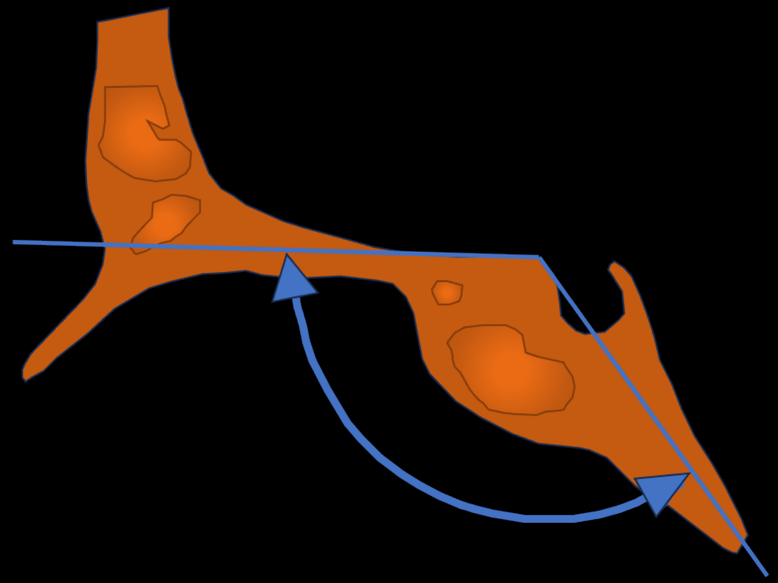
- Achondroplasia
- Down syndrome
- Chiari malformations
- Craniofacial anomalies
- Osteogenesis imperfecta

## Acquired

- Paget disease
- Osteomalacia
- Rickets
- Trauma
- Fibrous dysplasia
- Hyperparathyroidism
- Hypoparathyroidism

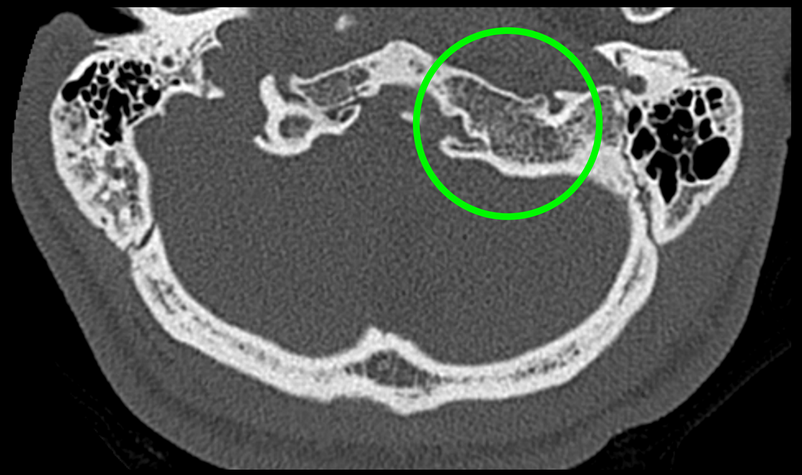
- Platybasia is characterized by abnormal flattening of the skull base as defined as a base of skull angle (Welcher basal angle) over 140º.

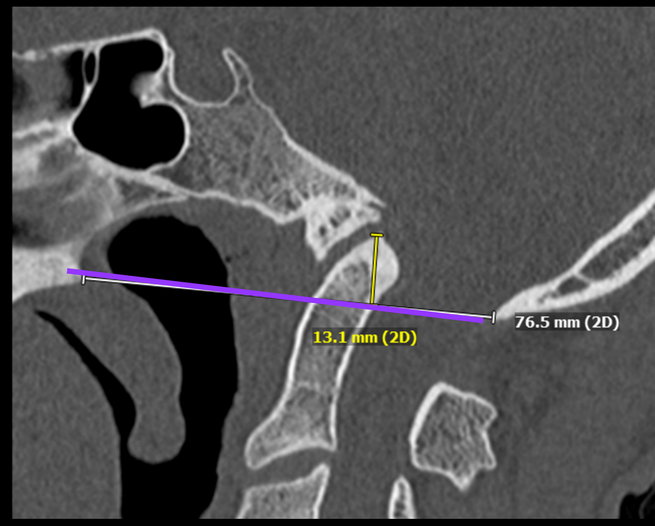
# Platybasia

17-year-old male with cervical neuritis

Congenital assimilation with fusion of the lateral masses of C1 with the occipital condyles. Elongated appearance of the dens. Basilar invagination with the tip of the odontoid process projecting 1.3 cm above the Chamberlain line. Platybasia with Welcher basal angle of 143°.





# Klippel-Feil Syndrome with Platybasia

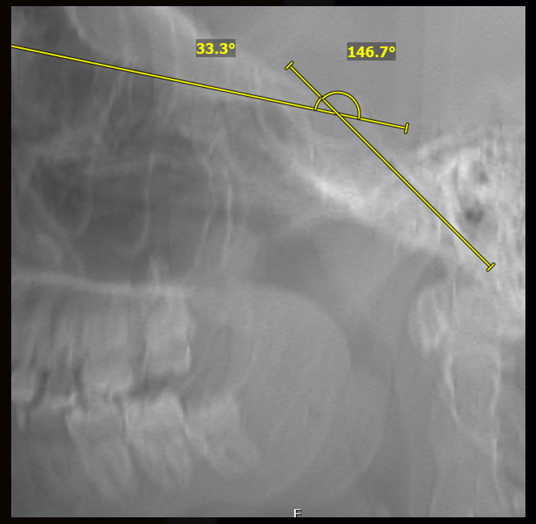
19-y/o female with neck pain.

