Upright M.R.I.in the study of the Cranio-cervical junction.

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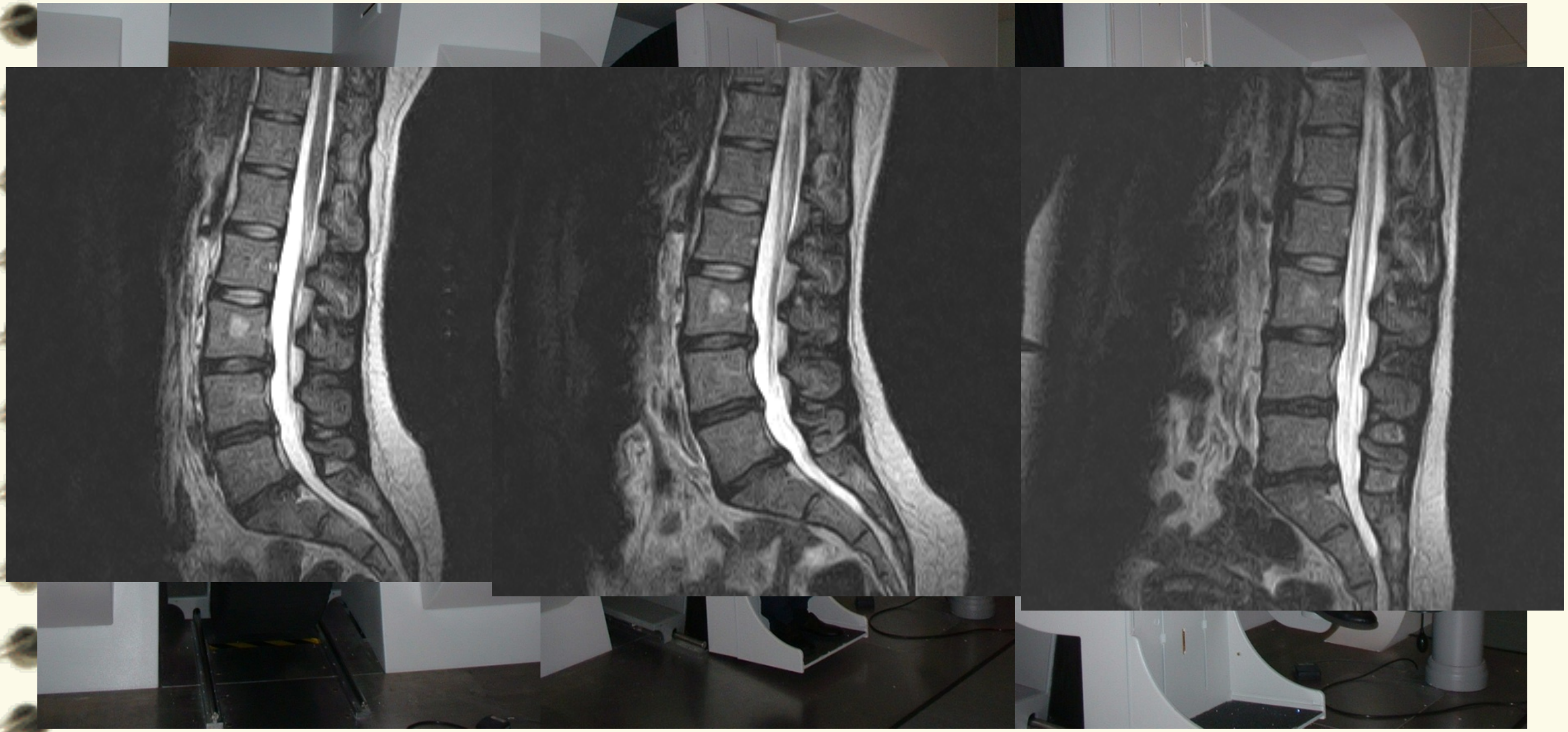
UPRIGHT M.R.I.

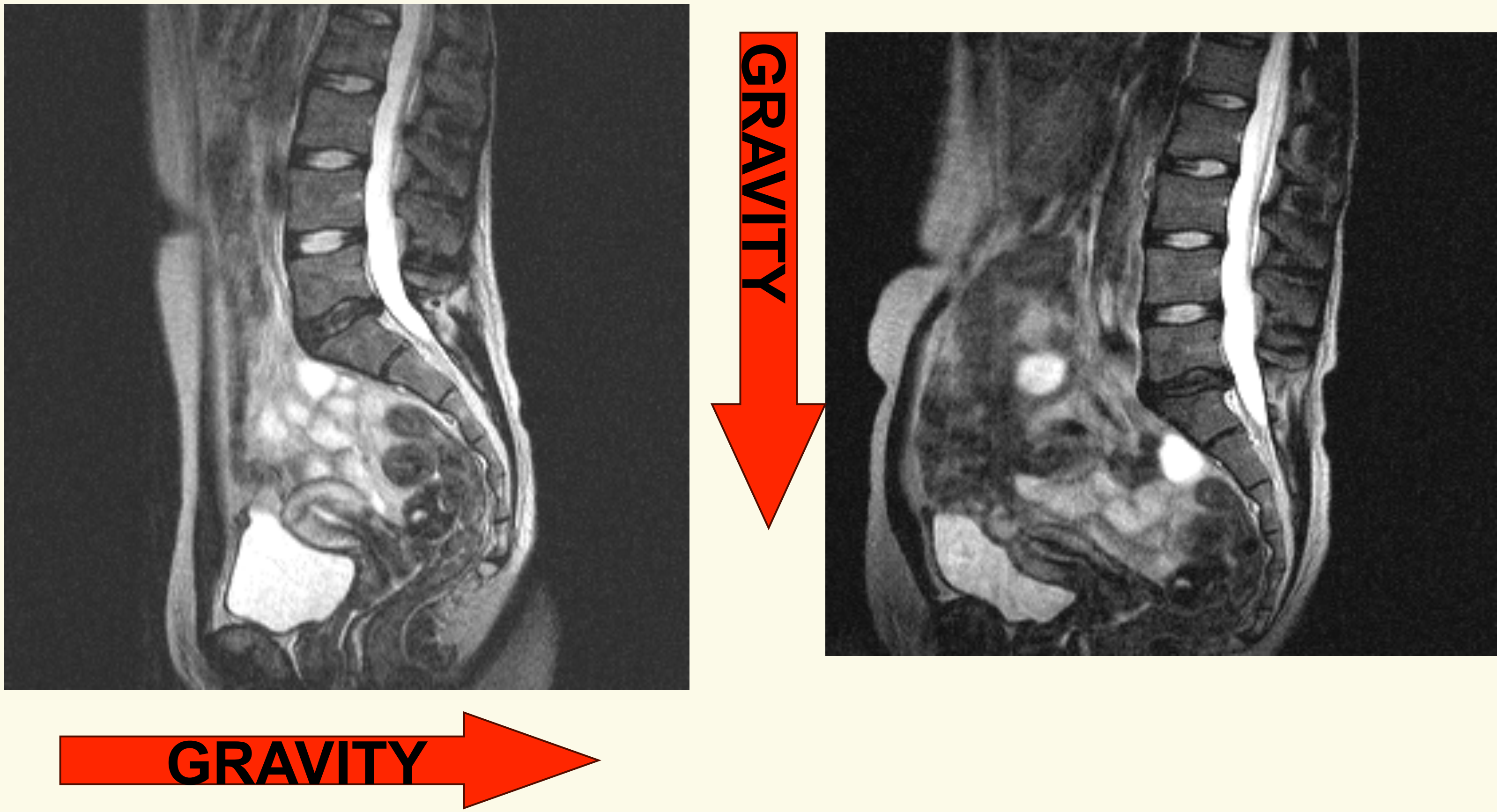
Why do we persist in scanning the spine lying down?

