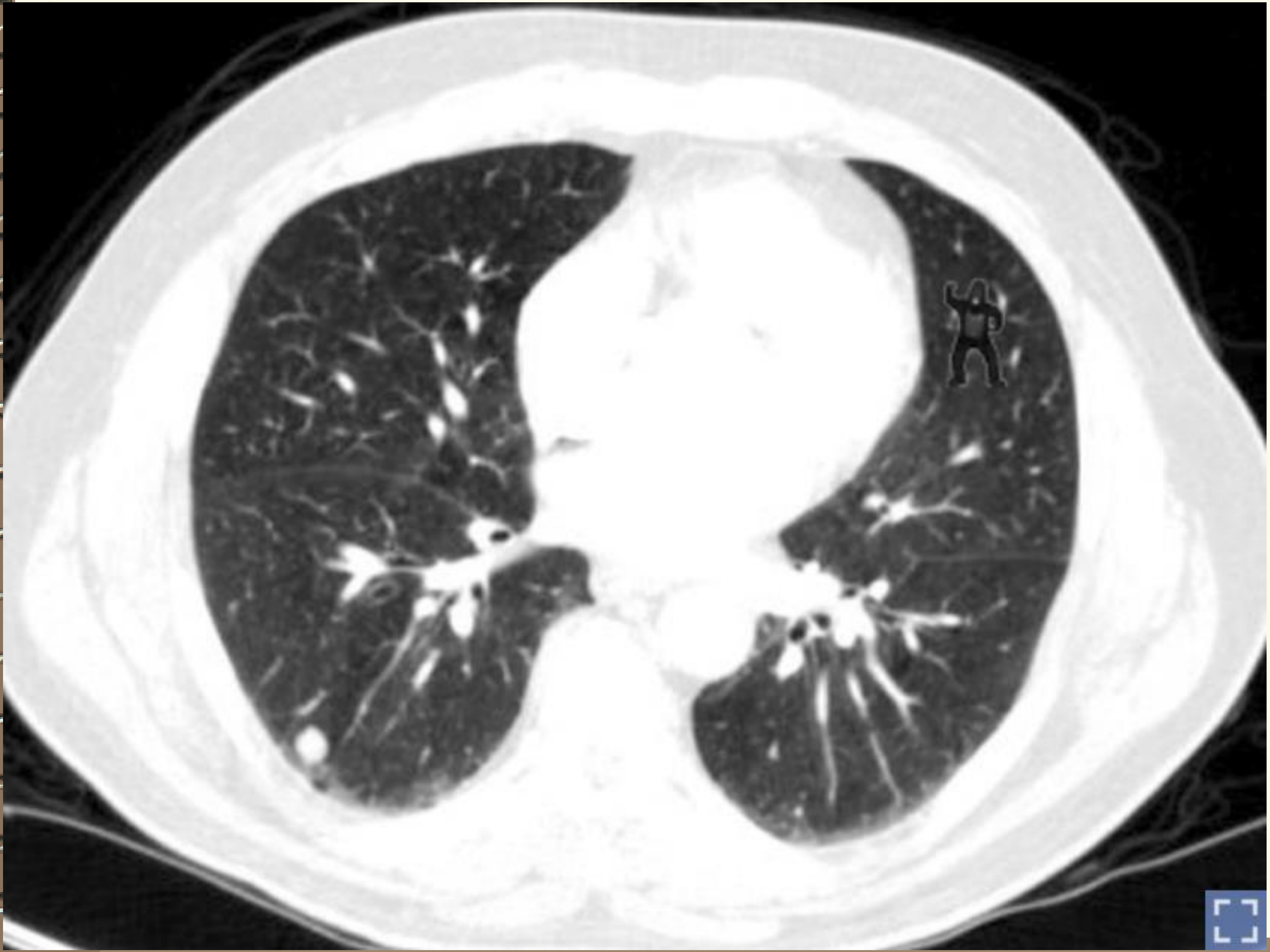
Upright M.R.I. in the study of the Cranio-cervical junction.

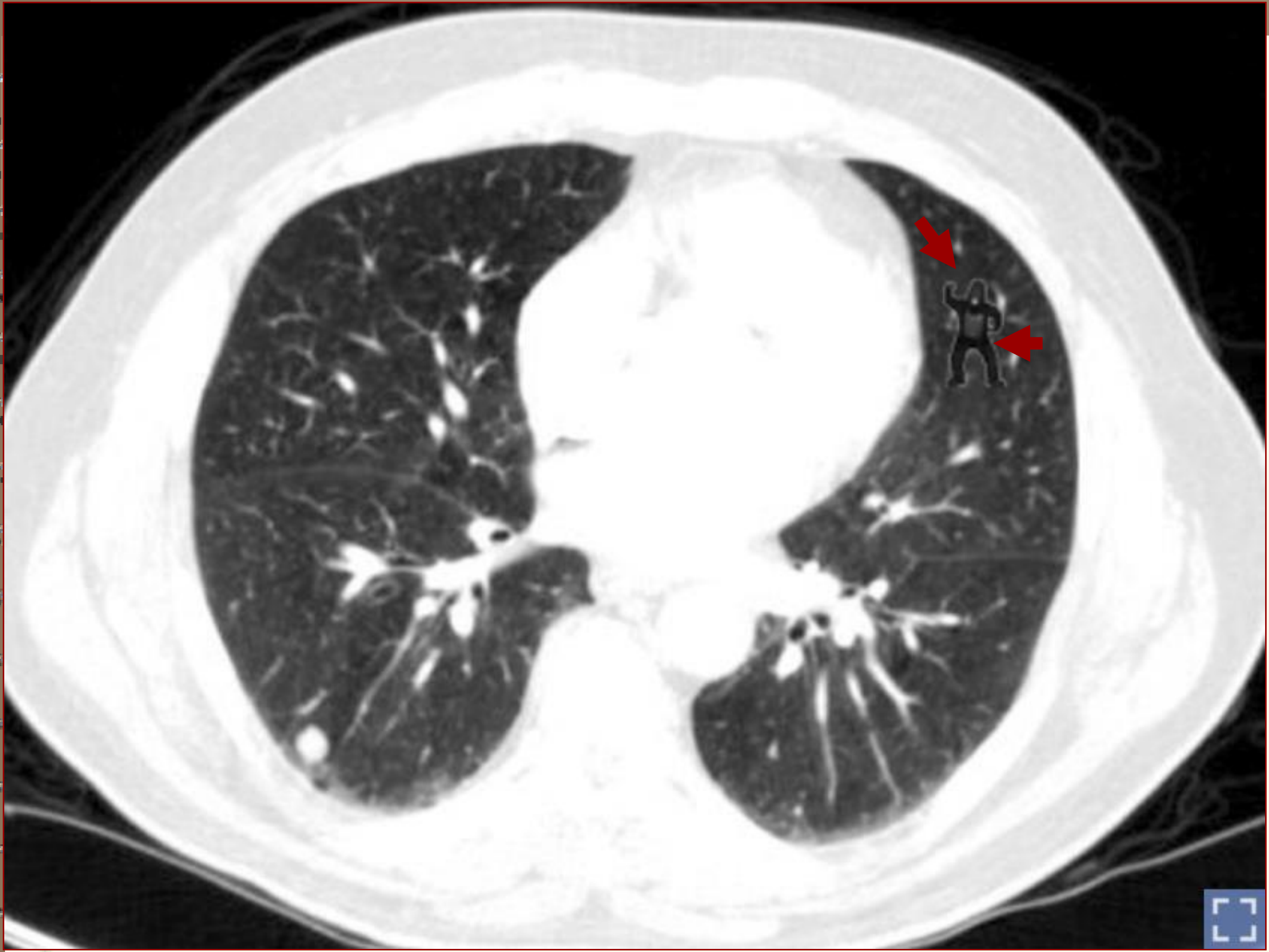
Francis W. Smith MD, FRCR, FRCS, FFSEM.

University of Aberdeen

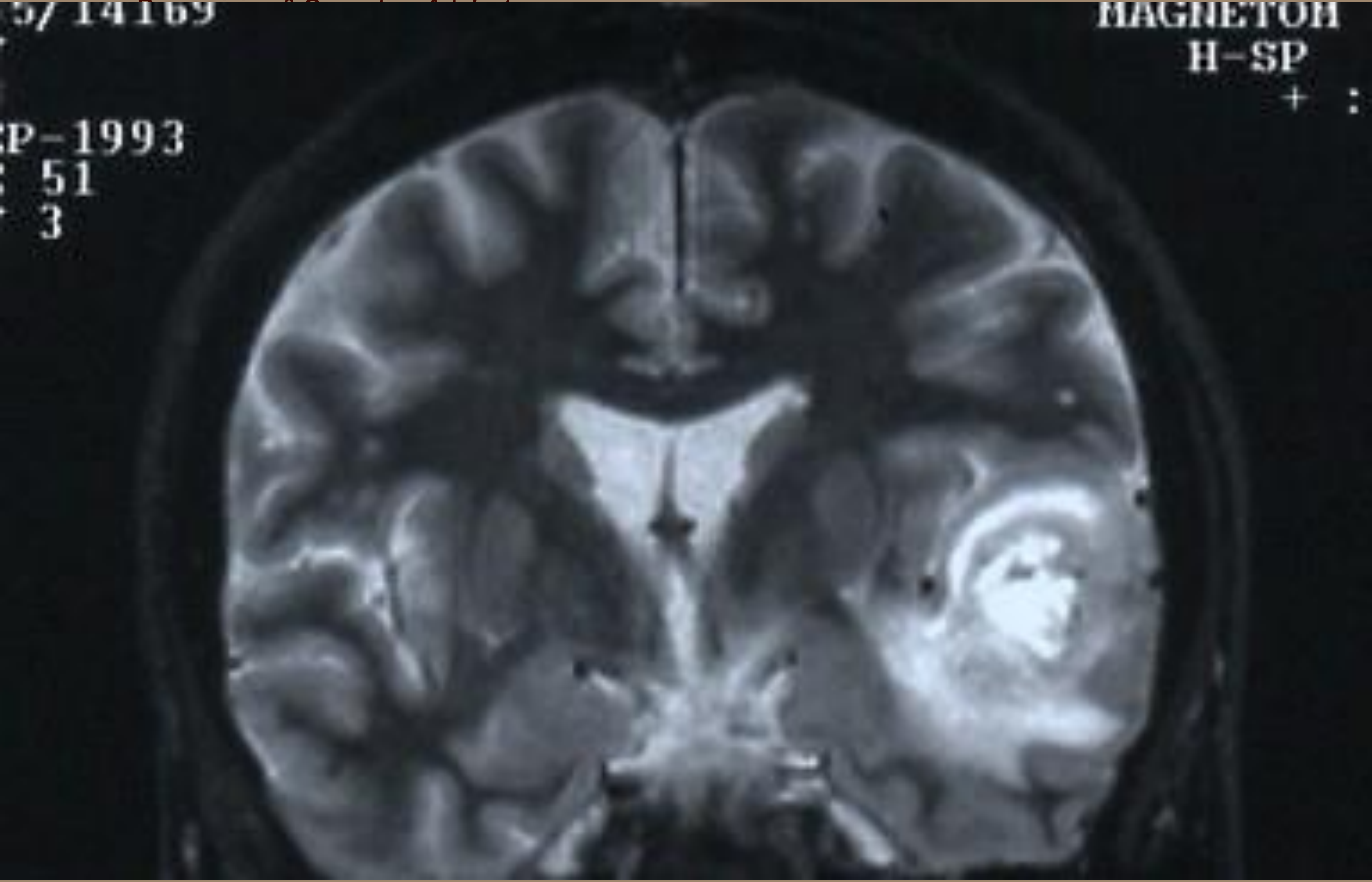
Scotland

Notice anything unusual about this CT lung scan? ?