Scout images illustrating (a) Standard Technique (147 degrees) and (b) Modified Technique (134 degrees) demonstrate platybasia; (c) Modified Technique on Sagittal CT confirms platybasia (132 degrees). Additionally, sagittal CT demonstrates congenital fusion of the anterior and posterior elements at C2-C3 (→).

(d) Coronal CT also demonstrates congenital fusion of C2-C3 (→), with marked flattening of the right atlanto-occipital joint (→).

(e) In addition to C2-C3 congenital fusion, Sagittal CT at the level of the right atlanto-occipital joint demonstrates a flattened joint with a hypoplastic right occipital condyle (→) and partially imaged dextroconvex curvature of the cervical spine.

(f) Axial CT demonstrates a posterior fusion anomaly at C1 (o).

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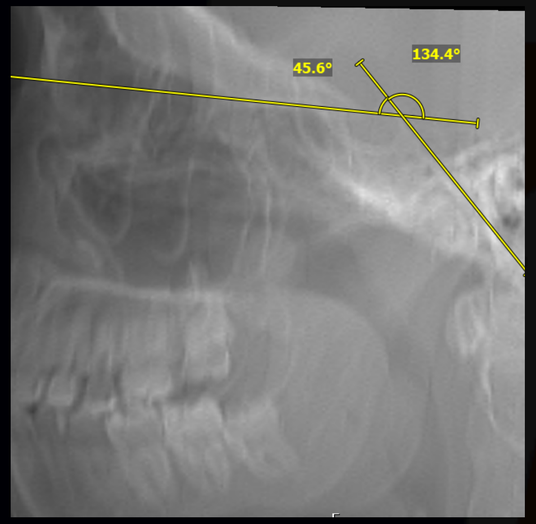


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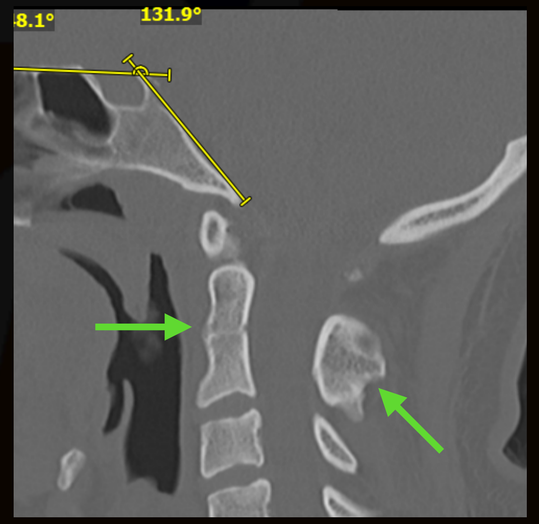


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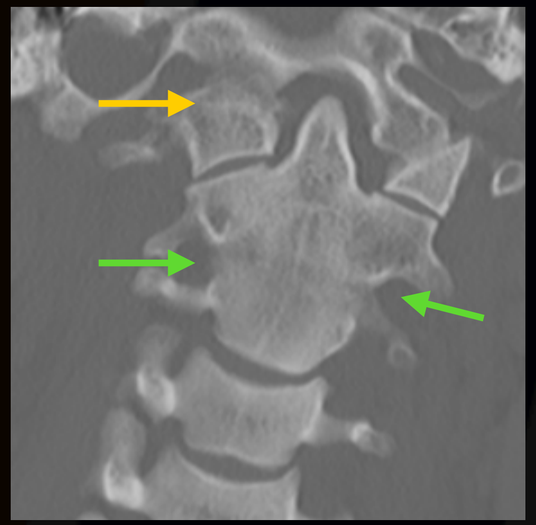

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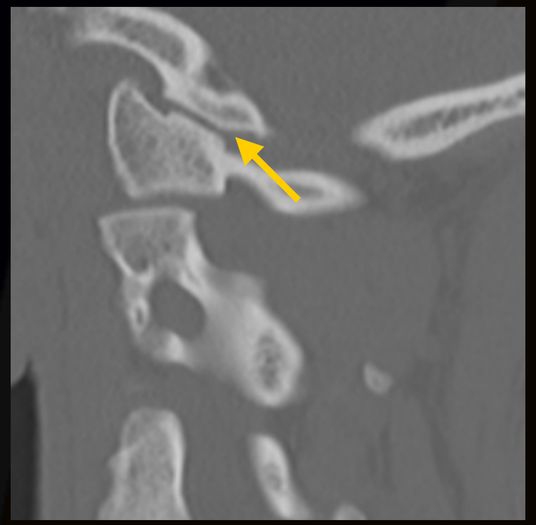
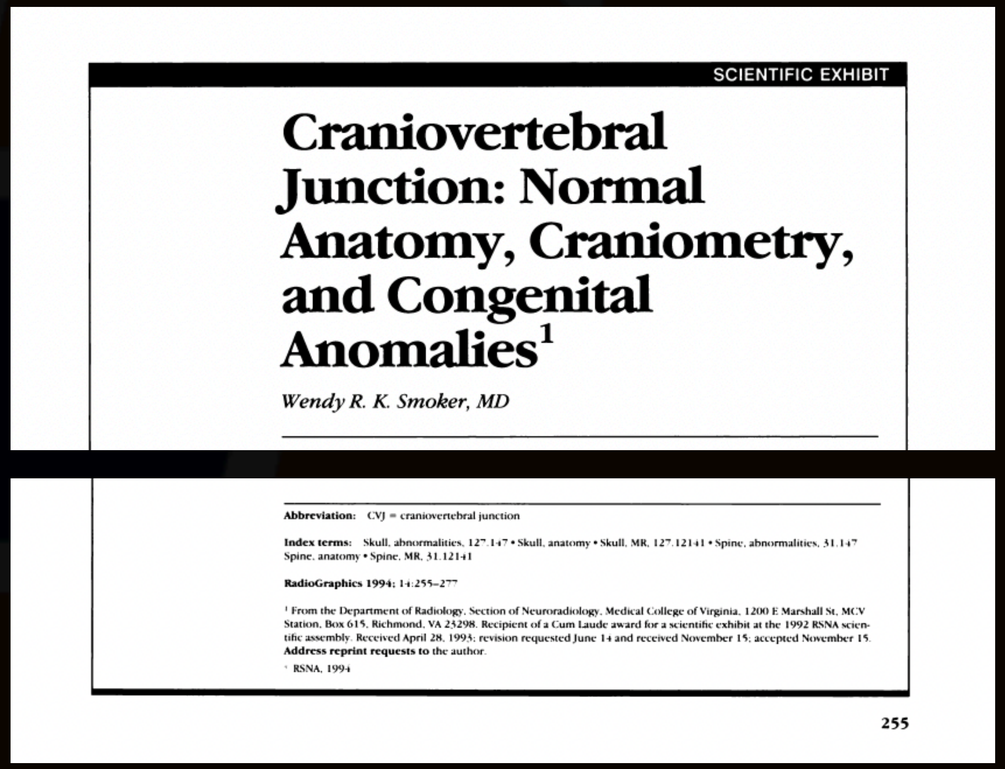