Upright MRI

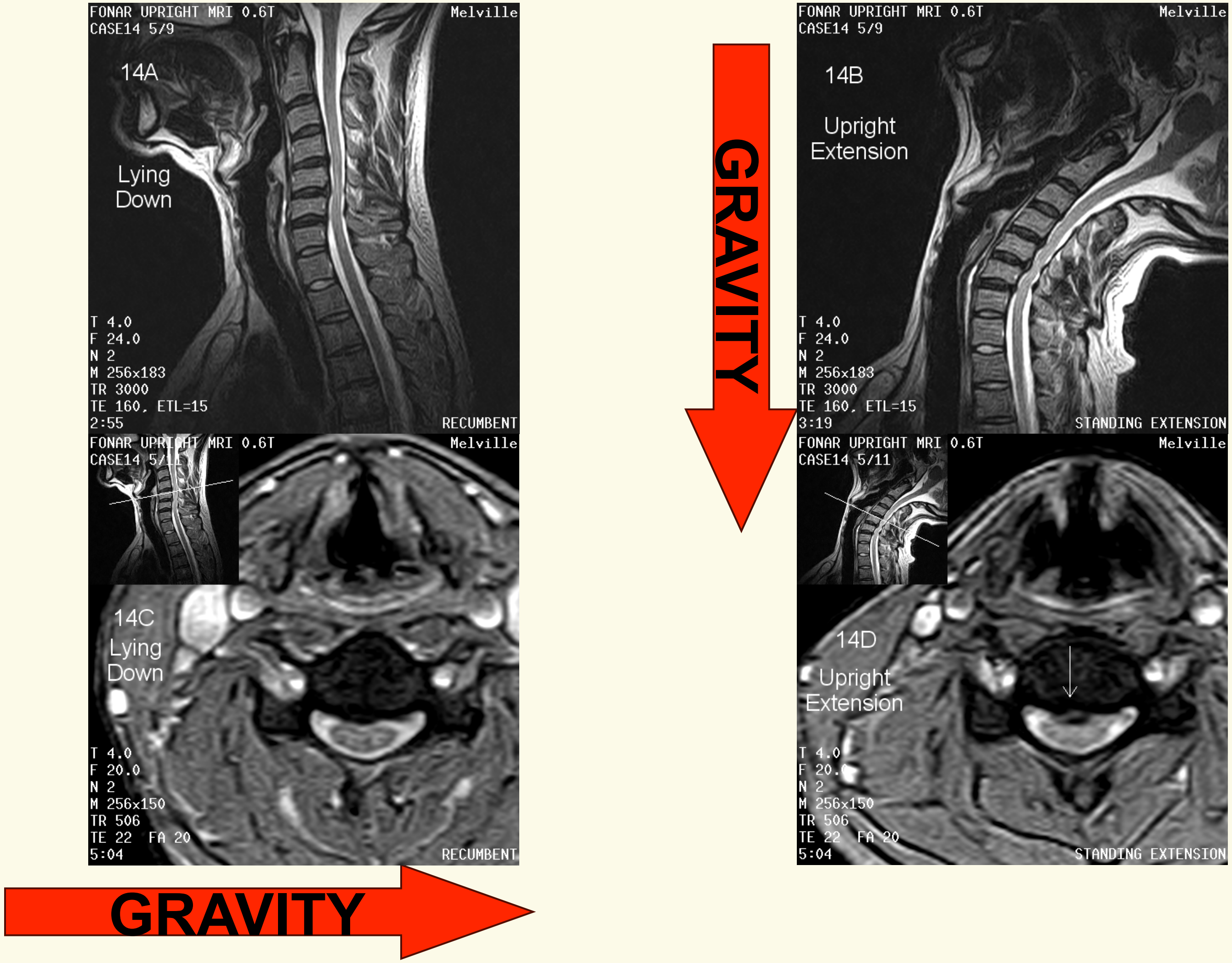
Upright MRI allows patients to simply walk in and be scanned while lying supine, standing up or sitting down.



UPRIGHT M.R.I.



UPRIGHT M.R.I.



FONAR UPRIGHT MRI 0.6T
Melville
CASE14 5/9
14A
Lying Down
T 4.0
F 24.0
N 2
M 256x183
TR 3000
TE 160, ETL=15
2:55
RECUMBENT
14B
Upright Extension
3:19
STANDING EXTENSION
GRAVITY
CASE14 5/11
14C
Lying Down
T 4.0
F 20.0
N 2
M 256x150
TR 506
TE 22 FA 20
5:04
14D
Upright Extension
GRAVITY

Cerebellar Tonsils

GRAVITY

GRAVITY

Case Study

Case courtesy of J.P. Elsig, M.D.
Zurich, Switzerland

A 50-year-old woman had been suffering for years from neck pain. A prior recumbent MRI had shown a C5-6 disc degeneration with a posterior bulge and a moderate segmental kyphosis.

Despite repeated attempts with conservative treatment, the patient's symptoms worsened and were marked by the onset of:

- ✓ ***transient paresthesia***
- ✓ ***transient loss of muscle tone in the legs***
- ✓ ***drop attacks***

Which could **not** be explained by the disc bulge.

The recumbent cervical MRI shows a C5-6 disc bulge in a patient with neck pain which sometimes radiates to the arms

The **UPRIGHT** MRI shows a position-related downward herniation (Chiari I malformation) with compression of the brain stem. This correlates with the additional complaints of dizziness and occasional drop attacks when bending forward.

Cerebellar Tonsils

- Chiari Type I malformation, or tonsular ectopia. is traditionally defined as caudal herniation of the cerebellar tonsils through the foramen magnum.
- May be associated with syringomyelia and osseous abnormalities at the cranio-vertebral junction, but can occur in the absence of both.

Cerebellar Tonsils

- Chiari Type II, also known as Arnold-Chiari malformation, is differentiated from Chiari I in as much as it is present at birth, nearly always associated with myelomeningocele (spina bifida), and includes downward displacement of the medulla, fourth ventricle, and cerebellum into the cervical spinal canal.[1]

- 1 *Stevenson KL. Chiari Type II malformation: past, present, and future. Neurosurg. Focus. Feb 15 2004;16(2):E5.*

Cerebellar Tonsils

- The criterion for diagnosis of a Chiari Type I malformation is most frequently given as MR evidence of low cerebellar tonsils relative to the foramen magnum. (2)

- *2 Ball WS, Krone KR. Chiari malformation from Dr. Chiari to MR imaging, Radiology 1995:195:602-604.*

Cerebellar Tonsils

- The threshold for diagnosis is variable; some authors have suggested that to be considered pathologic the cerebellar tonsils must be 5 mm or more below an imaginary line that runs from the basion, or the most anterior point of the foramen magnum, to the opisthion, or the posterior point of the foramen magnum (3),

- Others have suggested that the range of normal tonsil position ends at 2 mm below the basion-opisthion line (4).

3. Meadows J, Kraut M, Guarnieri M, Haroun RI, Carson BS. Asymptomatic Chiari Type I malformations identified on magnetic resonance imaging. J Neurosurg. 2000 Jun;92(6):920-6.

4. Barkovich AJ, Wippold FJ, Sherman JL, Citrin CM. Significance of cerebellar tonsular position on MR, AJNR 1986;7:795-799.

- ✓ Symptomatic activation of previously quiescent Chiari Type I malformations as a result of exposure to traumatic injury has been reported (5 – 8)

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5. Milhorat TH, Chou MW, Trinidad EM, Kula RW, Mandell M, Wolpert C, Speer MC. Chiari 1 malformation redefined: clinical and radiographic findings for 364 symptomatic patients. Neurosurgery 1999, 44:1005-1017.

6. Wan MJ, Nomura H, Tator CH. Conversion to symptomatic Chiari I malformation after minor head or neck trauma. Neurosurgery. 2008 Oct;63(4):748-53; discussion 753.

7. Pratticò F, Perfetti P, Gabrieli A, Longo D, Caroselli C, Ricci G. Chiari I malformation with syrinx: an unexpected diagnosis in the emergency department. Eur J Emerg Med. 2008 Dec;15(6):342-3.

8. Bunc G, Vorsic M. Presentation of a previously asymptomatic Chiari I malformation by a flexion injury to the neck. J Neurotrauma. 2001 Jun;18(6):645-8.

Cerebellar Tonsils

- It is not clear is how trauma plays a role in the activation of symptoms attributed to a Chiari Type I malformation.
- Are the symptoms merely coincidental to the trauma?
- Is the condition symptomatically “awakened” by the trauma?
- Could the Chiari be caused by the trauma?
- This last question is important, since quite often the presence of tonsular ectopia is not discovered until after trauma, and acquired tonsular herniation is radiographically indistinguishable from a pre-existing Chiari Type I (9)

9. Payner TD, Prenger E, Berger TS, Crone KR. Acquired Chiari malformations: incidence, diagnosis, and management. Neurosurgery. 1994 Mar;34(3):429-34.

Cervical Whiplash and Chiari : Coincidence, Correlation or Causation ?

A case-control study of Cerebellar Tonsillar Ectopia and Cervical Spine trauma

Freeman M D,	Forensic Epidemiologist
Rosa S,	Chiropractor
Harshfield D,	Radiologist
Smith F W,	Radiologist
Bennett R,	Rheumatologist
Olson T,	Anatomist
Centeno C,	Physiatrist
Kornel E,	Neurosurgeon
Heffez D,	Neurosurgeon
Nystrom A,	
Kohles S,	Biomechanist

Method

- MRI studies of the cervical spine and base of the skull from 1200 consecutive neck pain patients 18 years and older presenting to 4 different outpatient radiology centers over a 3 year period were reviewed.

Method

- Half of the scans (600) were acquired from a facility with a 0.6T upright open MRI scanner.
- The other half (600) were obtained from a facility with a 0.7T conventional recumbent open MRI scanner.

The scans were further subdivided into 2 subgroups;

- ✓ Half were from patients with neck pain following a road traffic accident.
- ✓ Half were from patients with no recent history of trauma.
- ✓ The resulting 4 groups comprise 300 scans each

- ✓ Recumbent Non-trauma (RNT),
- ✓ Upright Non-trauma (UNT),
- ✓ Recumbent Trauma (RT),
- ✓ Upright Trauma (UT).

- The images were interpreted by two radiologists, blinded with regard to the clinical history and scanner type.