Harvard researchers found that **83 percent of radiologists** didn't notice the gorilla in the top right portion of this image.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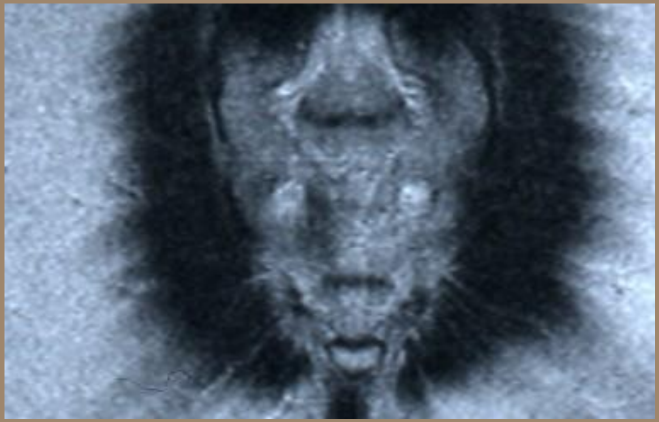
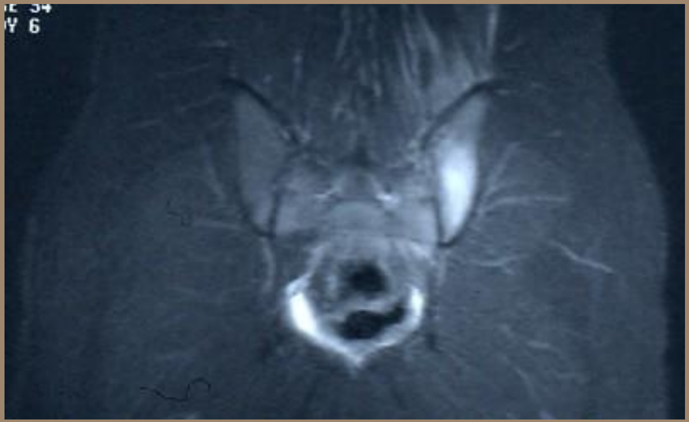
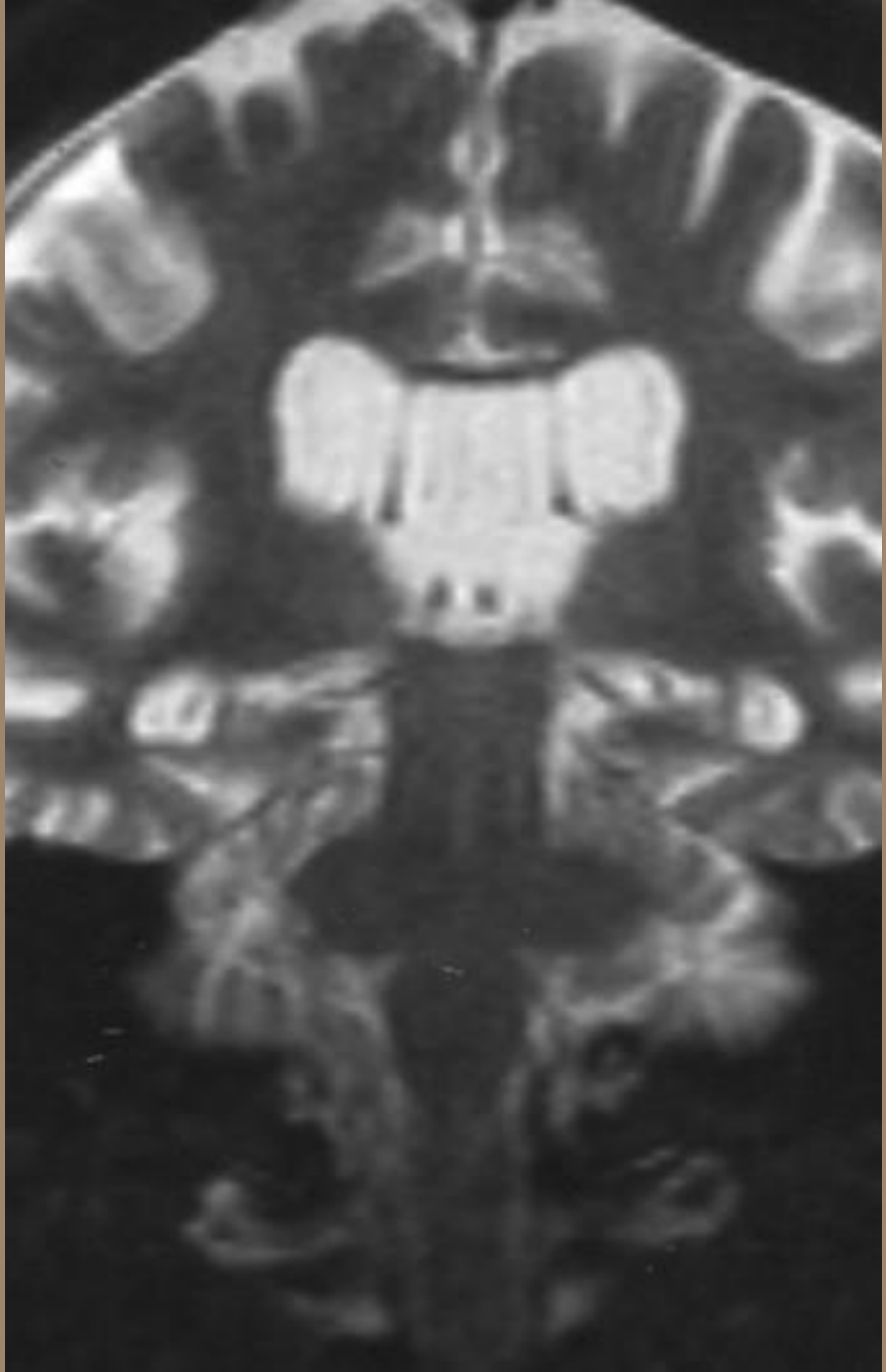
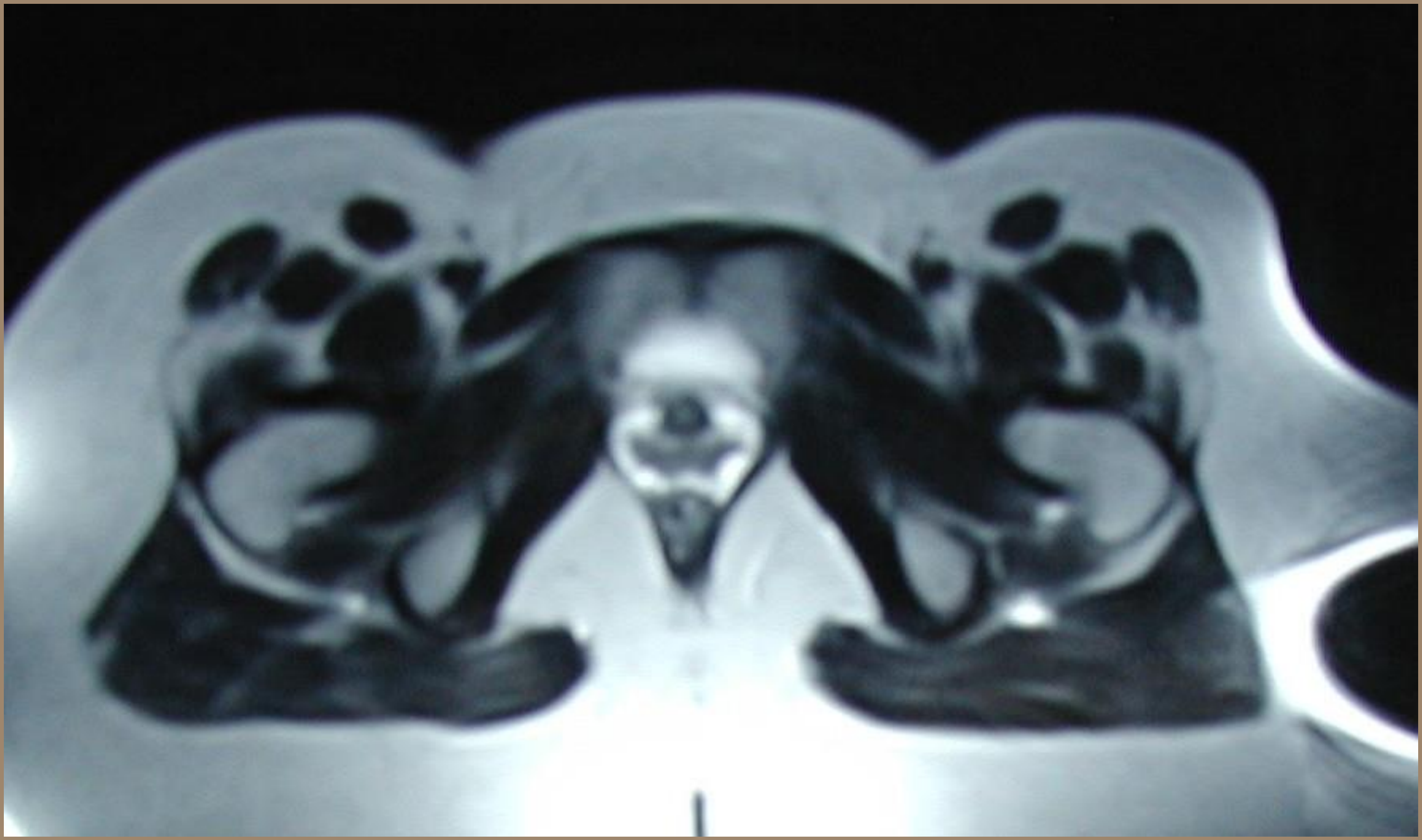
Recognising & Correcting Artefacts



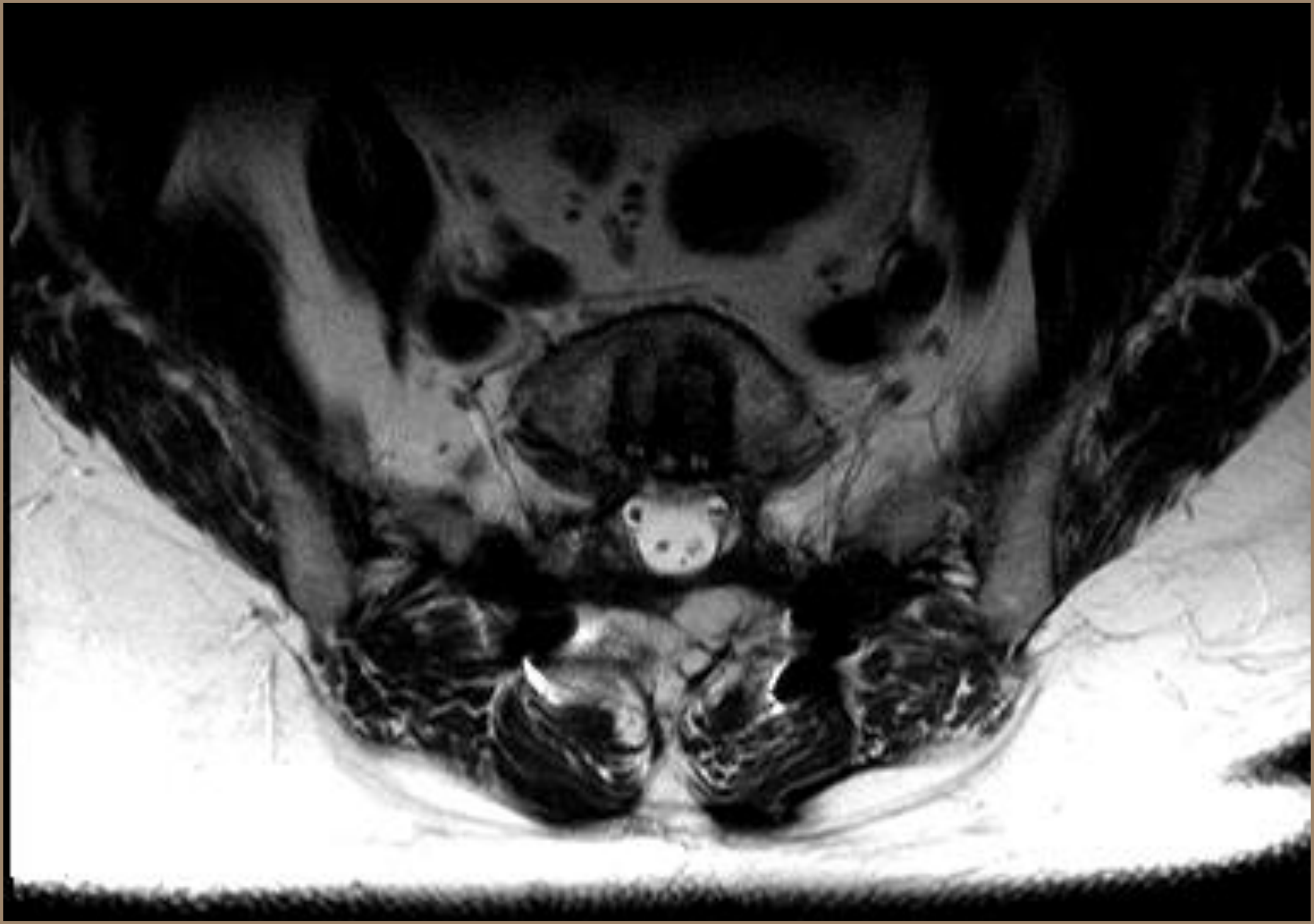




Recognising & Correcting Artefacts



Recognising & Correcting Artefacts



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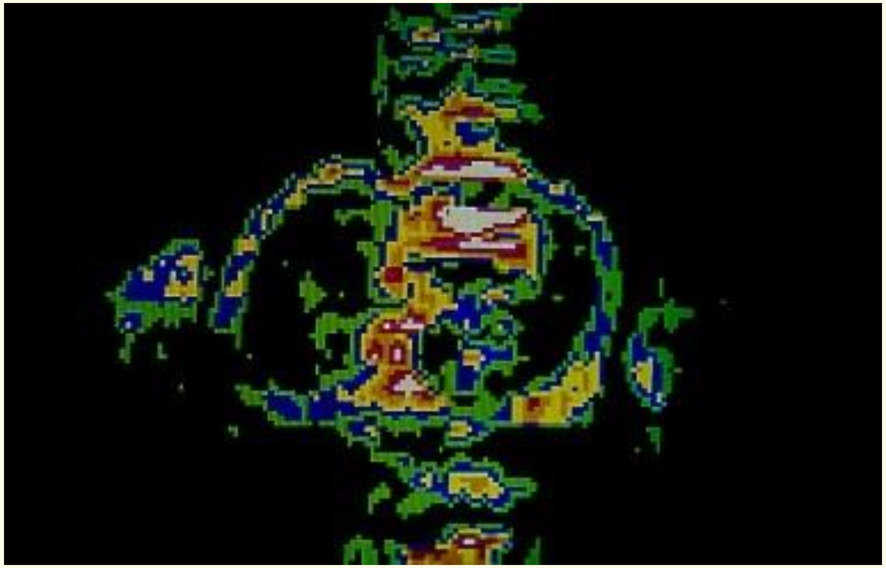
N.M.R. - M.R.I.