e

f

# Basilar “Invagination” Terminology

- Key Point: Basilar invagination, basilar impression, and cranial settling have nearly identical imaging features, but are **NOT** synonymous!
- Basilar invagination corresponds to a developmental anomaly in which the vertebral column is abnormally high and prolapsed into the skull. Some etiologies include:
  - Atlanto-occipital (AO) assimilation
  - Basiocciput hypoplasia
  - Occipital condyle hypoplasia
- Basilar impression refers to secondary or acquired etiologies of basilar invagination such as:
  - Osteogenesis imperfecta
  - Hyperparathyroidism
  - Paget’s disease
- Cranial settling specifically refers to basilar invagination due to rheumatoid arthritis.



SCIENTIFIC EXHIBIT

**Craniovertebral Junction: Normal Anatomy, Craniometry, and Congenital Anomalies**[1]

*Wendy R. K. Smoker, MD*

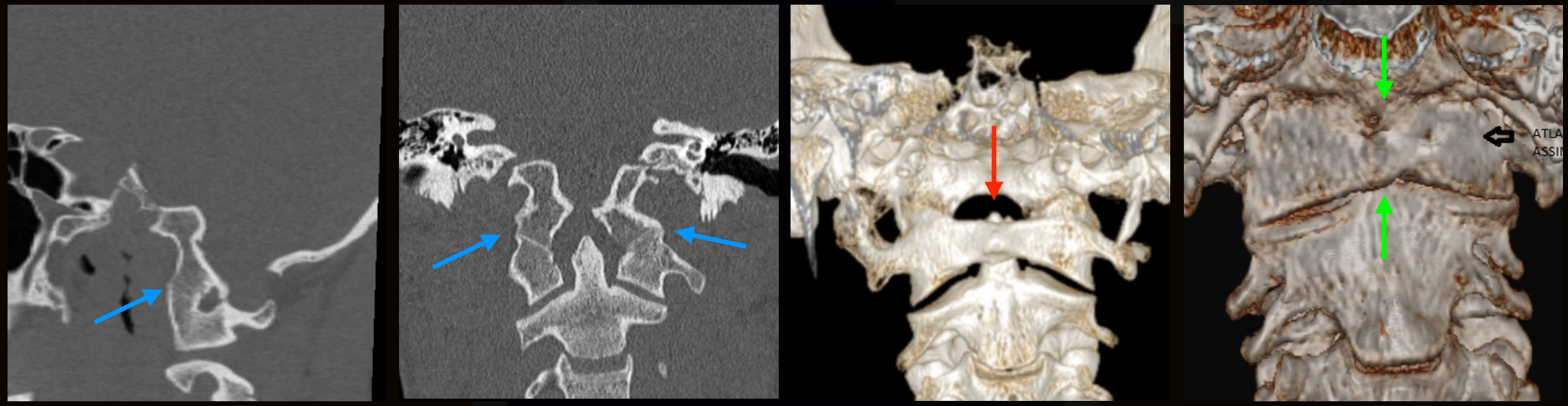
**Abbreviation:** CVJ = craniovertebral junction

**Index terms:** Skull, abnormalities, 12?.147 • Skull, anatomy • Skull, MR, 12?.12141 • Spine, abnormalities, 31.147 Spine, anatomy • Spine, MR, 31.12141

**RadioGraphics 1994;** 14:255–277

[1] From the Department of Radiology, Section of Neuroradiology, Medical College of Virginia, 1200 E Marshall St, MCV Station, Box 615, Richmond, VA 23298. Recipient of a Cum Laude award for a scientific exhibit at the 1992 RSNA scientific assembly. Received April 28, 1993; revision requested June 14 and received November 15; accepted November 15. **Address reprint requests to** the author.