- The scans were categorized by the level of the lowest point of the cerebellar tonsils relative to the basion-opisthion line

Basion-opisthion line

Tonsil position - grading criteria

Tonsil position	Position relative to B-OL
+3	>5 mm above
+2	3 mm to <5 mm above
+1	1 mm to <3 mm above
0	<1 mm above to <1 mm below
-1	1 mm to <3 mm below
-2	3 mm to <5 mm below
-3	>5 mm below

Results

- Average tonsil station
- The relative frequency of tonsil at and below the foramen magnum for each group and by gender.
- Analysis of variance (ANOVA) with a Tukey pairwise comparison was used to evaluate for significant differences in average station among the subgroups and genders.
- Chi-square goodness of fit test used for evaluation of the proportional differences between the groups.
- A Kappa statistic was used to assess the level of agreement between the two radiologists. (Analyse-It, Leeds UK).

Results

- Of the 1200 scans 5 were considered uninterpretable for tonsil station by one or the other of the radiologists.

- All 5 were in the recumbent trauma group.

- Amongst the remaining 1195 subjects

  The average age was 41.5 and 39.7 years in the trauma group

  and 57.4 and 54.0 years in the non-trauma group (recumbent and upright, respectively).
- The majority of subjects were female in all groups.

Results

- ✓ There was good agreement between the two radiologist readers regarding tonsil station (kappa range 0.85 to 0.95).

Results

- There was good agreement between the two radiologist readers regarding tonsil station (kappa range 0.85 to 0.95).
- Both injury status and scan type (recumbent vs. upright) were associated with significant differences in the average tonsil station ($p = <0.0001$).

Age, gender, and average tonsil station.

	Recumbent No Trauma	Recumbent Trauma	Upright No Trauma	Upright Trauma
Number	300	295	300	300
Age	57.4	41.5	54.0	39.7
(F/M%)	60/39	65/35	57/42	62/37
Tonsil Station Mean,	1.1	0.7	0.9	0.1
Tonsil Station Male	1.2	0.9	1.1	0.2
Tonsil Station Female	1.2	0.6	0.8	0.0

Results - Mean tonsil station

Recumbent non-trauma group	1.1
Upright non-trauma group	0.9
Recumbent trauma group	0.7
Upright trauma group	0.1

Results - Mean tonsil station

- True Chiari Type I cases were rare in all of the groups as there were only a total of 6 cases distributed relatively evenly;
- 3 in the trauma groups (2 upright and 1 recumbent)
- 3 in the non-trauma groups (1 upright and 2 recumbent).

Results - Mean tonsil station

- In the two non-trauma groups the tonsils were below the B-OL in 5.7% and 5.3% of cases in the recumbent and upright groups, respectively.
- In the trauma groups the tonsils were below the B-OL in 9.5% and 23.7% of cases in the recumbent and upright groups ($\chi 2=0.0001$).

Proportion of cases found to be at the level of the foramen magnum or below.

	Recumbent	Upright
Non-trauma	29 %	30 %
Trauma	41.7%	76 %

Conclusions

- The question remains as to whether these findings are a result of a previously asymptomatic condition that has been awakened by the traffic crash trauma or whether they were caused by the trauma.
- Our best explanation for the findings is that they are the result of an injury that resulted in a de-stabilisation of the ligaments supporting the spinal cord at the foramen magnum.
- It has been suggested in the literature that there is a causal relationship between whiplash injury and fibromyalgia syndrome (FMS). One author has reported a 13 times greater incidence in FMS in patients with whiplash injury than in those with lower extremity fracture. (10) and another has reported that 25% of FMS cases are initiated by trauma.(11)

10. Buskila D, Neumann L, Vaisberg G, Alkalay D, Wolfe F. Increased rates of fibromyalgia following cervical spine injury. A controlled study of 161 cases of traumatic injury. Arthritis Rheum. 1997 Mar;40(3):446-52.

11. Sukenik S, Abu-Shakra M, Flusser D. Physical trauma and fibromyalgia--is there a true association? Harefuah. 2008 Aug-Sep; 147(8-9):712-6, 749.

Conclusions

- Whether or not tonsilar ectopia results from whiplash trauma the condition is approximately 4 times more prevalent in whiplash-injured neck pain patients than neck pain patients with no recent history of trauma.
- Interestingly, the proportion of upright scans with tonsilar ectopia is approximately the same as the proportion of whiplash-injured patients who go on to experience chronic pain symptoms from their injury. (14)

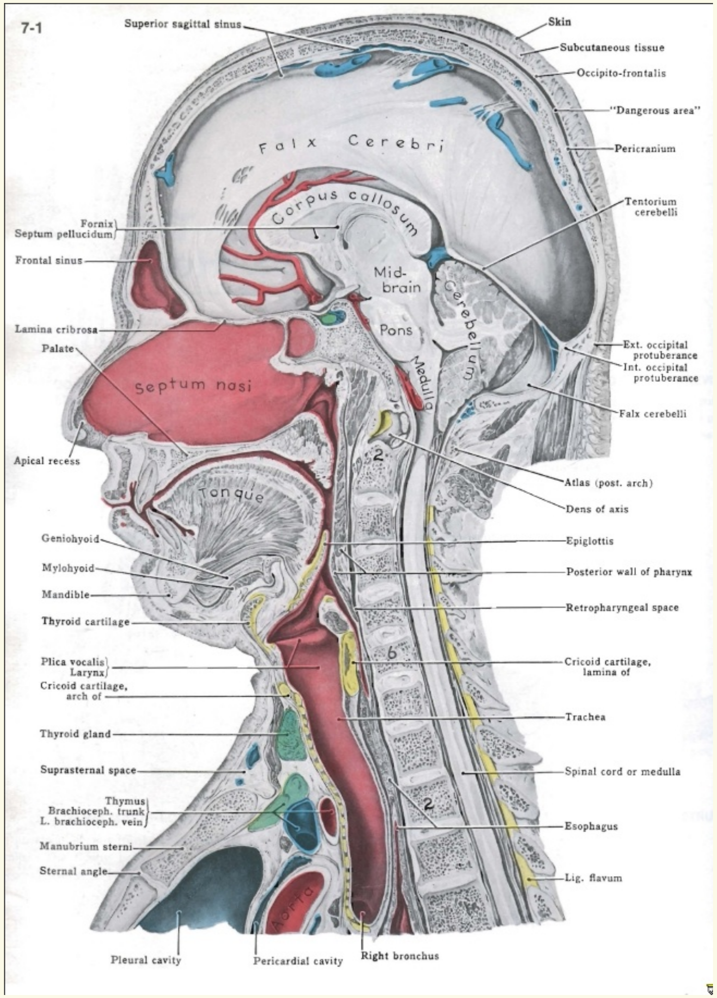
- *14. Freeman MD, Croft AC, Rossignol AM, Weaver DS, Reiser M. A review and methodological critique of the literature refuting whiplash syndrome. Spine 1999;24(1):86-98*

Conclusion

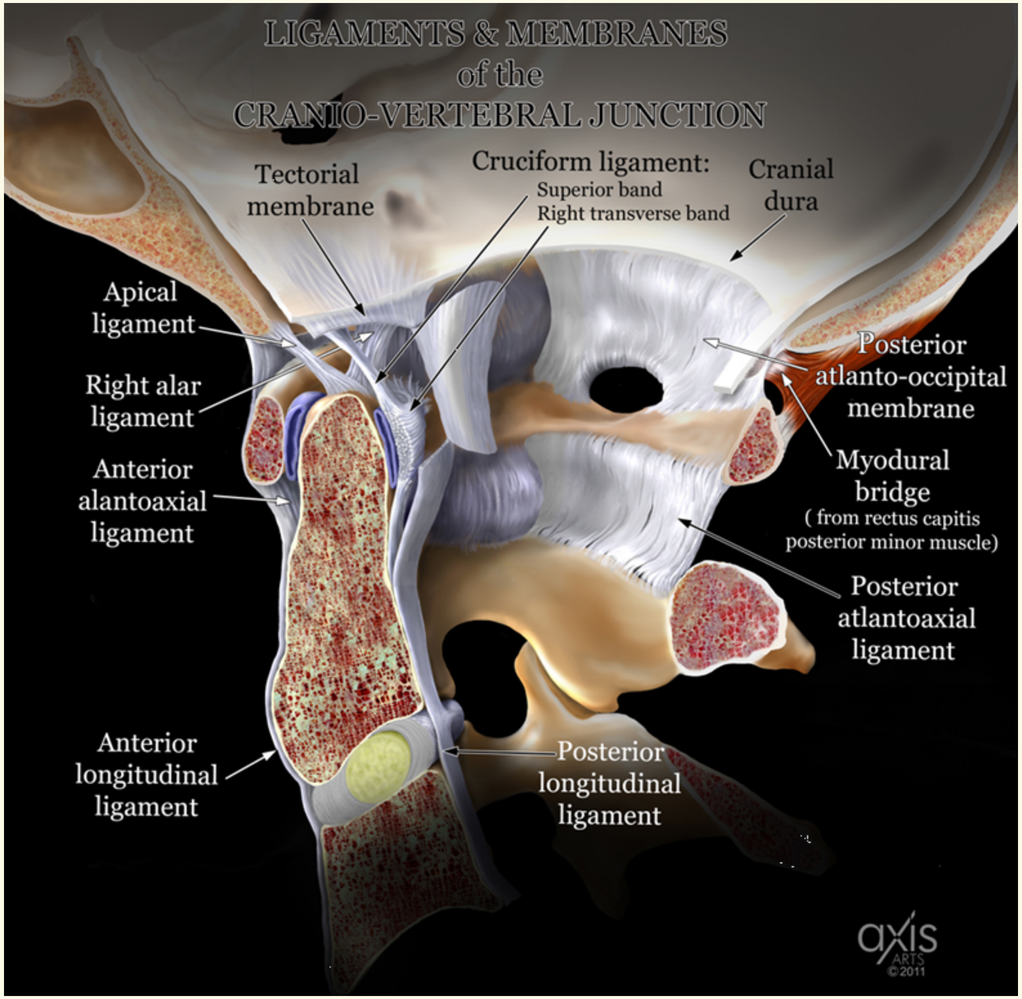
- In a study of 1200 patients, tonsilar ectopia was identified in 1 in 4 trauma patients versus 1 in 18 non-trauma patients.
- Upright position MR imaging appears to increase the sensitivity of MR to tonsilar ectopia by more than double, the utility of this modality deserves further study – wider acceptance.