1980 - 2005

UNIVERSITY OF ABERDEEN

1979

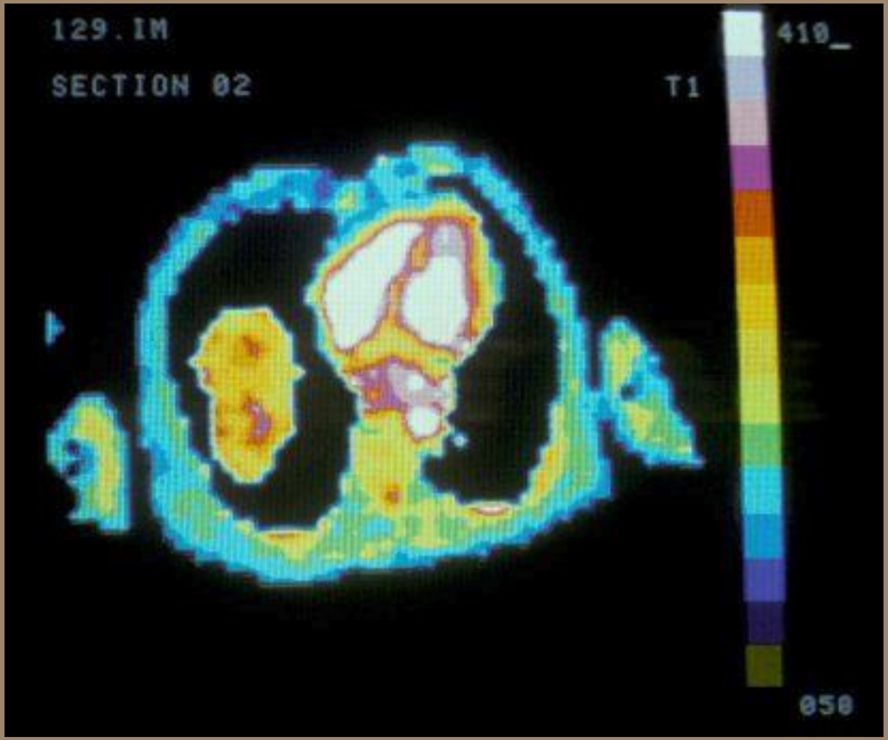
Bill Edelstein & Jim Hutchison

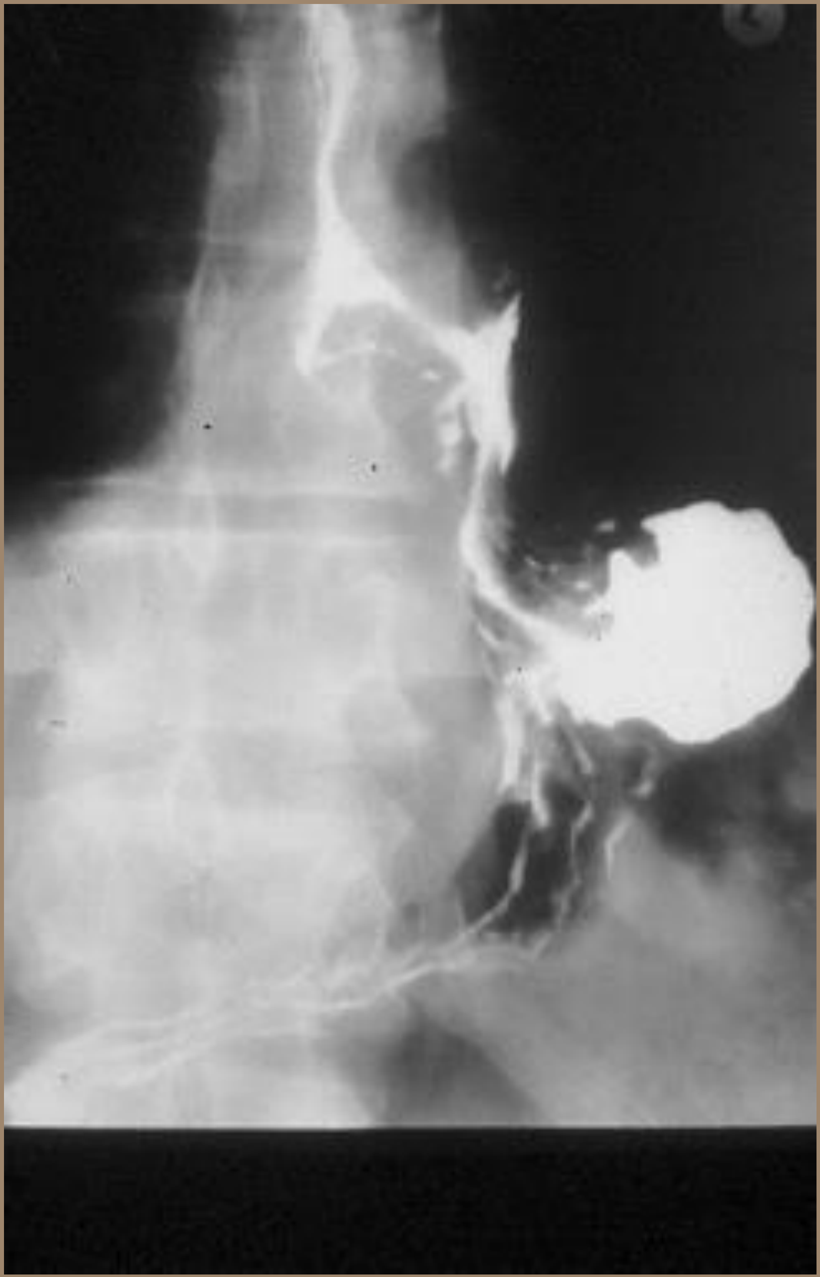


First Patient scanned on

28th August 1980

Aberdeen Royal Infirmary





First Patient scanned on 28th August 1980
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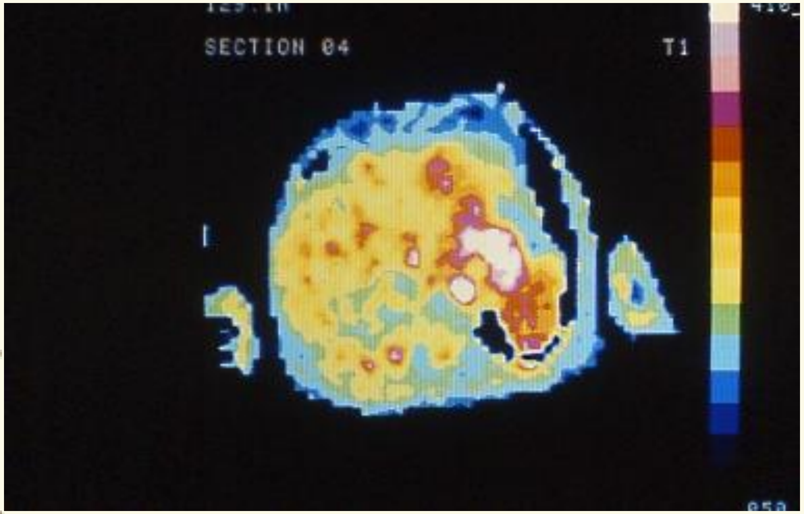
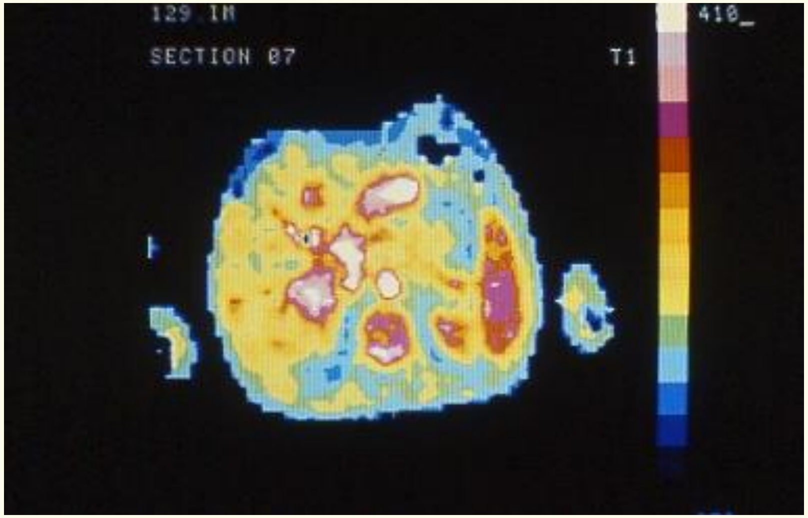
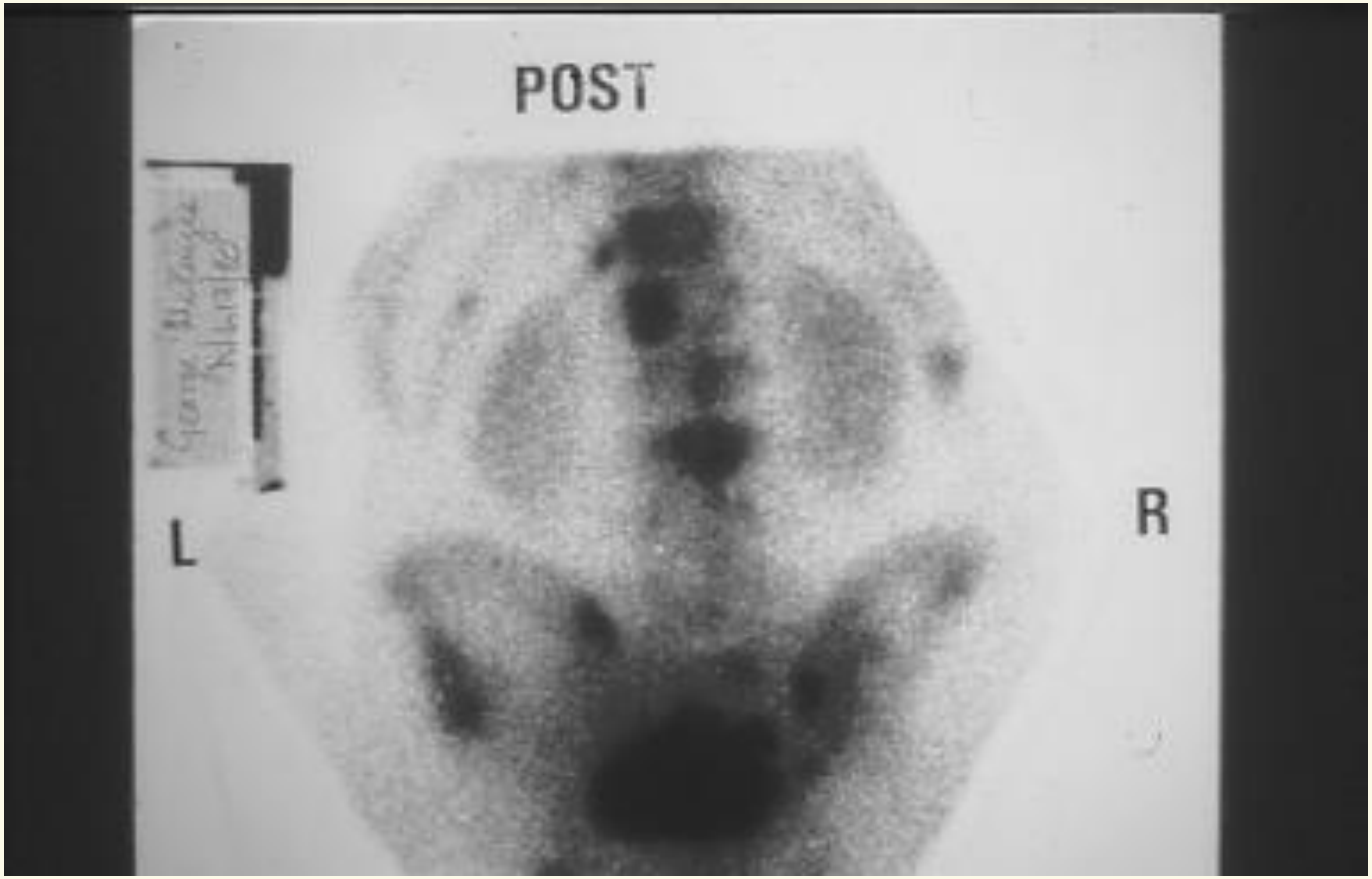




Liver metastases confirmed. Bone metastases discovered and proven next day by radionuclide bone scan.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6 Modlin IM, Bloom SR, Mitchell SJ. The role of VIP in diarrhoea. *Gut* 1977;**18**:A418.