# AO Assimilation




**a.** **b.** **c.** **d.**

This is a case of incidental AO assimilation; a. Sagittal and b. Coronal CT images demonstrate assimilation at the level of the bilateral AO joints (→) with c. CT 3D bone reconstruction demonstrating sparing of the anterior arch at C1 (→). There was also sparing of the C1 posterior arch (not shown).

AO assimilation may occur anywhere along the spectrum of partial to complete congenital fusion between the atlas and base of the occiput. AO assimilation is typically asymptomatic. When attributable symptoms are present, there is usually an abnormal CCA and/or basilar invagination. This patient did not have basilar invagination and had a normal CCA (not shown).

d. CT 3D bone reconstruction from the literature demonstrating complete AO assimilation (→).

Cureus

Open Access Case Report

DOI: 10.7759/cureus.1327

**Complete Atlantooccipital Assimilation with Basilar Invagination and Atlantoaxial Subluxation Treated Non-Surgically: A Case Report**

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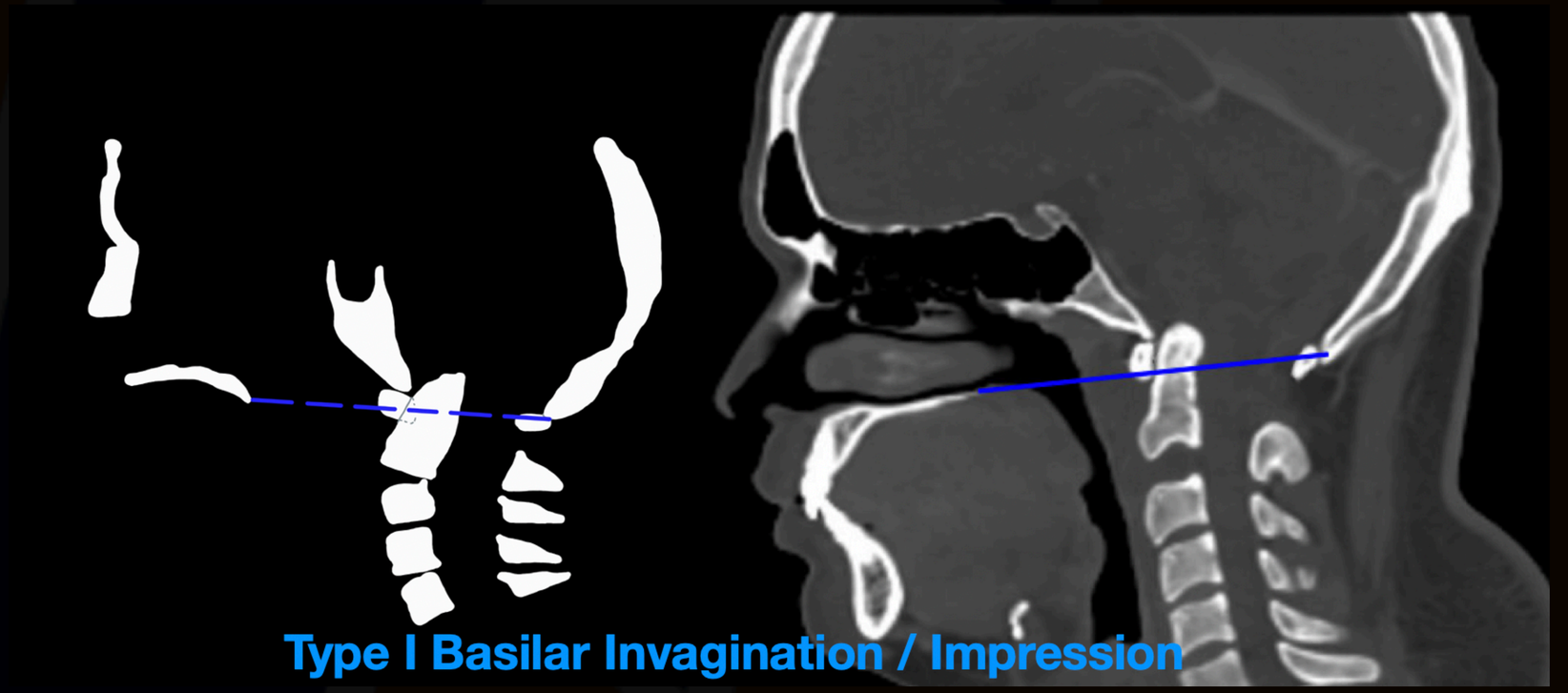
1. Department of Orthopaedics, Electricwala Hospital and Clinic 2. Ruby Hall Clinic Wanowrie, Pune, Maharashtra, India., Ruby Hall Clinic 3. Orthopaedics, Orthocarespecialtyclinic, Satara Road,Pune

# CL Violation Type I

Type I Basilar Invagination / Impression

- Odontoid process extends superiorly (CL violation), occupying the ventral aspect of the foramen of magnum
- This is associated with craniocervical instability