Freeman M, Rosa S, Harshfield D, Smith FW, Bennett R, Centano CJ, Kornel E, Nystrom A, Heffez DS, & Kohles SS.
A Case-controlled study of cerebellar tonsillar ectopia (Chiari) and cervical spine trauma*.*
Brain Inj. 24 (7-8):988-94. 2010

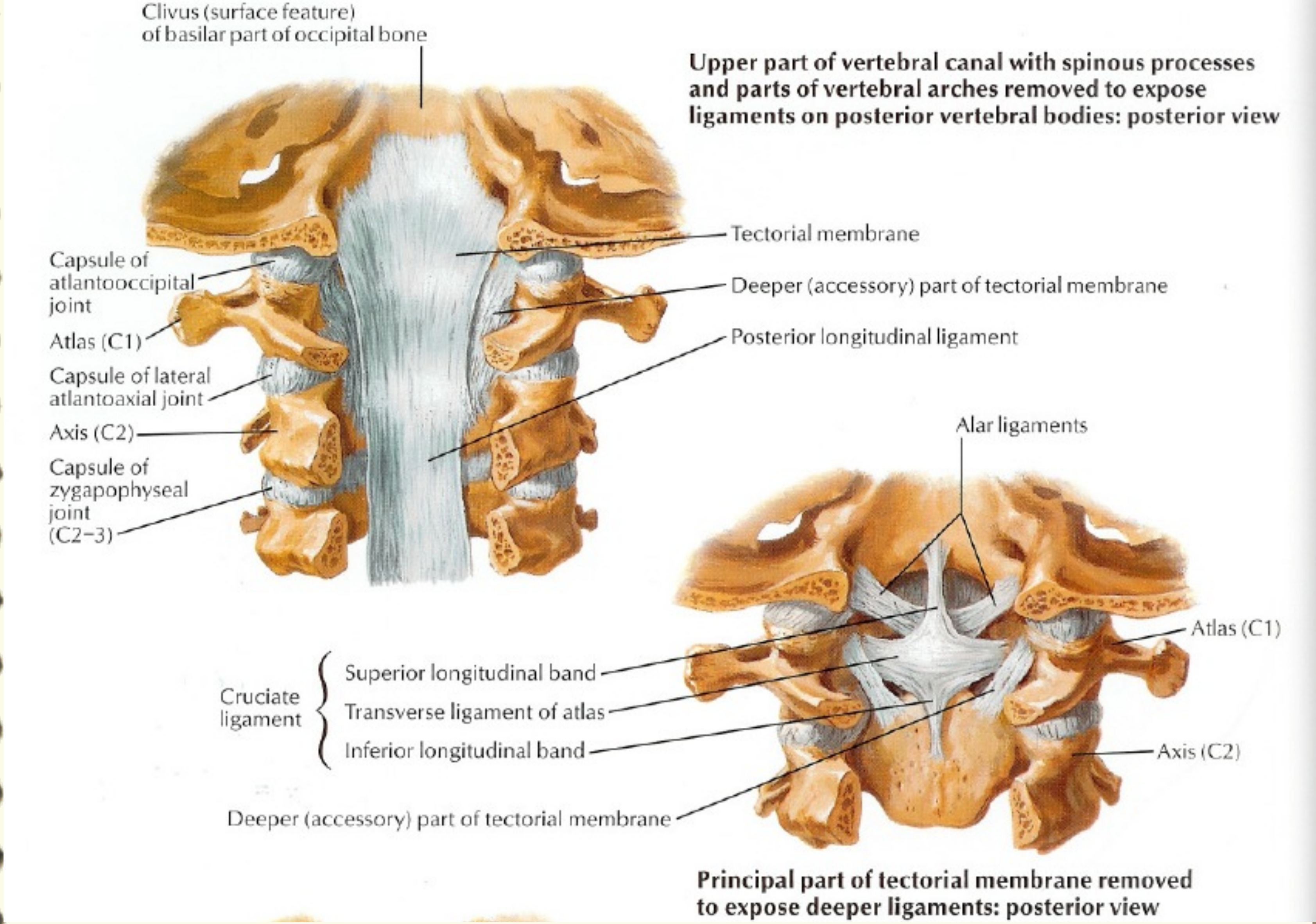
Concept of NORMAL from Gray's Anatomy:



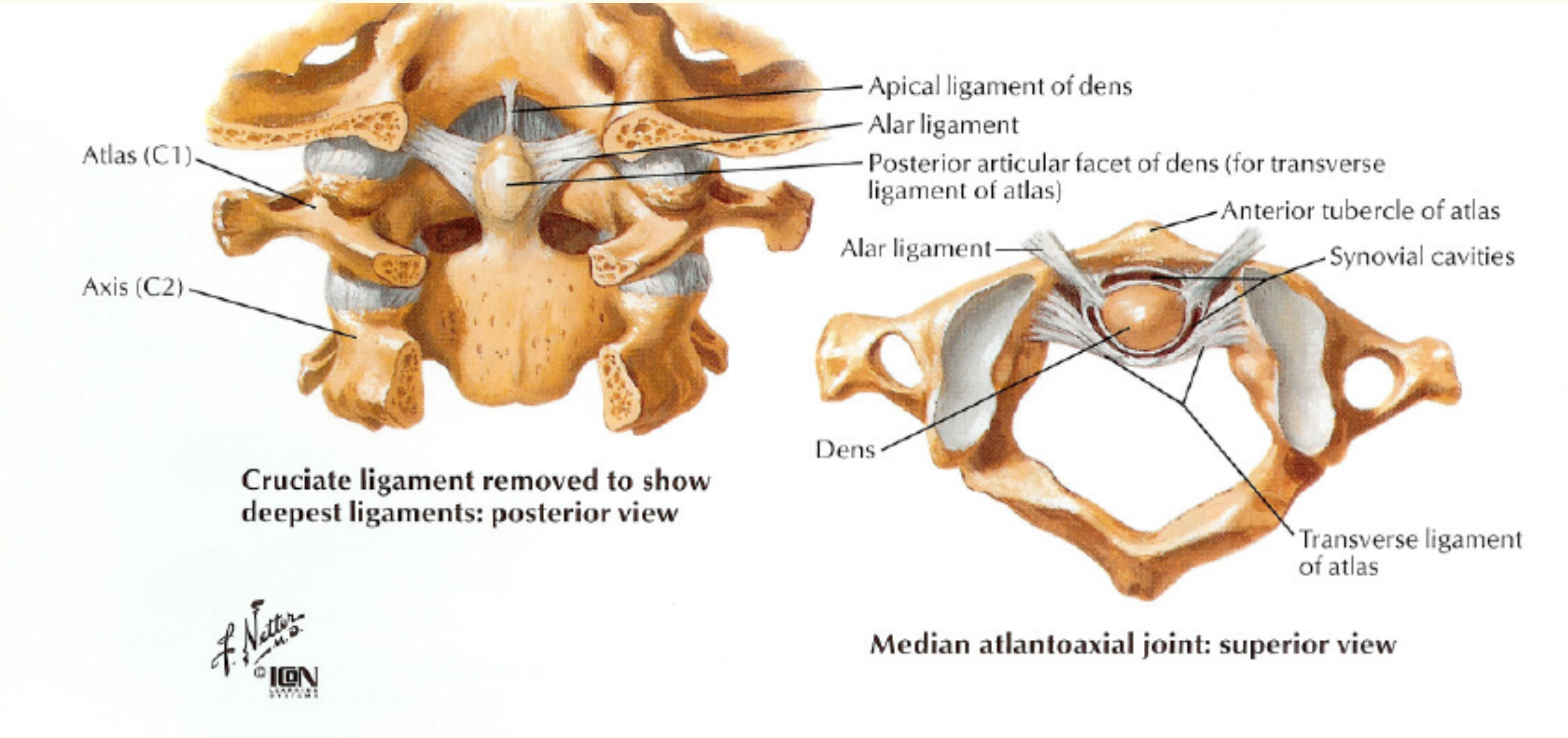
Ligaments and membranes of the Cranio-cervical junction