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(*Accepted 21 November 1980*)

Oesophageal carcinoma demonstrated by whole-body nuclear magnetic resonance imaging

F W SMITH, J M S HUTCHISON, J R MALLARD, G JOHNSON, T W REDPATH, R D SELBIE, ANNE REID, C C SMITH

Abstract

The quality of the images produced by nuclear magnetic resonance (NMR) imaging has steadily improved over the past five years. Images of the head, thorax, and abdomen have clearly shown the normal anatomy. A clinical trial of NMR imaging has therefore been started in Aberdeen to assess its diagnostic accuracy and compare it with conventional radiography and other imaging techniques. The first patient examined by whole-body NMR imaging had carcinoma of the oesophagus diagnosed on barium meal examination. A technetium-99m-sulphur colloid liver scan also showed hepatic metastases. NMR imaging showed a large tumour in the lower third of the oesophagus, and areas of increased proton spin-lattice relaxation time (T_1) on a section through the liver corresponded with the metastases shown on the radionuclide scan. Increased areas of T_1 were present in some vertebrae, and a technetium-99m bone scan confirmed the presence of bone metastases.

The NMR images in this patient compared well with the images from other techniques. The continuing clinical trial may show that NMR is an accurate diagnostic aid which will complement existing techniques for diagnosing intrathoracic and intra-abdominal conditions.

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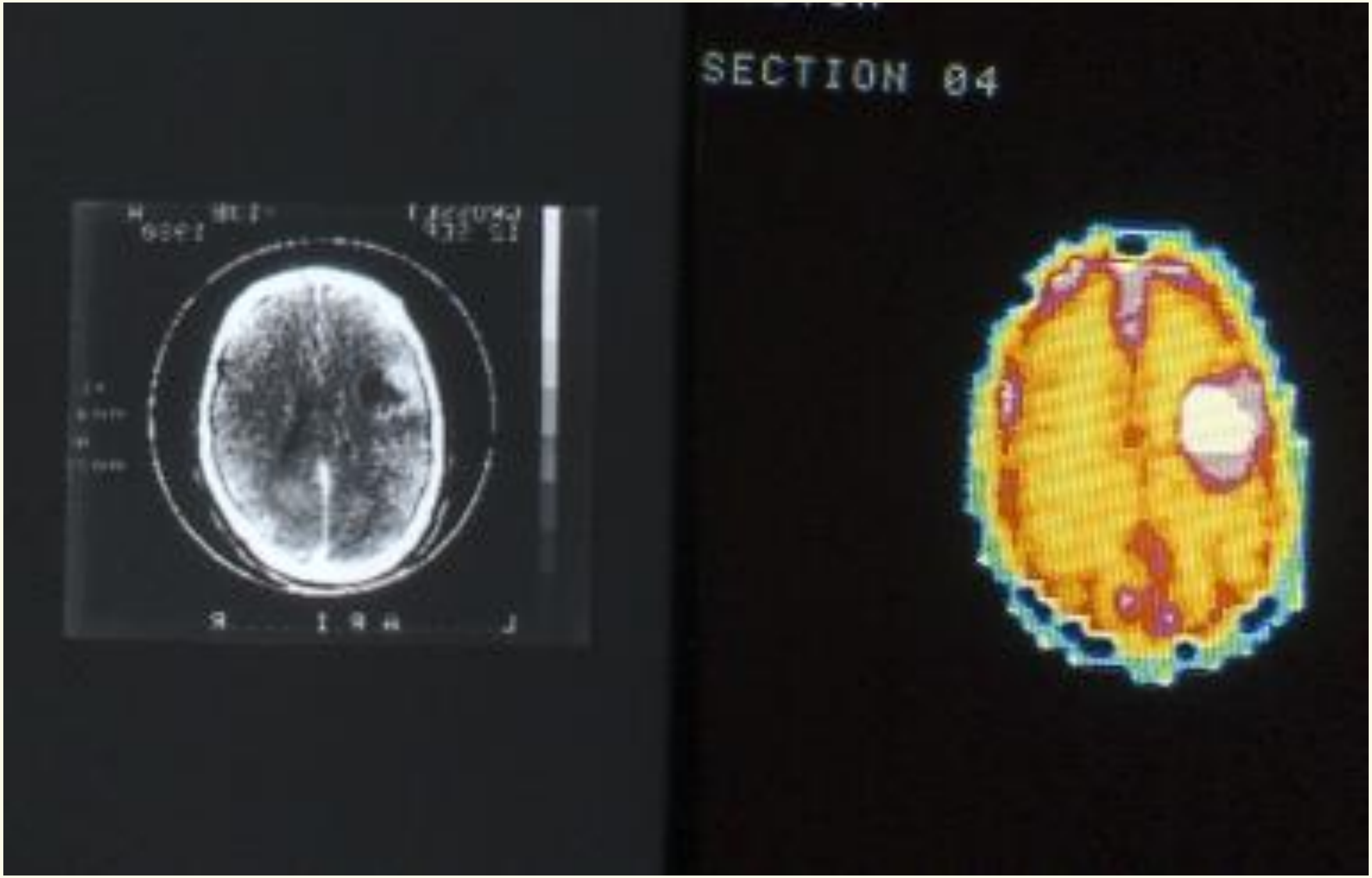
C C SMITH, MB, FRCP, consultant physician

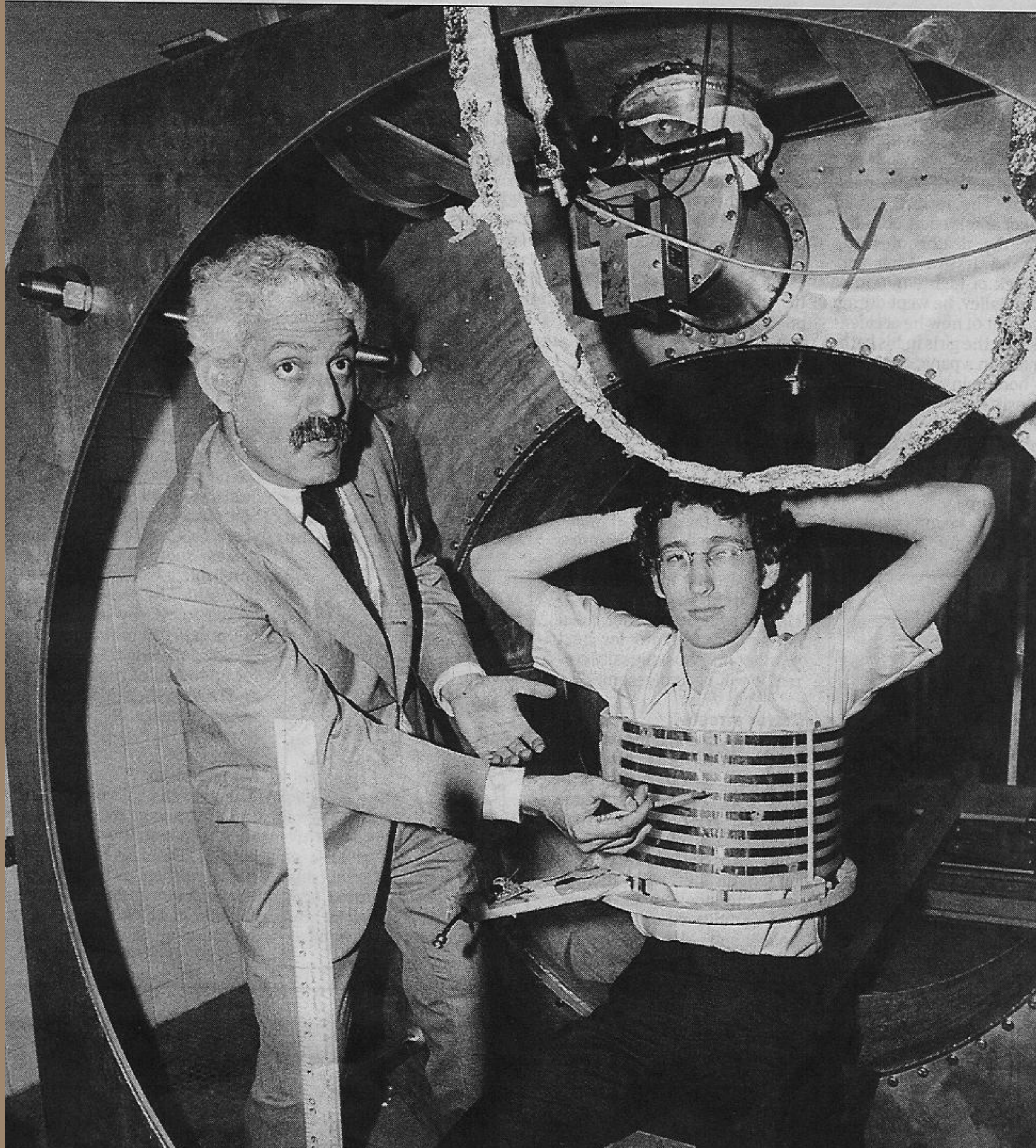
FIG 1—Anteroposterior view of lower oesophagus outlined with barium showing oesophageal carcinoma.

Introduction

During the past five years there has been a steady improvement in the image quality produced by nuclear magnetic resonance (NMR) imaging of the human body. Early NMR images were reported which showed the normal cross-sectional anatomy of a finger[1] and of the wrist.[2] Transverse tomographic sections of the skull, demonstrating the normal anatomy, have shown a steady improvement in image quality.[3 4] Imaging of the thorax and abdomen has proved more difficult, and early images of the abdomen were disappointing,[5 6] but recent images of the thorax and abdomen produced by our group in Aberdeen have given a clear demonstration of the normal anatomy.[7 8] Transverse

CYSTIC GLIOMA

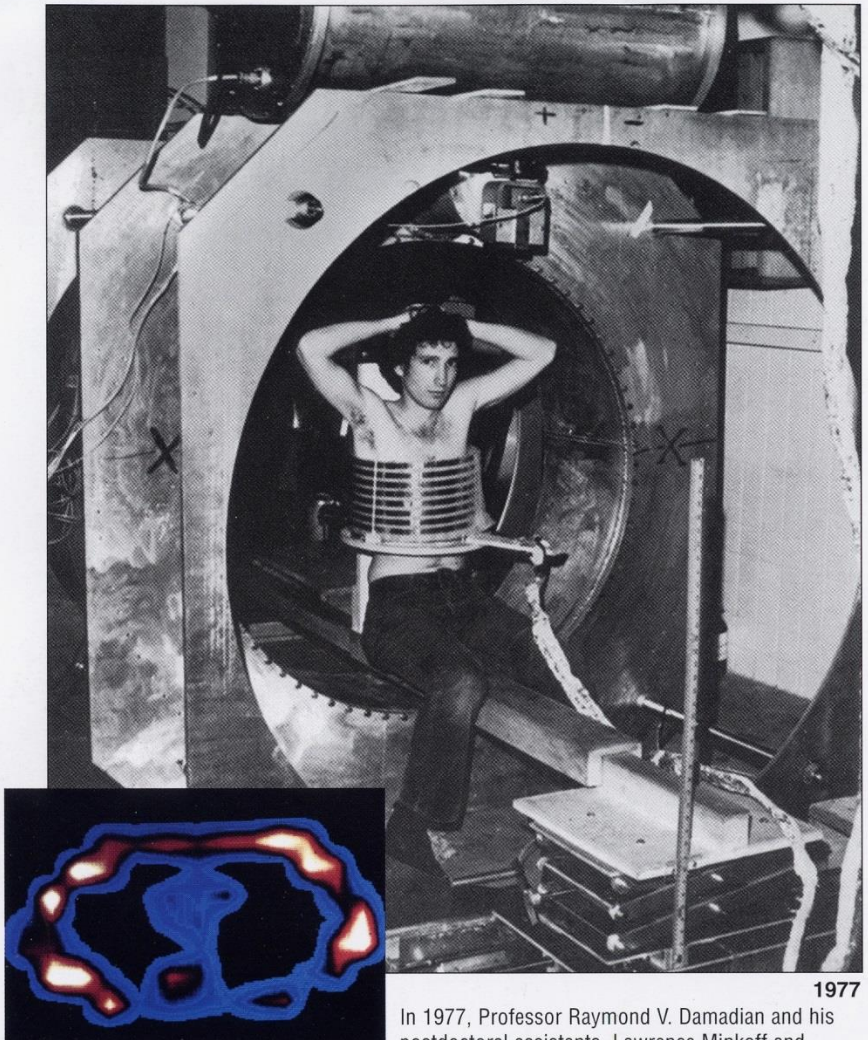




aking waves: Dr Raymond Damadian, left, demonstrates a "super magnet", an early MRI machine, to the press in 1977

30 YEARS OF PROGRESS

FONAR



1977

In 1977, Professor Raymond V. Damadian and his postdoctoral assistants, Lawrence Minkoff and Michael Goldsmith, completed the construction of the first whole-body Magnetic Resonance scanner, called *Indomitable*, at Downstate Medical Center in Brooklyn, New York. The world's first whole-body MR scan was performed in the early morning hours of July 3, 1977. Larry, wearing a transceiver coil wrapped around a cardboard vest, sat with his arms suspended over his head for 4 hours and 45 minutes while the 500-Gauss *Indomitable* performed a single-slice cross-sectional scan of his chest. The 106-pixel image shown above is a product of that historic scan.