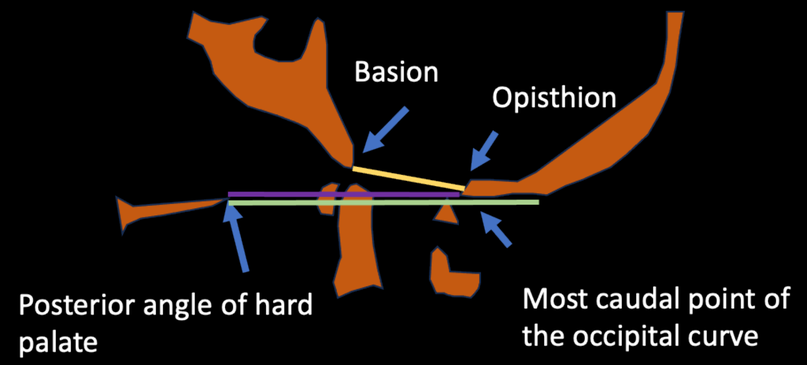


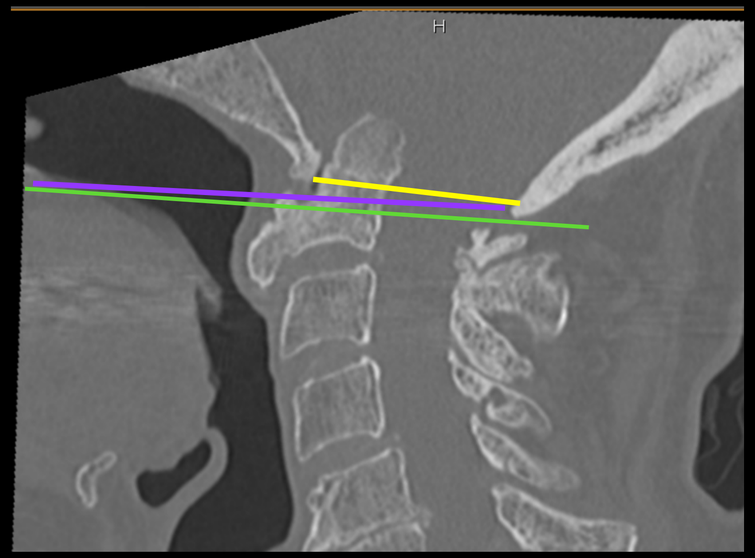

Botelho RV, Melo Diniz J. J Neurol Neuromed (2017) 2(3): 15-19
www.jneurology.com
Journal of Neurology & Neuromedicine
Mini Review Open Access

## Basilar Invagination: cranio-cervical kyphosis rather than prolapse from the upper cervical spine

Ricardo Vieira Botelho[1], Juliete Melo Diniz[1]
*Post-graduation program-IAMSPE; Neurosurgical department-Hospital do Servidor Público Estadual and Conjunto Hospitalar do Mandaqui-São Paulo, Capital, Brazil.*

# Basilar Impression



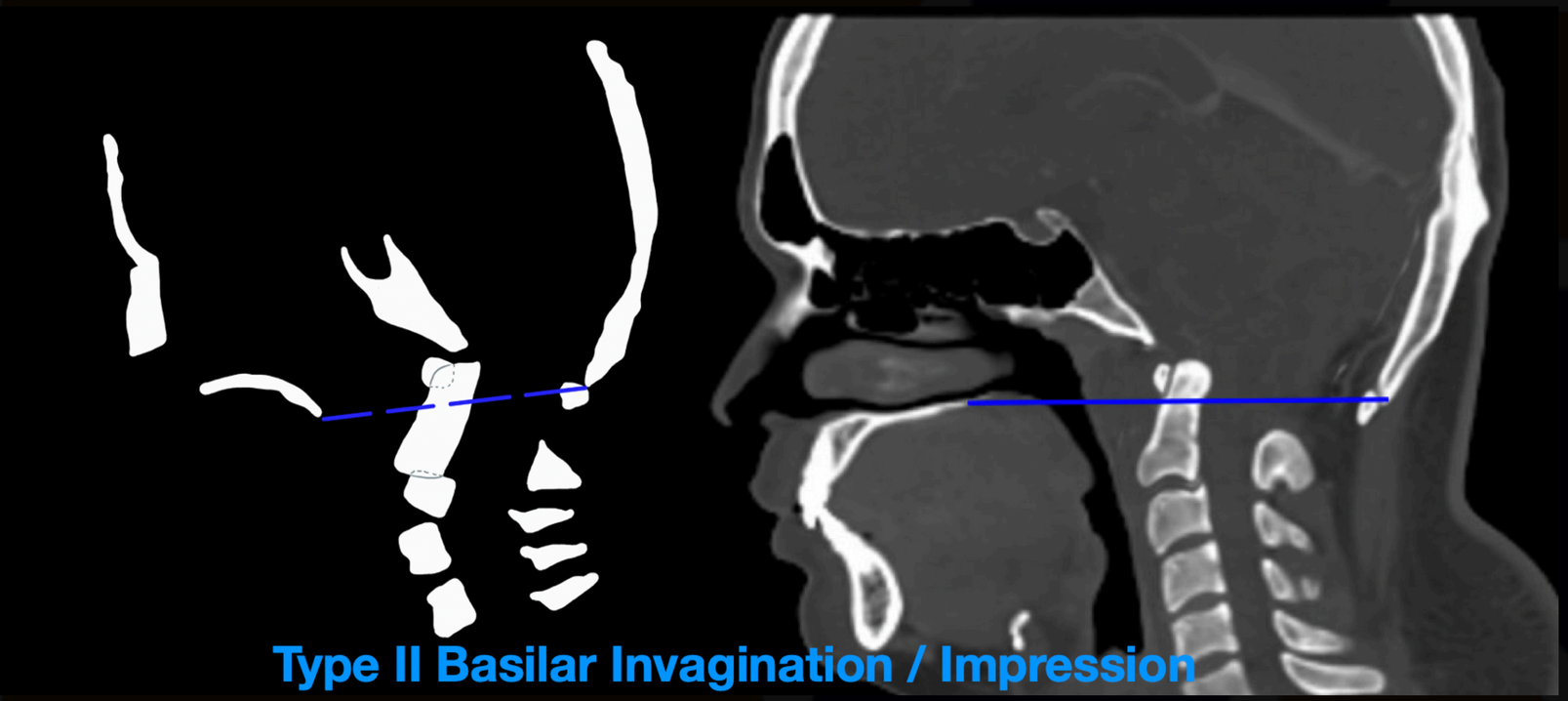



## CL Violation Type I

**Dens occupying the ventral aspect of the foramen of magnum.**

70 year old male with advanced liver disease and abnormal mineralization in trabecular and cortical bone with secondary acquired basilar impression.