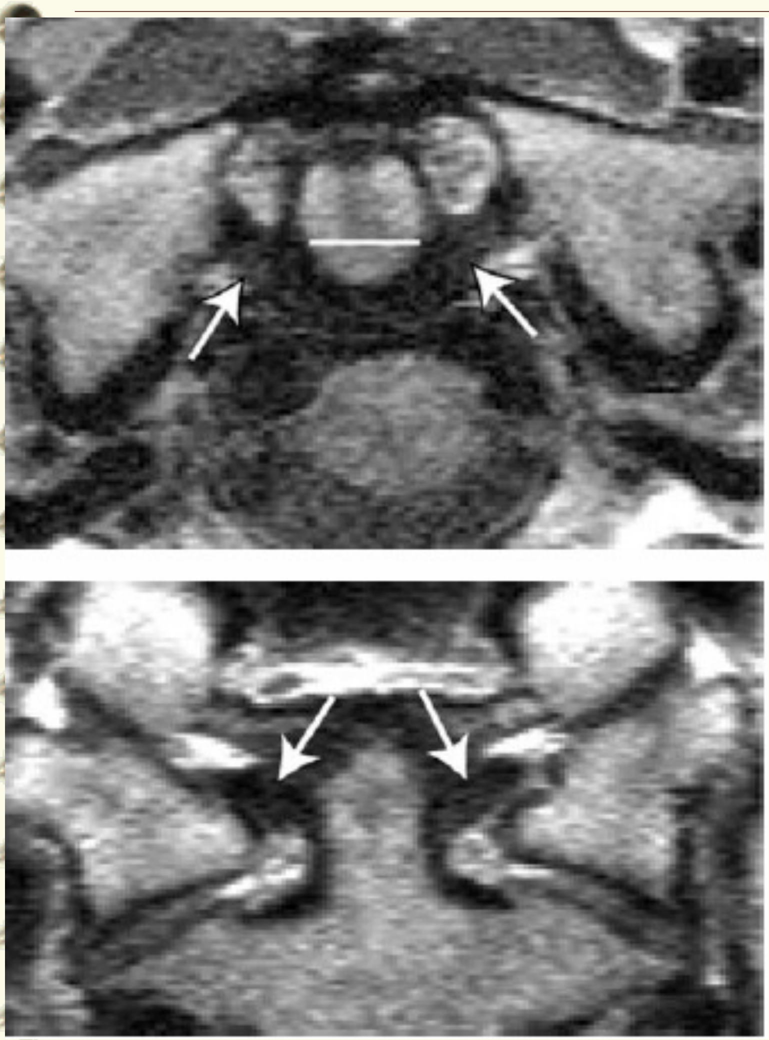
Craniocervical Junction.



Cranio-vertebral Junction.



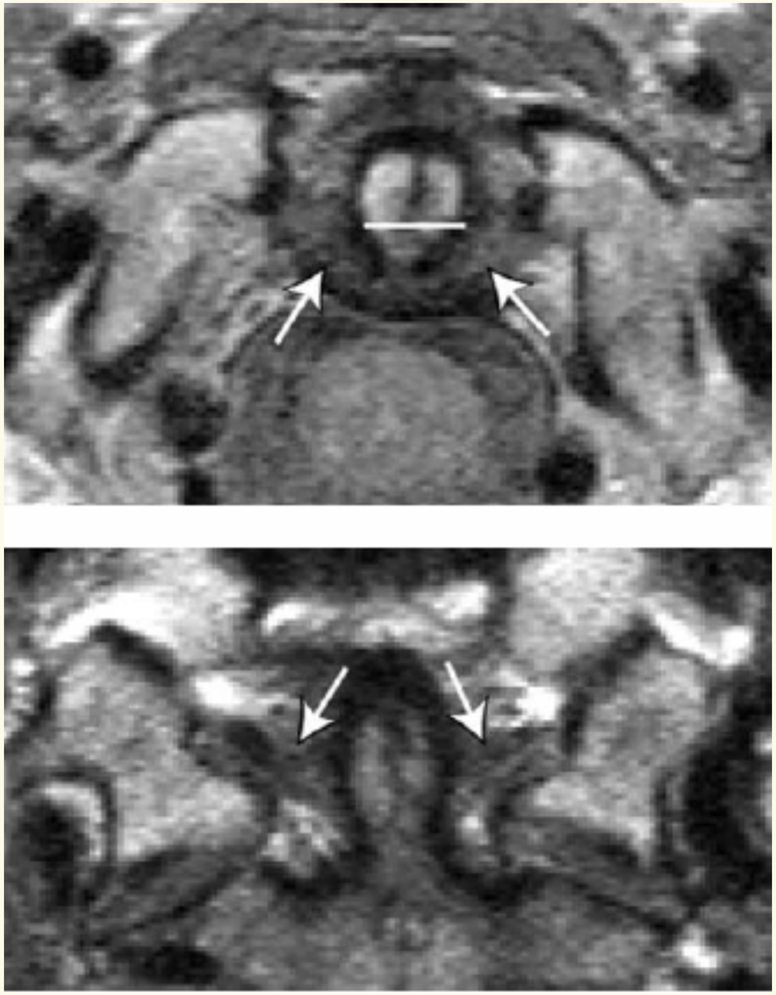
Proton-density images (TR/TE 2200/15)
Normal transverse ligament.



(**A**) Axial image shows low signal intensity indicating a normal ligament appearing dark (arrows).

(**B**) Coronal view (along the line in A) verifies that the transverse bands of the cruciform ligament is normal (dark, arrows).

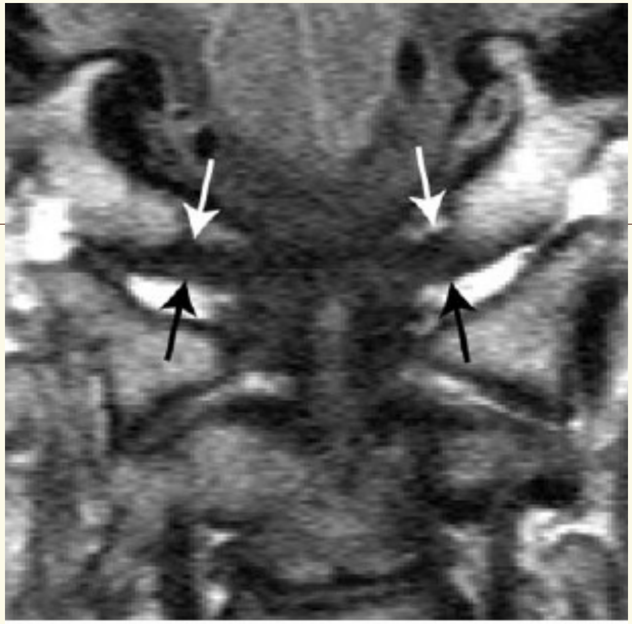
Transverse band cruciform ligament grade 3 lesions (similar imaging planes and parameters as in previous slide).



(**A**) The ligament is ill defined and shows generally increased signal intensity (arrows), appearing gray.

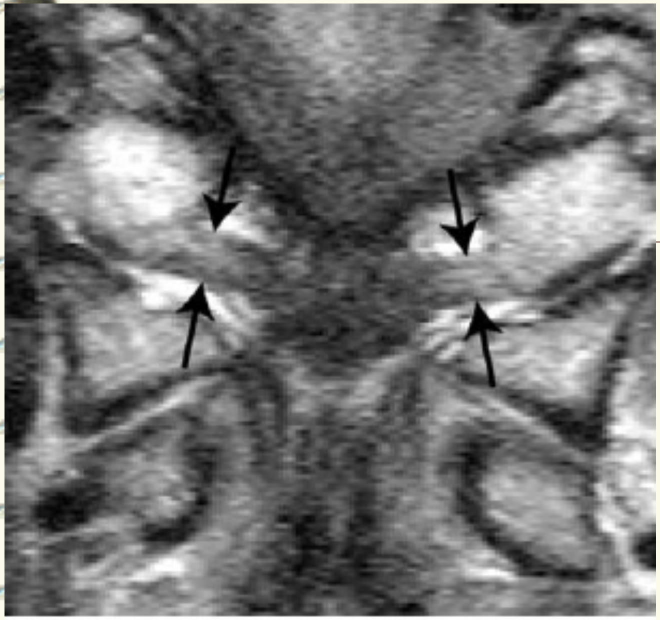
(**B**) The increased signal intensity is verified in coronal imaging plane (arrows).

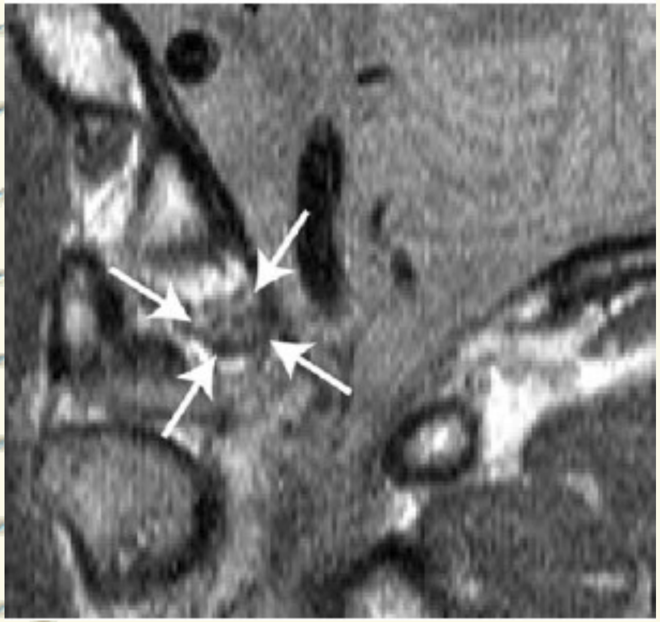
Normal alar ligaments



(**A**) The ligaments are well defined, appearing dark, and can be followed from the posterior part of the dens axis to the occipital condyles (arrows).