2007

30 years later, Dr. Minkoff strikes his now-famous 1977 pose in the FONAR Upright™ Multi-Position™ MRI. While most patients are scanned seated and watching a 42" flat-screen TV, patients can also be scanned standing, reclining, or lying down – whichever position is needed to provide the most diagnostic information. For the purpose of comparison, today's 6000-Gauss FONAR Upright™ Multi-Position™ MRI scanner can acquire a 65,536 pixel, single-slice image of Minkoff's chest in just seconds.

It is interesting to note that the first MR image was made with the patient in an upright, weight-bearing position. Today, with the exception of the FONAR Upright™ Multi-Position™ MRI, every other FDA-approved MRI remains a single-position, recumbent-only scanner.

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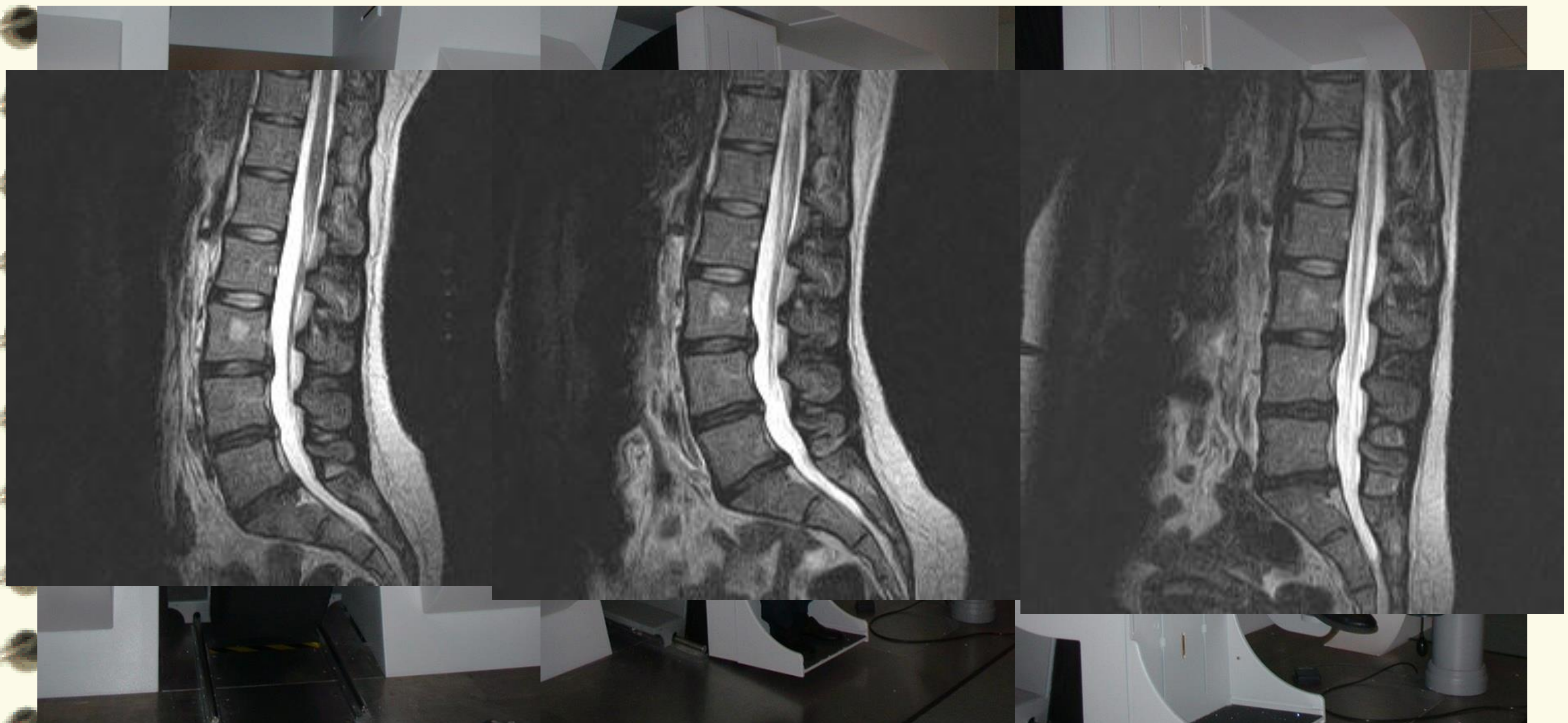
UPRIGHT M.R.I.

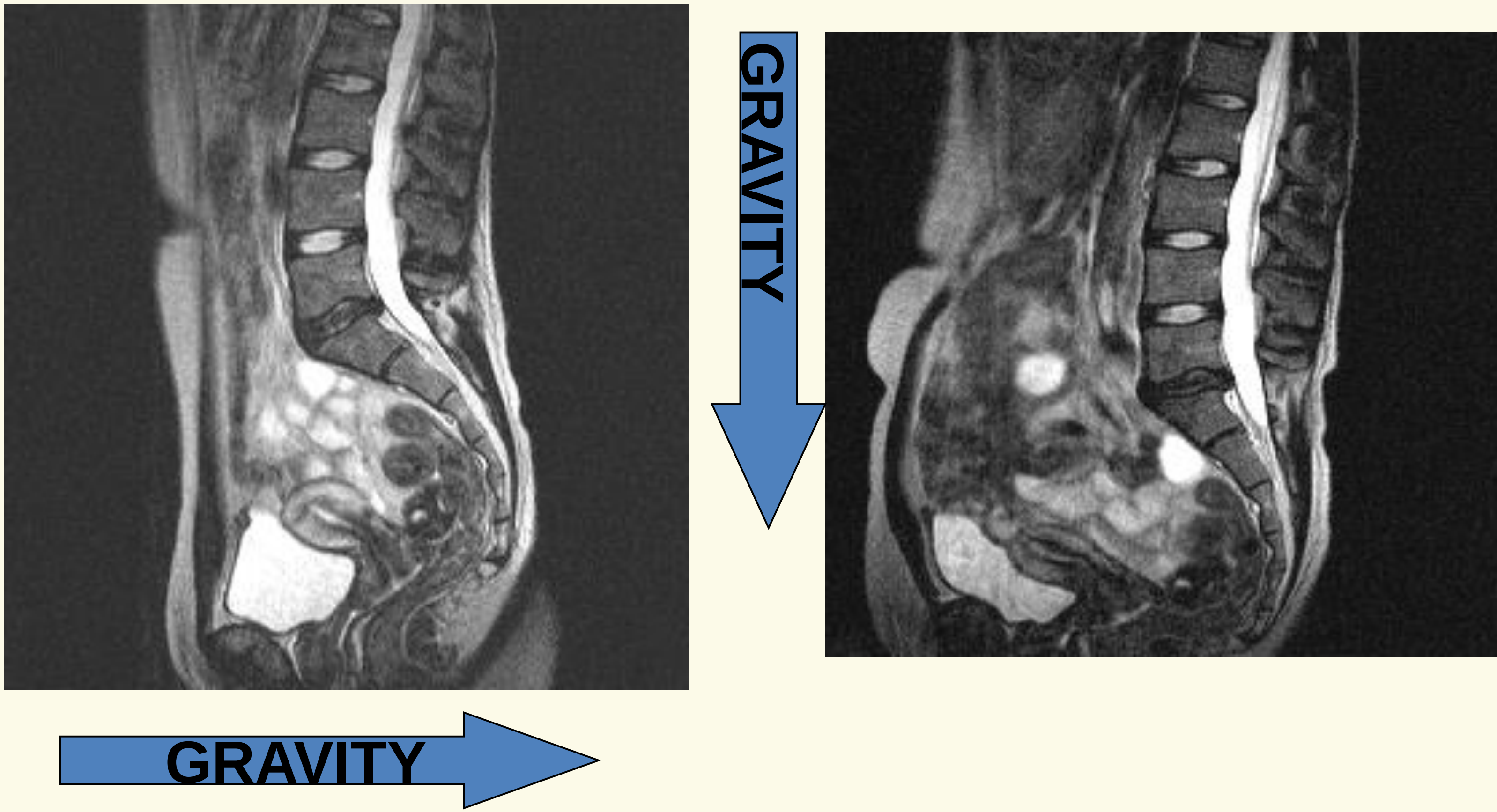
Why do we persist in scanning the spine lying down?

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.



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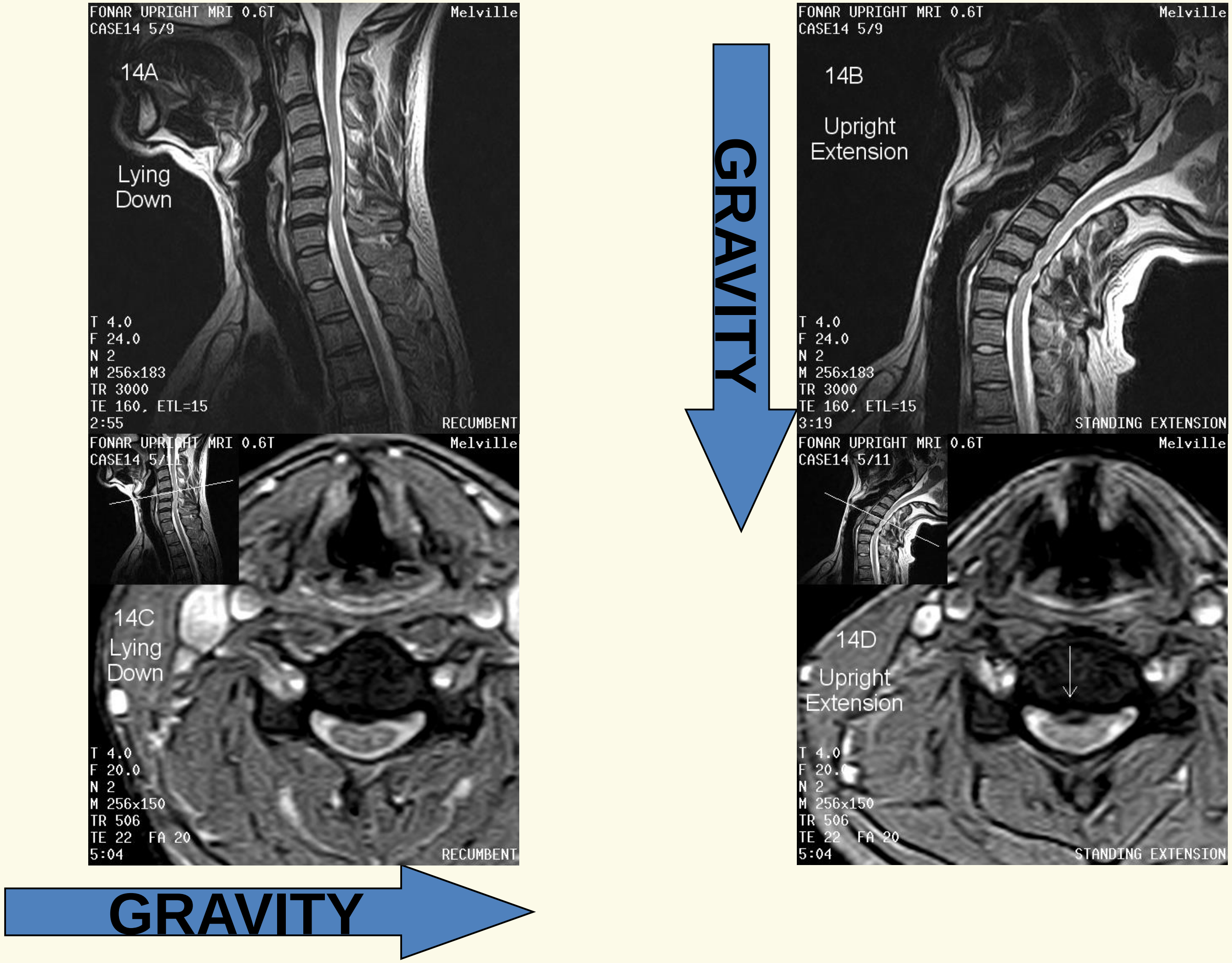
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Melville
CASE14 5/9
14A
Lying Down
T 4.0
F 24.0
N 2
M 256x183
TR 3000
TE 160, ETL=15
2:55
RECUMBENT
GRAVITY
FONAR UPRIGHT MRI 0.6T
Melville
CASE14 5/9
14B
Upright Extension
T 4.0
F 24.0
N 2
M 256x183
TR 3000
TE 160, ETL=15
3:19
STANDING EXTENSION
FONAR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

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.

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.

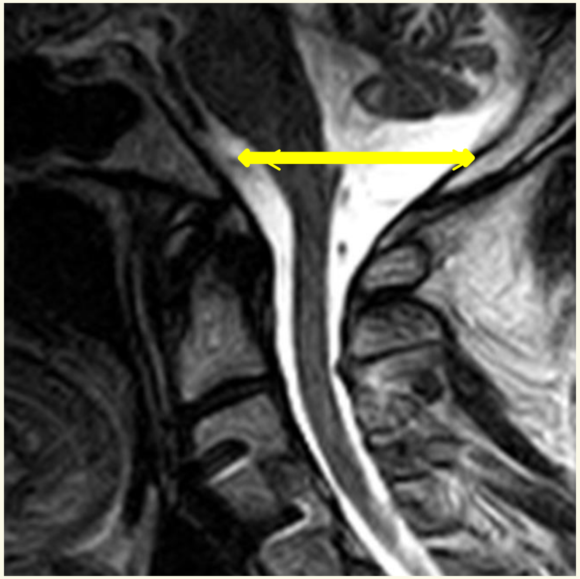
Half were from patients with no recent history of trauma.