# CL Violation Type II

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## Basilar Invagination: cranio-cervical kyphosis rather than prolapse from the upper cervical spine

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### Type II Basilar Invagination / Impression

- Odontoid process extends superiorly (CL violation), but does NOT enter foramen of magnum
- Less associated with craniocervical instability
- Commonly associated with platybasia

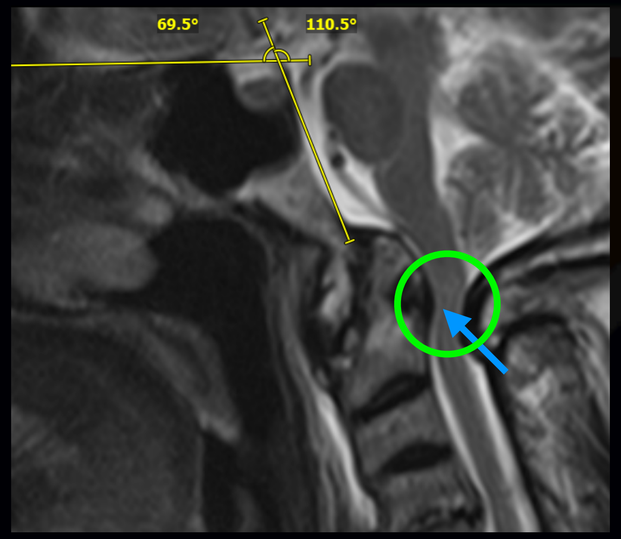
# Cranial Settling

Rheumatoid arthritis with cranial settling

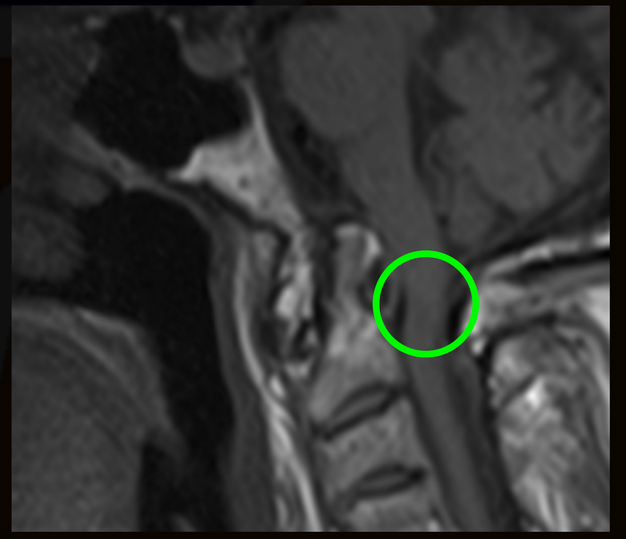
a. Sagittal T2 and b. T1 imaging demonstrating posterior and superior extension of the odontoid process into the foramen magnum with associated dental erosion, pseudoarticulation with the clivus, and surrounding pannus (→).

Furthermore the skull base angle demonstrates mild platybasia (110 degrees). These imaging findings of cranial settling combine to result in compression and distortion of the CMJ with severe foramen magnum stenosis (O).

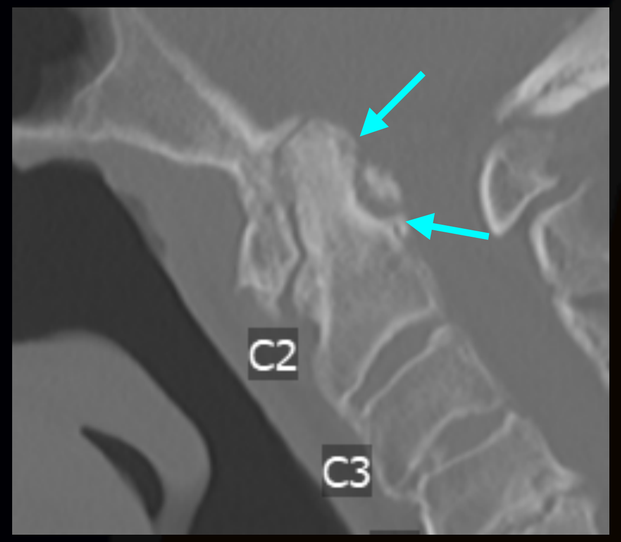
c. Sagittal and d. Coronal CT images corroborate the MRI findings but also demonstrate erosive changes at the bilateral AO joints (→) and along the posterior dens (→) related to the pannus to advantage.