(**B**)
Sagittal image near the insertion (at the right arrow in A) shows low signal intensity in the cross-sectional area (arrows).



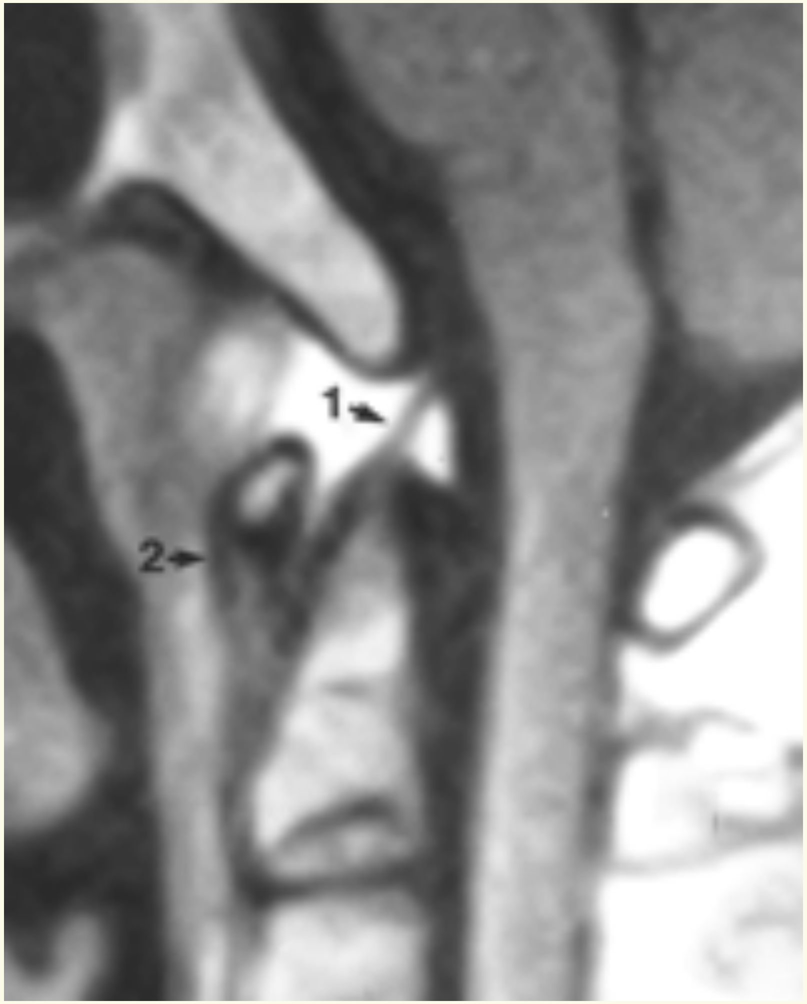


Alar ligaments
Post-traumatic grade 3 lesions

(**A**) The ligaments
show high signal intensity, appearing light-gray, on both sides, most prominent in the lateral parts (arrows).

(**B**) The high signal is reflected in a sagittal image near the right insertion. The entire cross-sectional area (arrows) shows high signal intensity.

Apical ligament

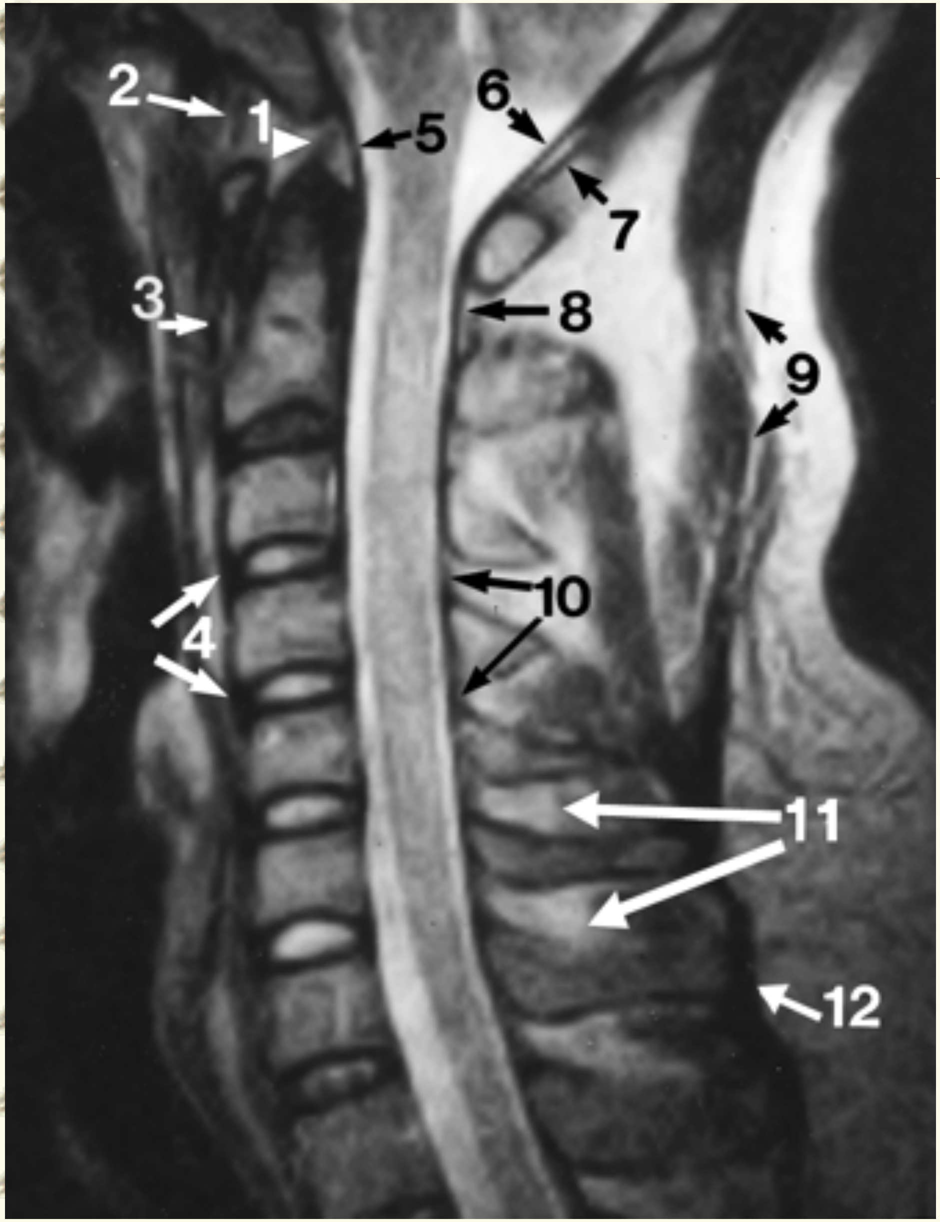


Normal anatomy in 21-year-old man.
Sagittal T1-weighted MR image showing :-

1. normal apical ligament

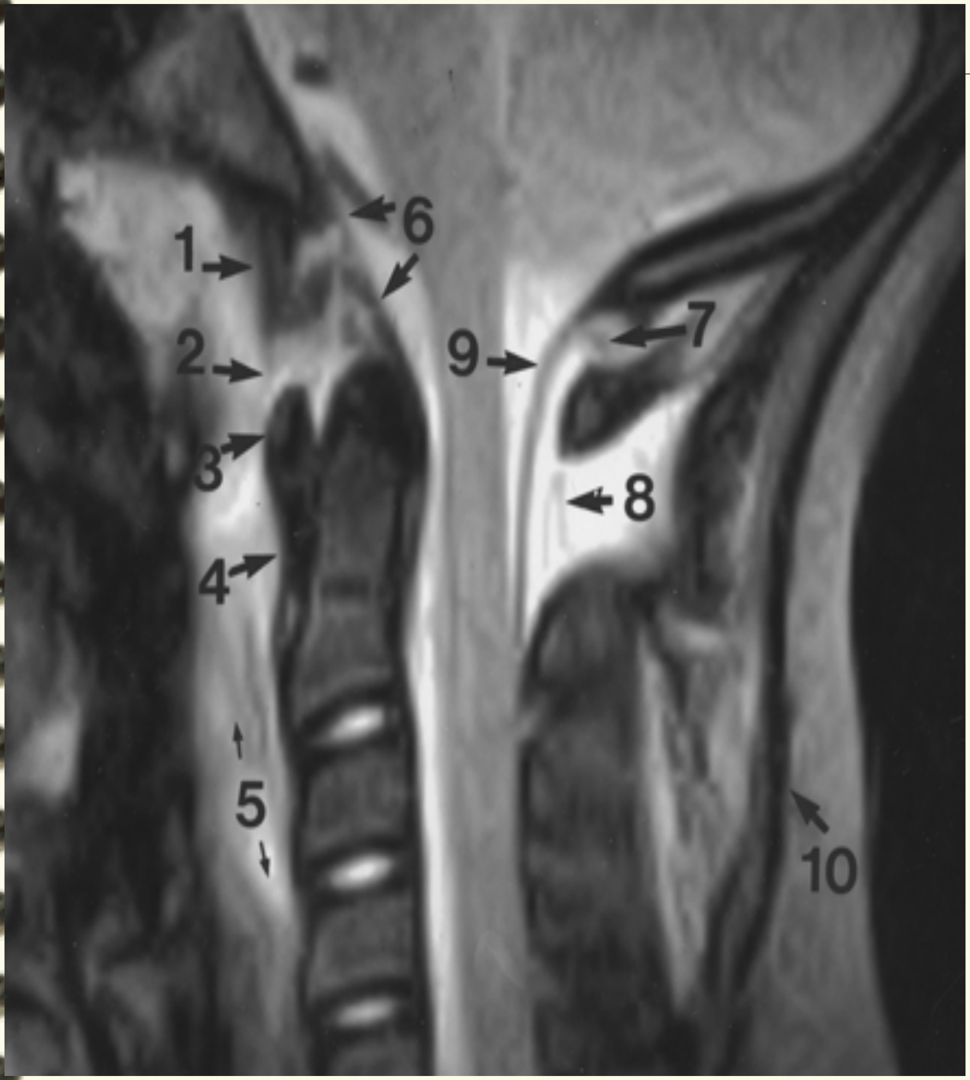
2. anterior atlantoaxial membrane .