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 – Opsthion Line

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

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).

Both injury status and scan type (recumbent vs. upright) were associated with significant differences in the average tonsil station ($p = <0.0001$).

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 %

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

	Recumbent	Upright
Non-trauma	5.7%	5.3 %
Trauma	9.5%	23.7%

(X^2 = 0.0001)

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 tonsillar 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 tonsillar 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

Conclusions

In this study of 1200 patients, tonsillar ectopia was identified in :

1 in 4 trauma patients

but only

1 in 18 non-trauma patients.

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

OVERALL CONCLUSION

When cost implications of under diagnosis of mechanical damage at the cranio-cervical junction is very large, the current practice of limiting imaging to below C2 is inadequate and under-estimates the incidence of post traumatic ligamentous damage.

For thorough MRI examination, imaging of the cranio-cervical junction is important, to find or exclude ligamentous damage.

We believe it is of paramount importance :

1. To show any dislocation and ligamentous damage when present
2. Also to exclude such damage when it is not present

(Unless it is specifically looked for, any damage at the cranio-cervical junction cannot be excluded from a limited cervical spine MRI examination.)

CLINICAL RELEVANCE/APPLICATION

The cost implications of under diagnosis of mechanical damage at the cranio-cervical junction, both in terms of patient suffering and cost in insurance claims, is very large

We believe it is of paramount importance :

1. To show any dislocation and ligamentous damage when present
2. Also to exclude such damage when it is not present

(Unless it is specifically looked for, any damage at the cranio-cervical junction cannot be excluded from a limited cervical spine examination.)

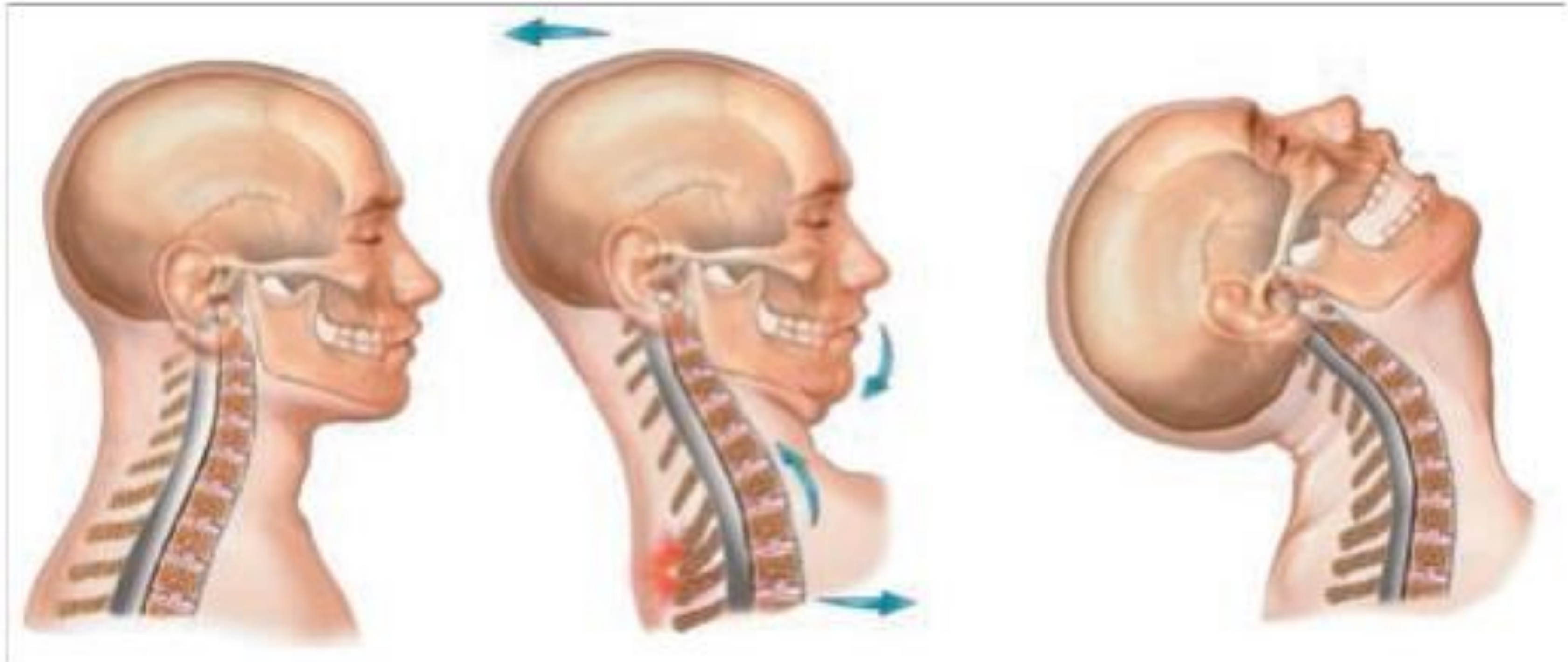
The Cranio-Cervical Syndrome

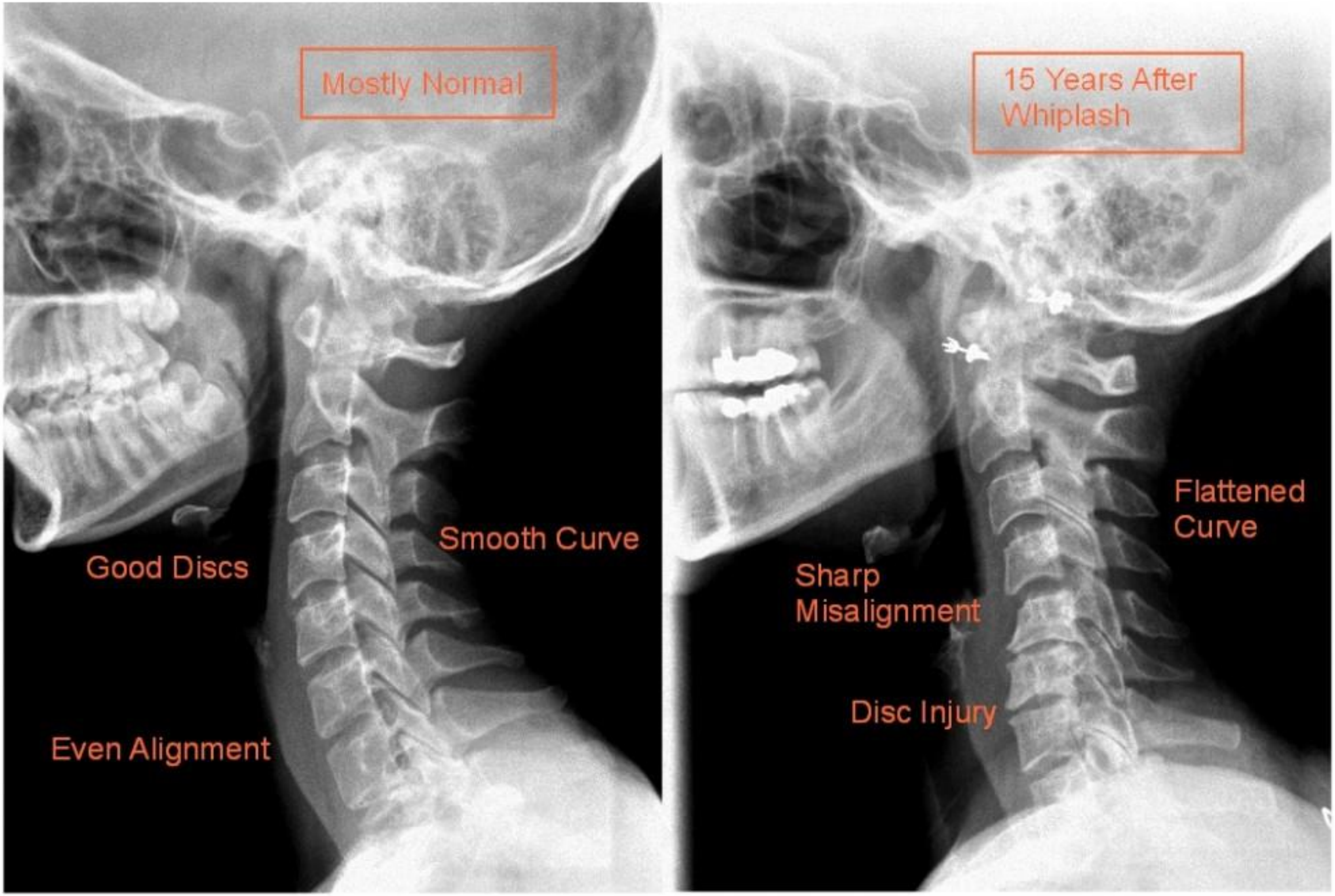
- Neck pain
- Headache
- Drop attacks
- Insomnia
- Lack of concentration
- Fatigue
- Irritability
- Nausea
- Dizziness , Vertigo & Tinnitus
- Loss of balance
- Loss of colour vision, blurred vision
- Numbness of legs
- Difficulty walking
- Sudden dropping of things from hands
- Loss of motor skills in the lower extremities and potential
- wheel chair confinement
- Numbness and tingling in the legs and feet
- Numbness and loss of motor control in the arms

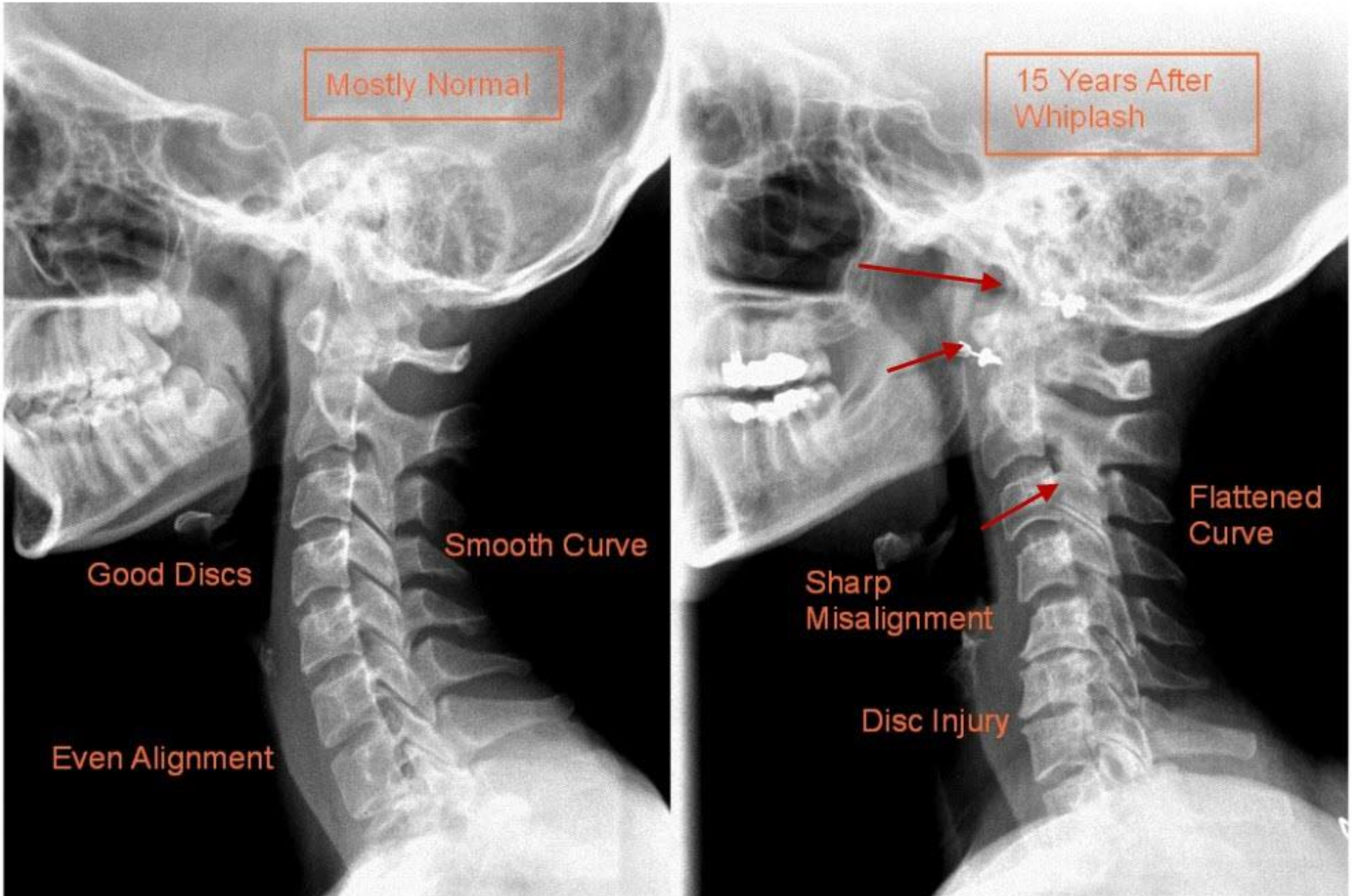
The Cranio-Cervical Syndrome

Is associated with a collection of symptoms centered around different types of headaches and different types of neck pain including:

•Pressure Headaches or migraines
•Sub-occipital neck pain (in the “back of the neck” at the base of the skull)
•Neck pain that is frequently position dependent (e.g. “skull forward”, “skull backward”, “turning of the head”, etc.)
•Neck pain” described as “knife stabbing” or “pins and needle stabbing at the base of the skull”
•Headaches occurring randomly throughout the day but frequently generated by a change of head position (e.g. moving of the head from the recumbent to the upright position)
•Headaches accompanied by tinnitus and visual disturbances such as “blurred vision”, “tunnel vision”, “double vision”, “kaleidoscopic vision”, nystagmus
•Pressure headaches accompanied by dementia and loss of cognitive skills




Mostly Normal
Smooth Curve
Good Discs
Even Alignment
15 Years After Whiplash
Flattened Curve
Sharp Misalignment
Disc Injury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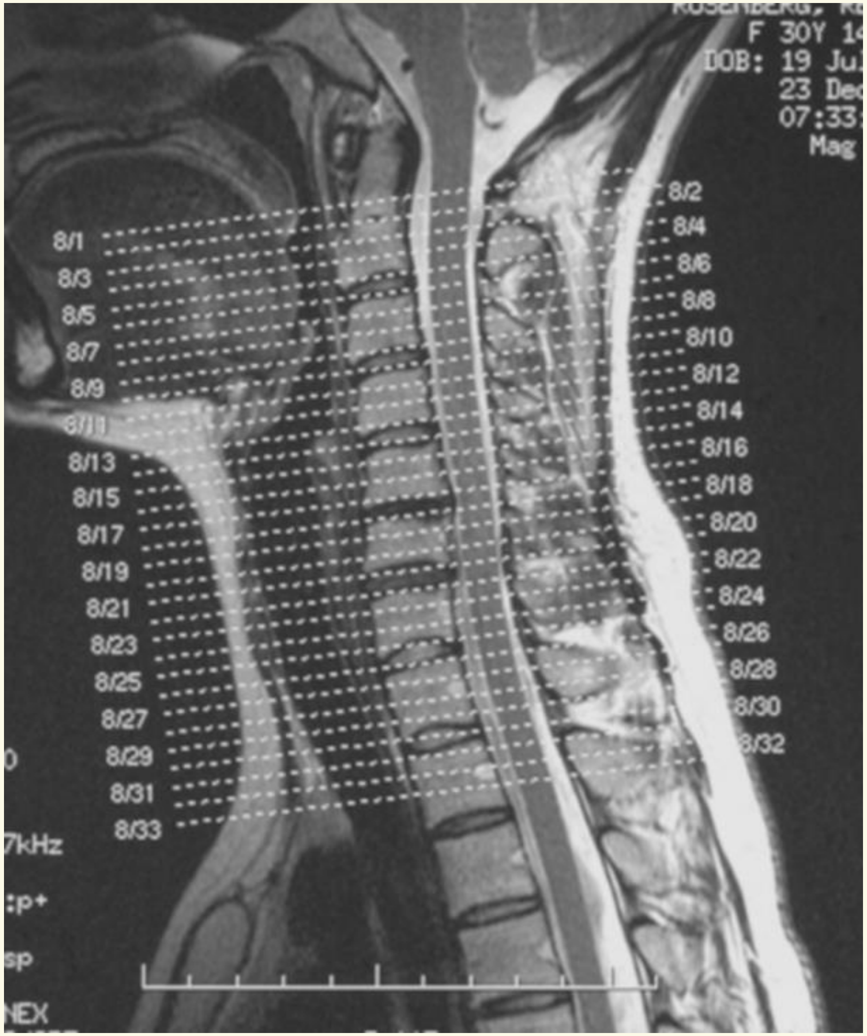
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Method and Materials :

All the patients previously investigated following hyperextension injury of the neck , who had reportedly normal MRI examination of the cervical spine were entered in to the study.

The previous MRI examinations had comprised :

Sagittal T1 & T2 weighted images

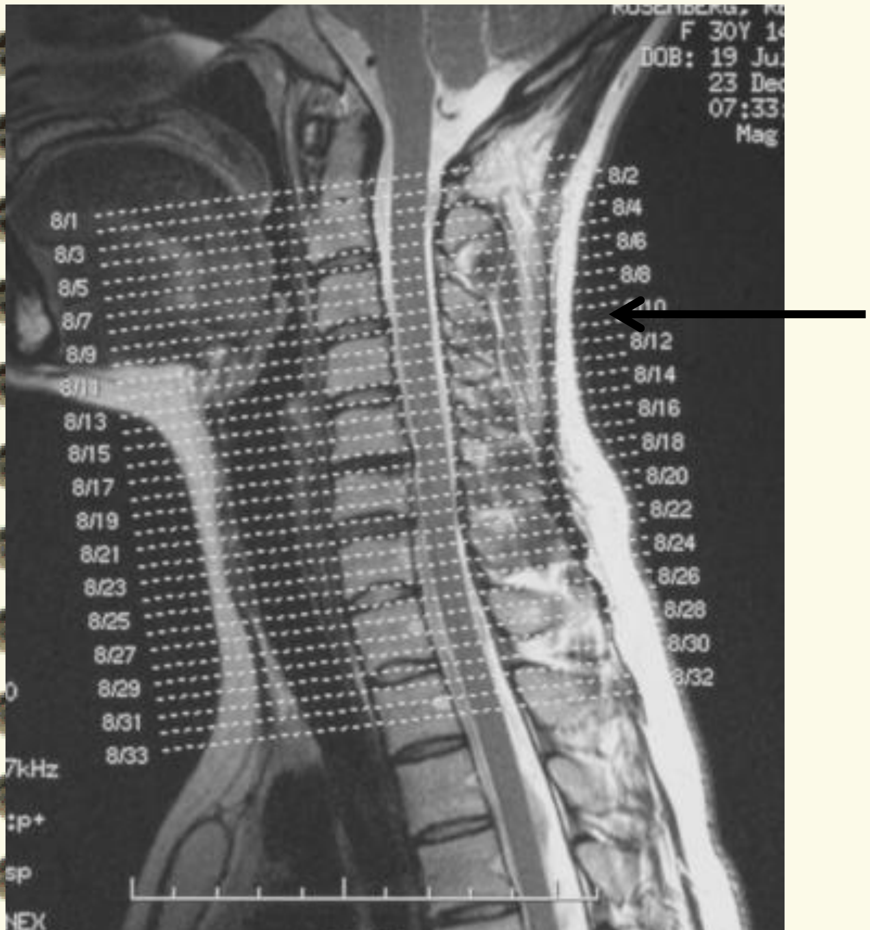
Axial T2 weighted images at all levels from C2 - T1

In a study of 332 patients examined for symptoms of the craniocervical syndrome following whiplash injury, approximately 85% show abnormality at the atlantoaxial joint, and 70% an element of cerebellar tonsillar ectopia, a condition well recognised following whiplash injury.

Interestingly, approximately 12% of these patients also exhibit signs consistent with them suffering from a connective tissue disorder such as the hypermobile Ehlers-Danlos syndrome.

Previous MRI examinations had comprised :

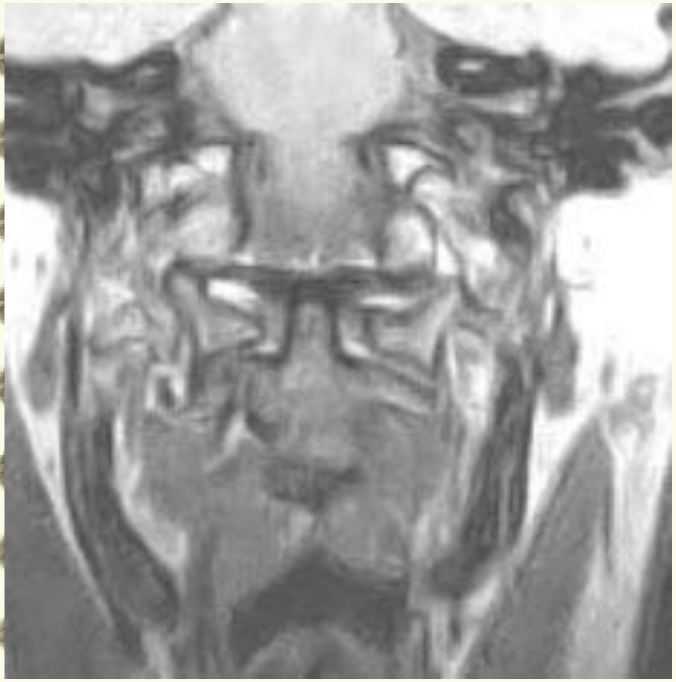
Sagittal T1 & T2 weighted images
Axial T2 weighted images at all levels from C2 to T1



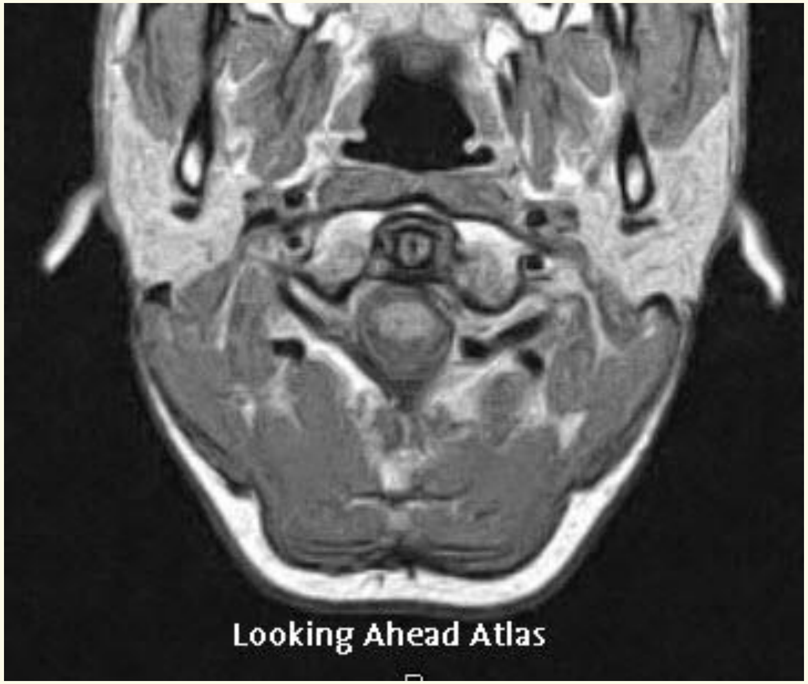
This Scout view from a conventional Supine (Lying down) MRI Scan, shows the limited levels at which the axial sections are made

You will note the junction between the head and spine is not routinely scanned (The cranio-cervical junction)

Cranio –vertebral Ligaments



Normal Alar Ligaments



Normal Transverse band of the Cruciate Ligament

Patients were studied in the seated upright position

Images were made as follows:

All patients were scanned seated in an Upright MRI scanner

1. Sagittal T1 & T2 weighted images together with axial T2 weighted images at all levels from C2/3 to C7/T1
   (The same as is routinely performed in supine position)

2. Sagittal T2 weighted images with the neck in flexion and extension.

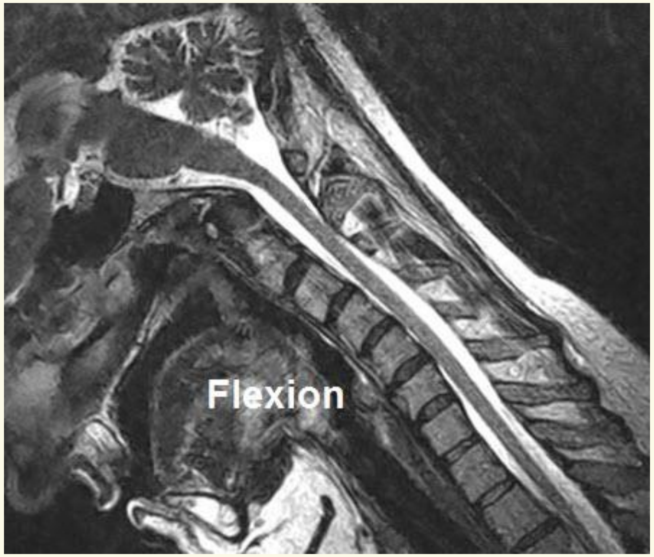
3. Coronal and axial proton density images made from the skull base down to the C2/3 level.