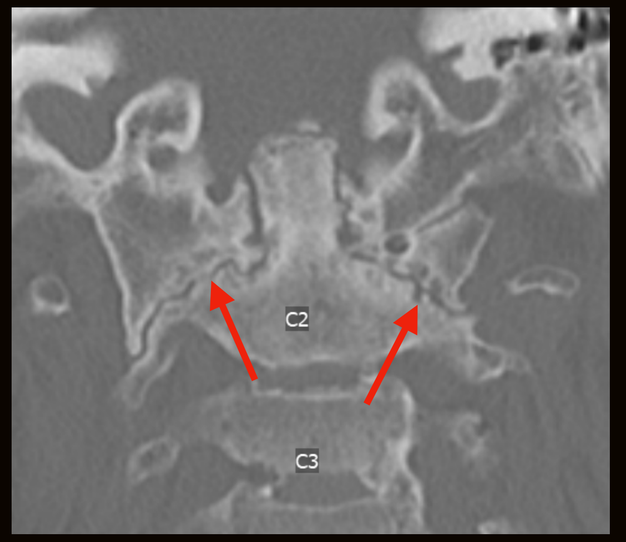

a



b

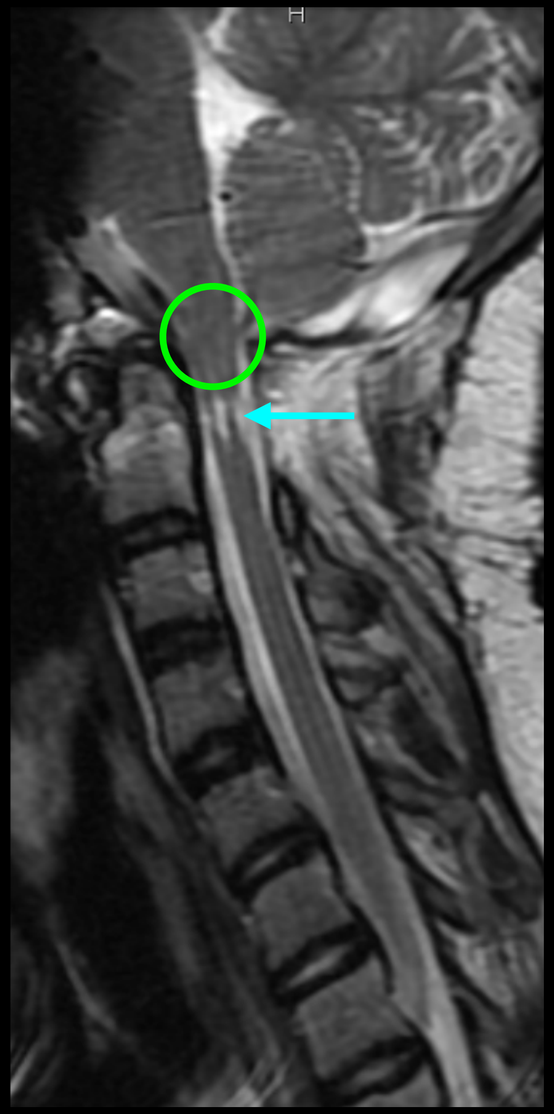


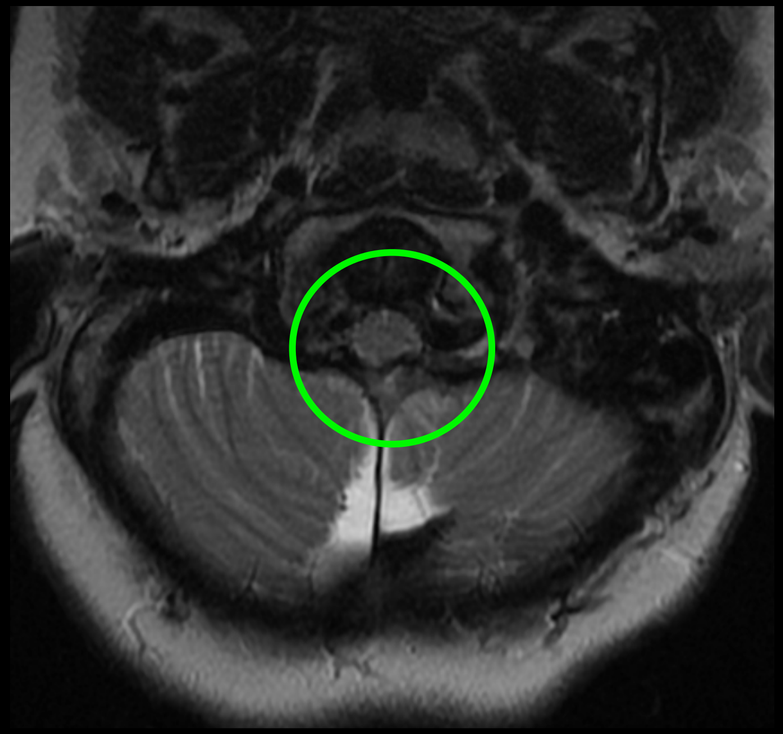

c




d

# Stenosis of Foramen Magnum

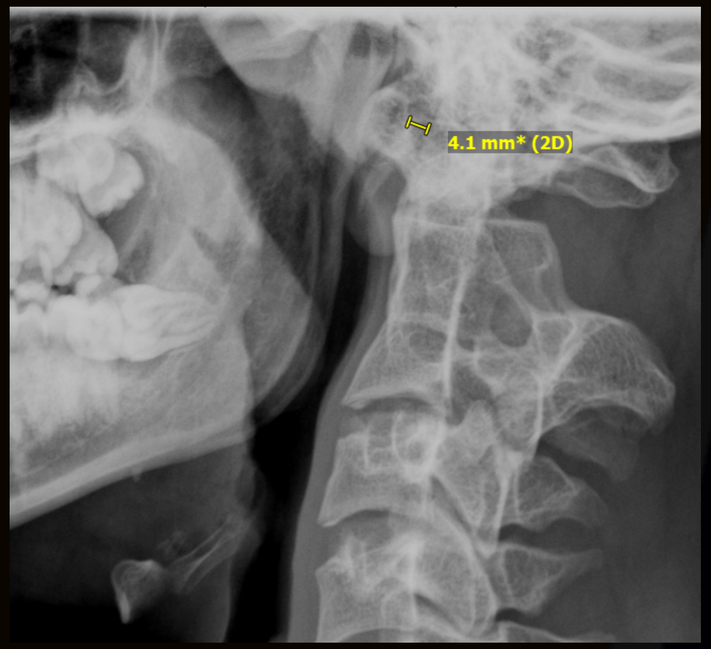




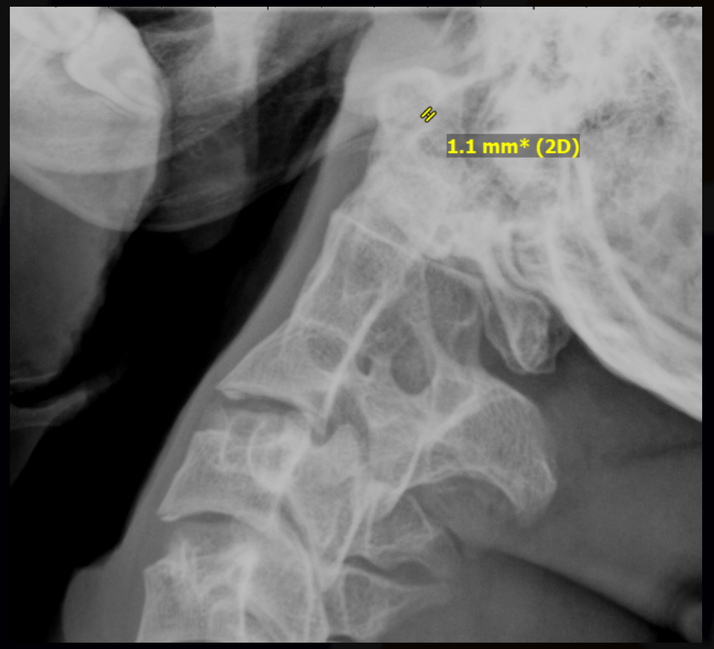
5 year old Male with achondroplasia.

Demonstrates foramen magnum stenosis that resulted in early hydromemyelia in the upper cervical cord.

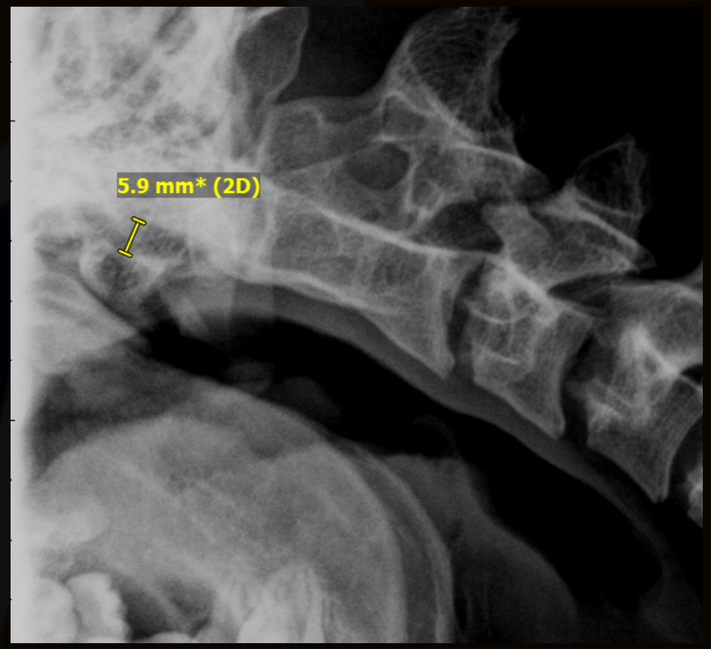
# Atlanto-Axial Subluxation




**Lateral**




**Extension**




**Flexion**

Symptomatic AO assimilation with an abnormal CCA; recurrent dizziness. Case continued from prior slide.

Given the AD interval, the patient underwent flexion and extension radiographs, which demonstrate atlanto-axial subluxation to 6 mm with flexion with reduction to 1 mm with extension. Of note, radiographs also demostrate congenital fusion of C2-3 anterior and posterior elements).

# Summary of Key Points

- Clival-Canal angle: Kyphotic CCA < 150 degrees. Kyphotic CCA less than 135 degrees is far more likely to be symptomatic due to ventral cord compression and/or deformation.
- GOM greater than 9 mm is at increased risk for ventral brainstem compression.
- Platybasia is characterized by abnormal flattening of the skull base. Welcher basal angle; over 140º.
- Chamberlain's Line (CL): "Vliolation": The tip of the dens is greater than 3 mm above CL in adults; 5 mm above in children.
- Basilar invagination, basilar impression, and cranial settling have nearly identical imaging features, but are NOT synonymous!
- Basilar invagination corresponds to a developmental anomaly. Basilar impression refers to secondary or acquired etiologies.

  - Type I Basilar Invagination/Impression: Odontoid occupying the ventral aspect of the foramen of magnum

  - Type II Basilar Invagination/impression Odontoid process extends superiorly (CL violation), but does NOT enter foramen of magnum.

The tip of the odontoid process is normally 5 mm below this line; basilar invagination is diagnosed w

- Head and neck radiologist need to assess CCA even in the absence of compression!