Sagittal MRI of a normal cervical spine



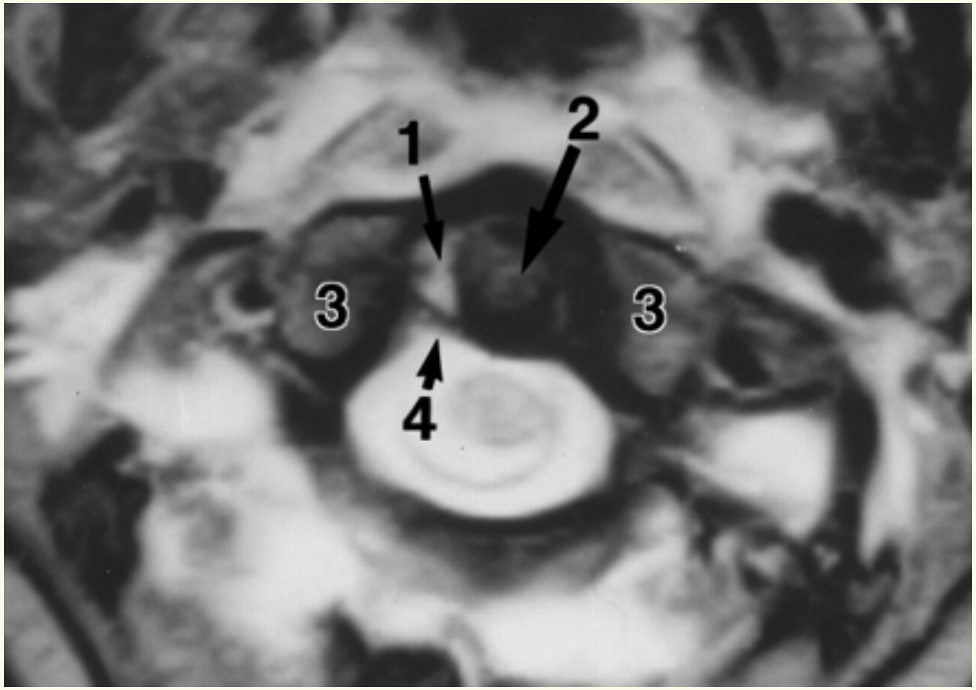
1. Normal apical ligament
2. Anterior atlanto-occipital membrane
3. Anterior atlantoaxial membrane
4. Anterior longitudinal ligament
5. Tectorial membrane
6. Dural reflection (posterior)
7. Posterior atlanto-occipital membrane
8. Posterior atlanto-axial membrane
9. Nuchal ligament
10. Flaval ligaments
11. Area of interspinous ligaments
12. Supraspinous ligament

Sagittal MRI of a clinically unstable cervical spine



1. Intact portions of anterior atlanto-occipital membrane
2. Torn portions of anterior atlanto-occipital membrane
3. Anterior arch of C1
4. Intact anterior atlantoaxial membrane
5. Prevertebral edema or hemorrhage
6. Torn tectorial membrane
7. Torn posterior atlanto-occipital membrane
8. Torn posterior atlantoaxial membrane
9. Intact dural reflection
10. Intact nuchal ligament

Atlantal-occipital dislocation in 11-year-old boy who was neurologically intact after MVC.

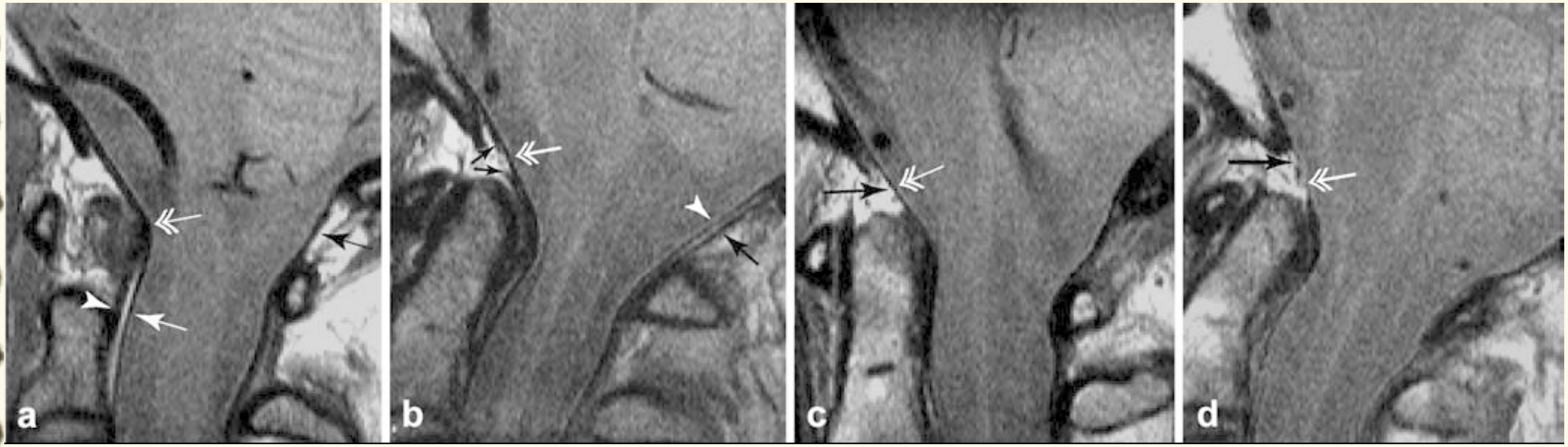


1. Torn right alar ligament
2. Displacement of dens to left with respect to lateral masses of C1(3)
4. Intact transverse ligament.

Abnormal tectorial (anterior atlanto-occipital) membranes

a. Normal. Arrow = Dura mater. Arrowhead = Tectorial Membrane. Double arrow = where the two merge at the tip of the dens.

b. Discontinuity of tectorial membranes. Double arrow = only the dura mater is present. Above the black arrows is a normal membrane. The black arrows indicate a rupture



c. The black arrow indicates absence of the entire membrane. Only the dura mater is present at the double arrow.

d. Absence of the membrane at the black arrow. The double arrow is showing focal thinning of the dura mater indicating a severe injury

Tectorial and the posterior atlanto-occipital membranes.

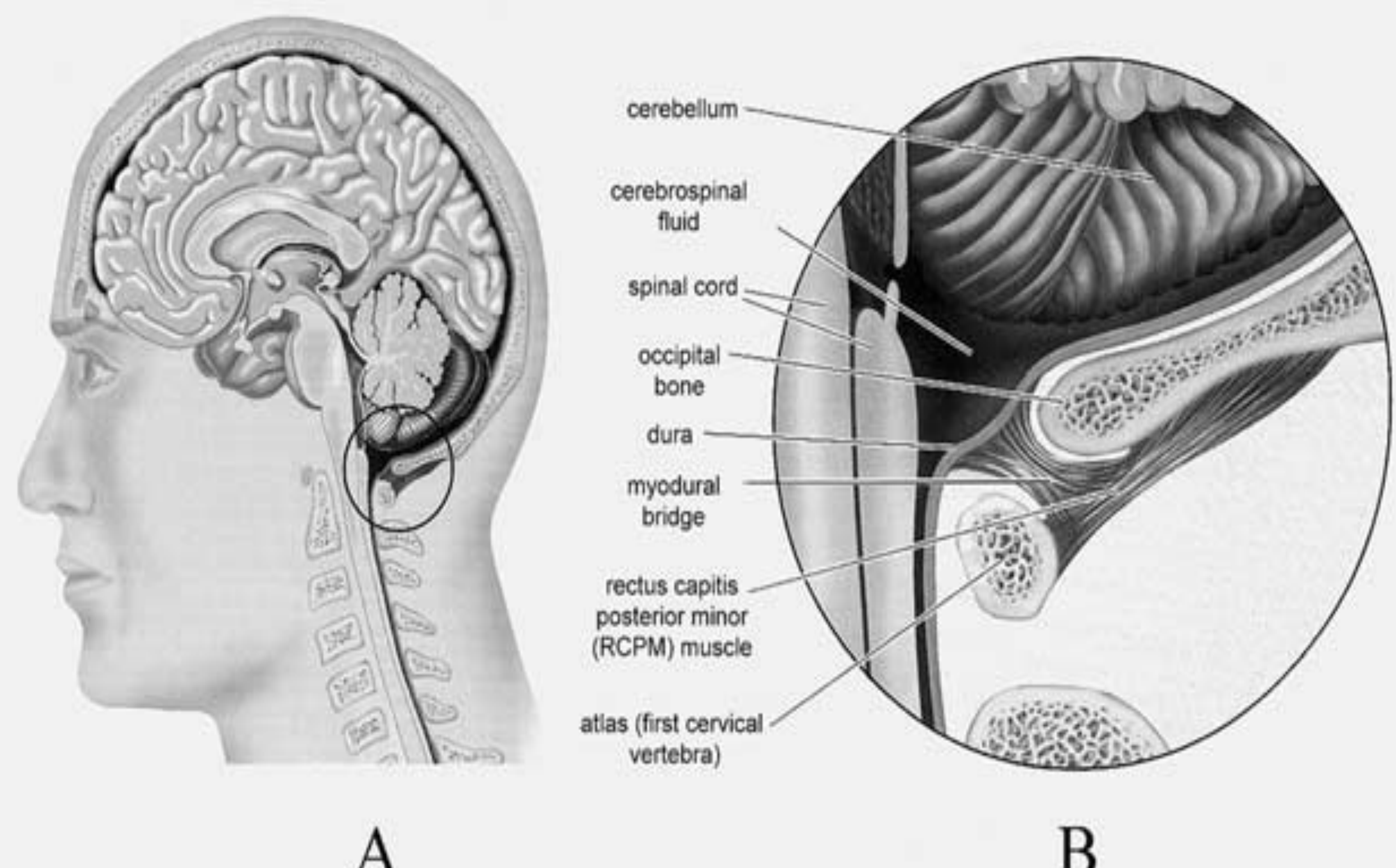
(**A**) Thinning of the tectorial membrane from the dens level upward (white arrow), classified as a grade 3 lesion. Only the dura mater is remaining. The posterior atlanto-occipital membrane (black arrow) and the dura mater (double arrow), which is separated from the membrane in this particular case, is normal.

(**B**) Normal tectorial membrane (white arrow). The posterior atlanto-occipital membrane is gray and ill-defined (black arrow). The dura mater shows an anterior flap (infolding indicated by double arrow) indicating a transverse rupture, classified as grade 3.

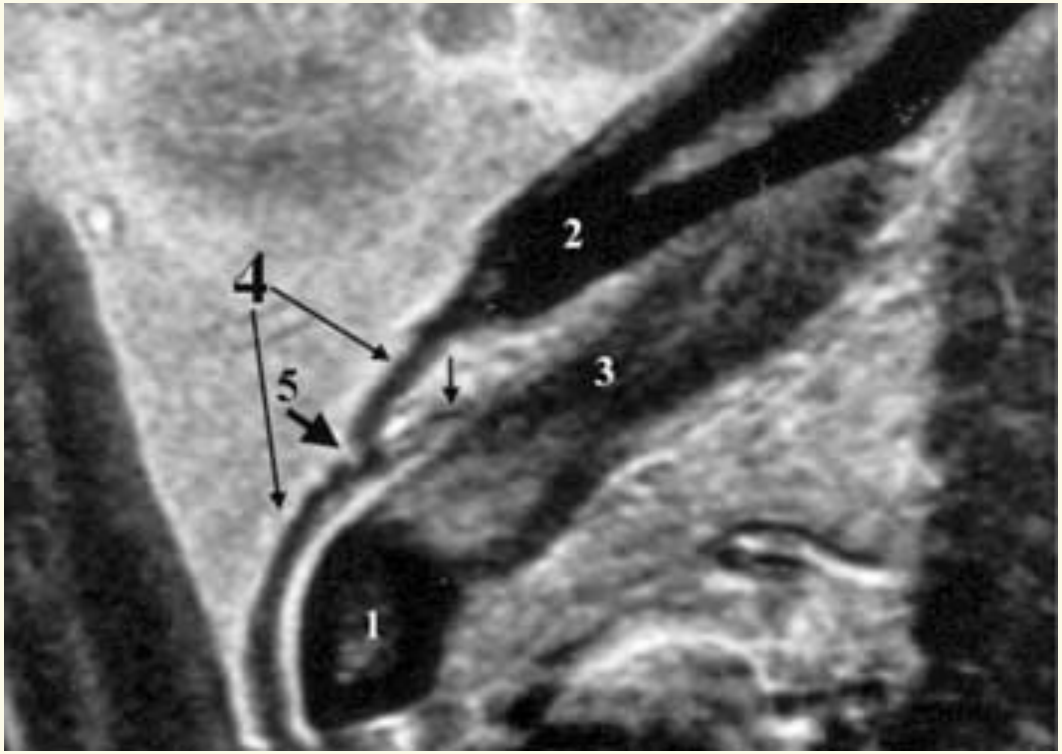
Cervical Myodural Bridge

- ✓ Nowhere in early editions of Gray's Anatomy is a functional relationship described between the Rectus capitis posterior minor muscle and the dura mater.
- ✓ The naturally occurring physical connection between suboccipital muscles and the dura mater at the atlanto-occipital junction has been described in recent studies.
- ✓ The 38th edition of *Gray's Anatomy* now notes the presence of a myodural bridge connecting the rectus capitis posterior minor muscles to the dura mater.

Cervical Myodural Bridge



Magnetic Resonance Imaging of the atlanto-occipital junction..



1. First cervical vertebra.

2. Occiput

3. Suboccipital musculature

4. Dura mater

5. Dural fold

Fresh cadaveric specimen showing relations of anatomic myodural bridge.

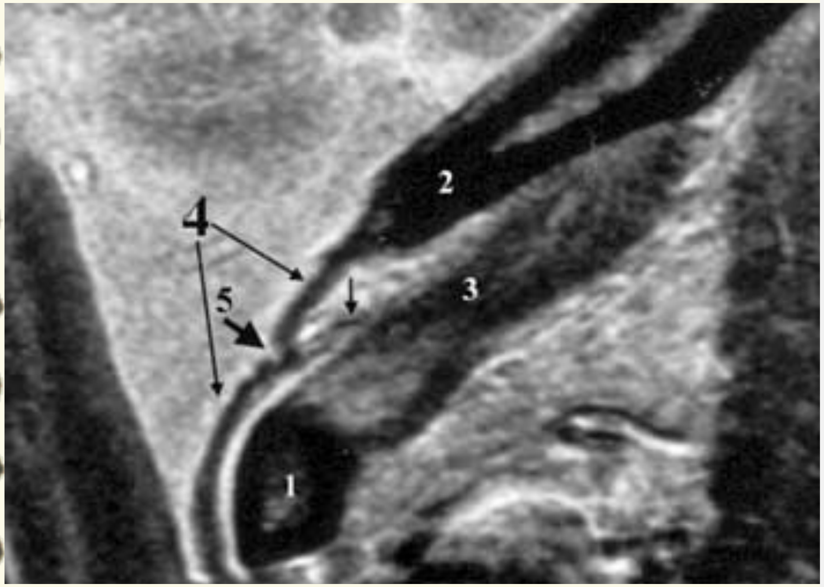
1. First cervical vertebra

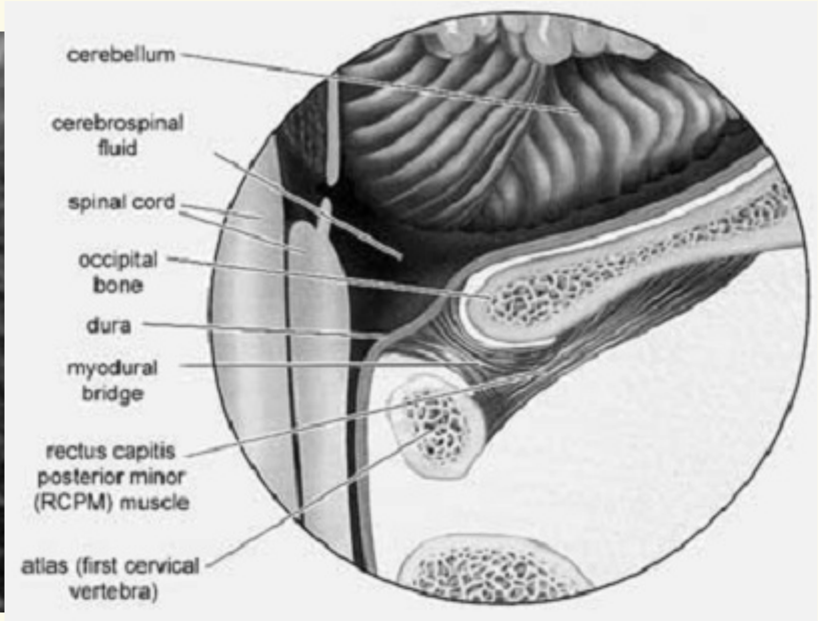
2. Occiput
(Arrows) indicate the anatomic myodural bridge.

3. Suboccipital musculature .

4. Dura Mater.

Cervical Myodural Bridge





medserena

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