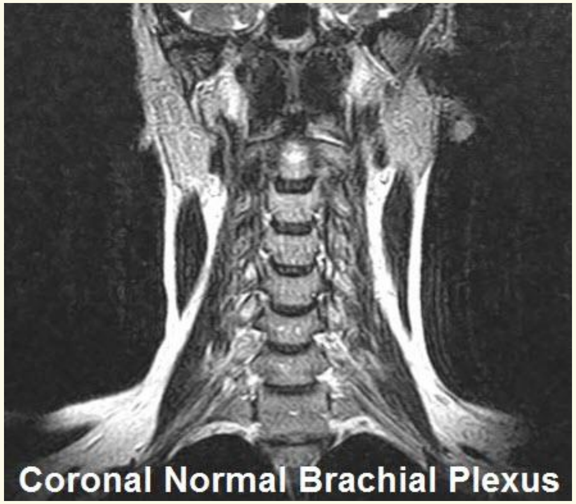
4. Axial proton density images of the atlanto-axial joints made with head turned to the right and to the left

All studies were assessed for:

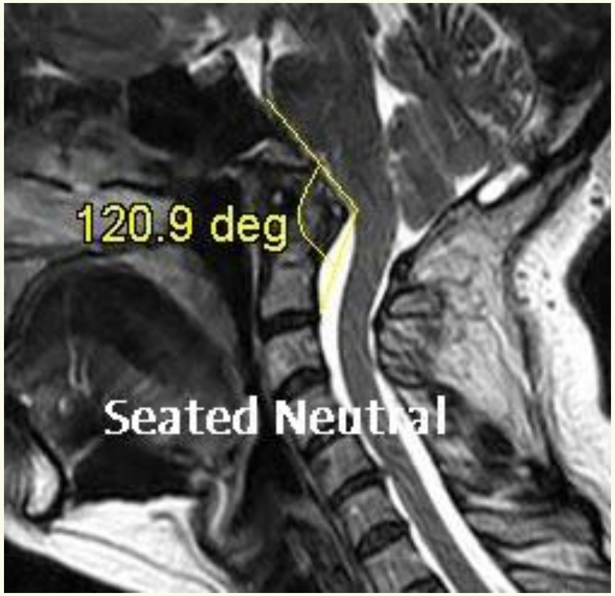
- Spinal alignment
- Integrity of the intervertebral discs
- Integrity of the neck muscles
- Facet joint alignment
- Spinal instability
- Alignment of the atlanto-axial joints and atlanto-occipital joints
- Integrity of the alar and cruciate ligaments
- Cerebellar tonsillar ectopia

Views used to examine the cervical spine





Clivo-vertebral or Clivo-axial angle (normal range 150°-180°).

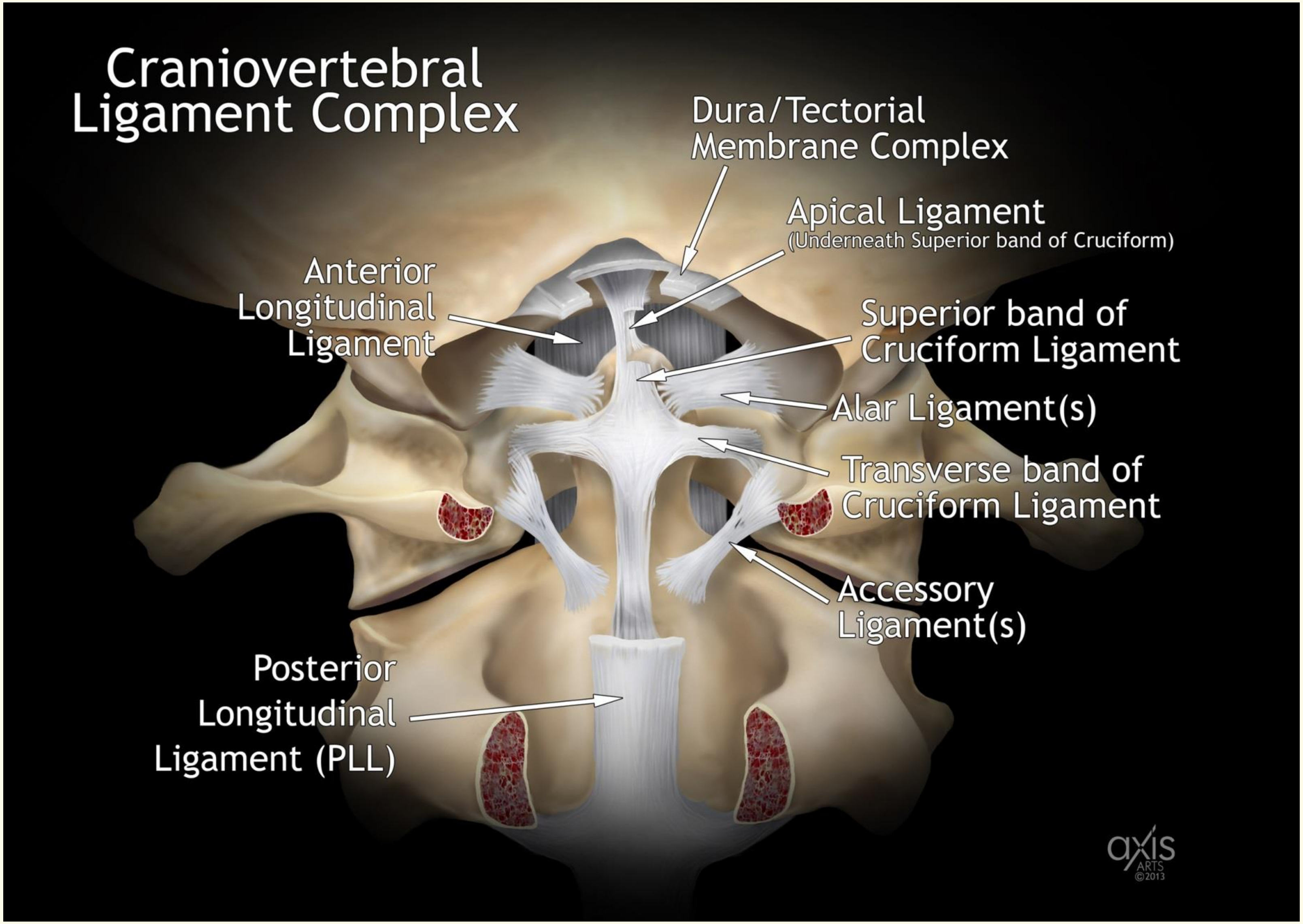


NORMAL

ABNORMAL

(The Grabb-Oakes measurement is the perpendicular distance from the BpC2 line [Basion to posterior inferior C2 body] to the dura.
A value greater than or equal to 9 mm indicates ventral brainstem compression)

(The basion axial interval is the length of a line drawn between the tip of the basion and a line drawn along the posterior aspect of the odontoid peg. The basion dental interval is a distance measured between the tip of the basion and the tip of the dens. Both these measurements should be less than 12 mm. If they are greater than 12 mm, then occipito-atlantal disassociation has occurred. These measurements are often referred to as "The rule of 12")


Craniovertebral
Ligament Complex
Dura/Tectorial
Membrane Complex
Apical Ligament
(Underneath Superior band of Cruciform)
Anterior
Longitudinal
Ligament
Superior band of
Cruciform Ligament
Alar Ligament(s)
Transverse band of
Cruciform Ligament
Accessory
Ligament(s)
Posterior
Longitudinal
Ligament (PLL)
axis
ARTS
©2013

Specific coronal views of the cranio-cervical junction to show the position of the odontoid peg

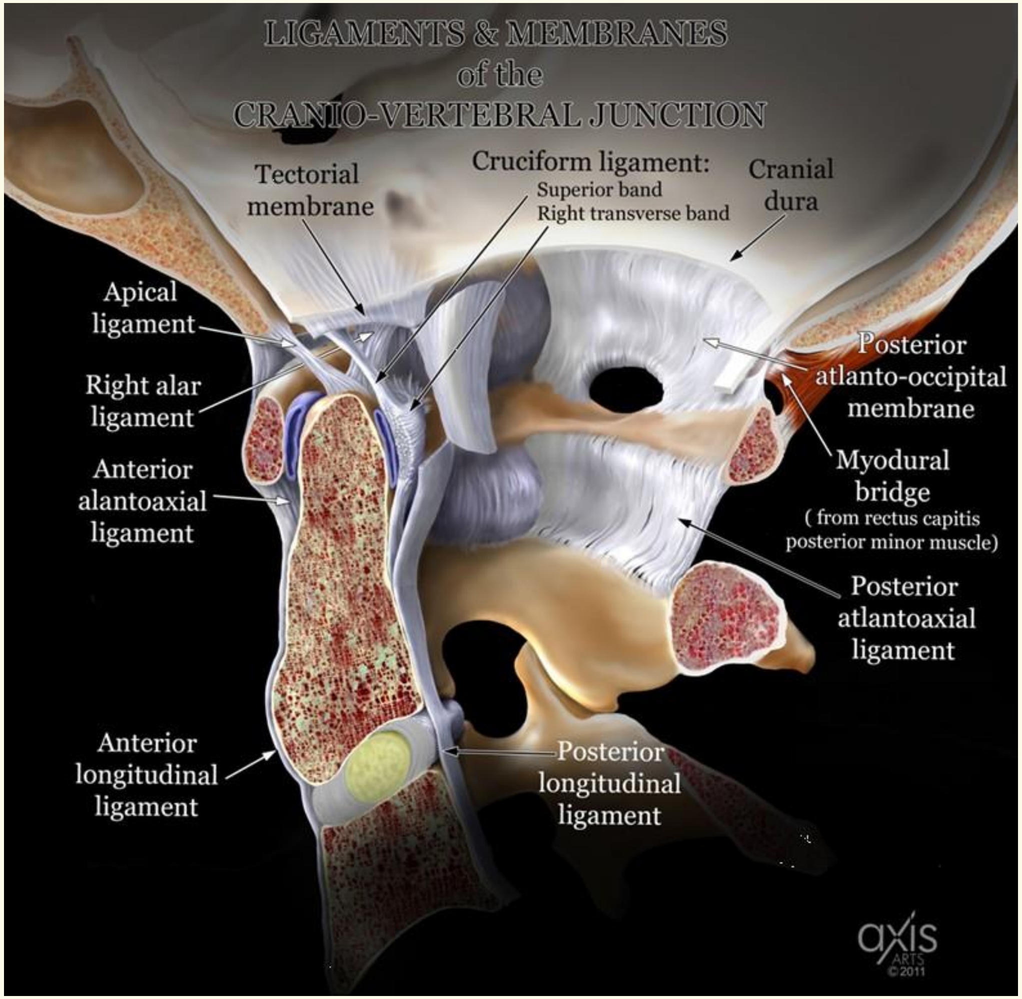
Normal position of the odontoid peg

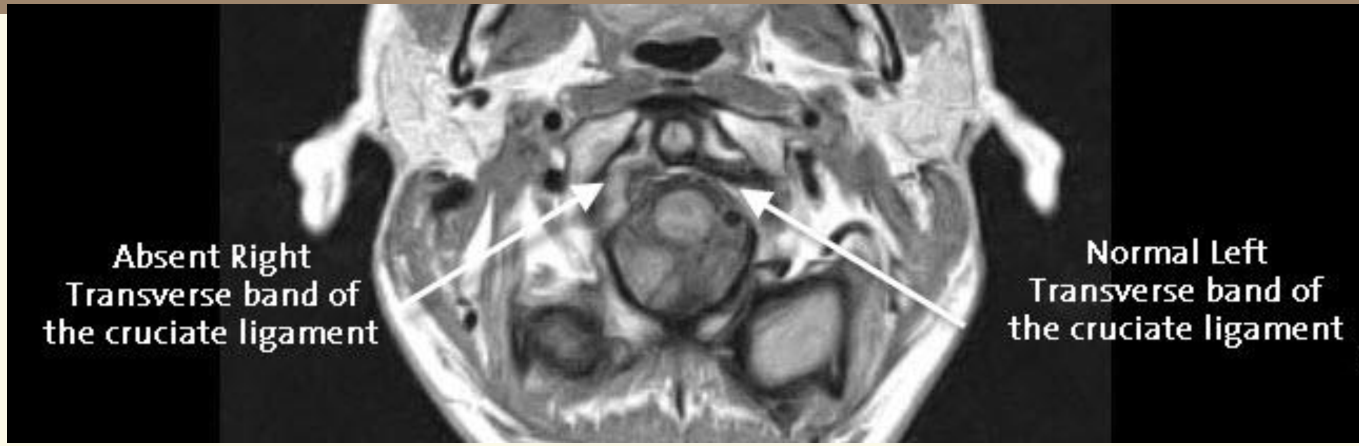
The alar ligaments are intact (arrows)

The odontoid peg is deviated to the right

The alar ligaments are not clearly seen due to them being damaged

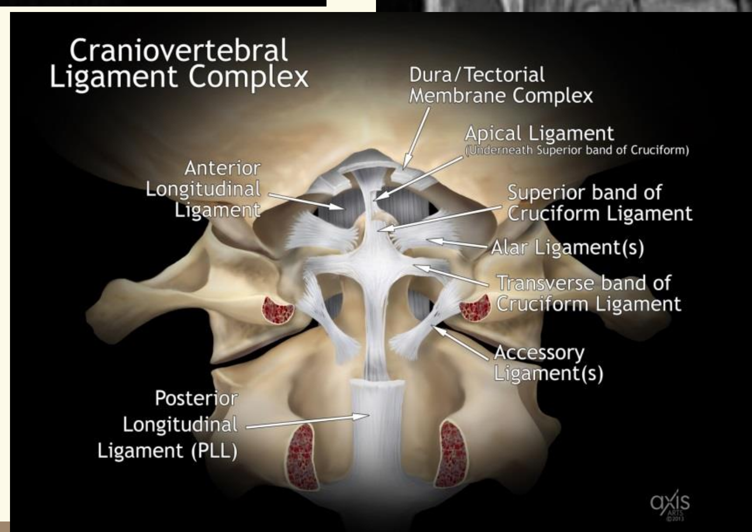
Ligaments and membranes of the Cranio-cervical junction



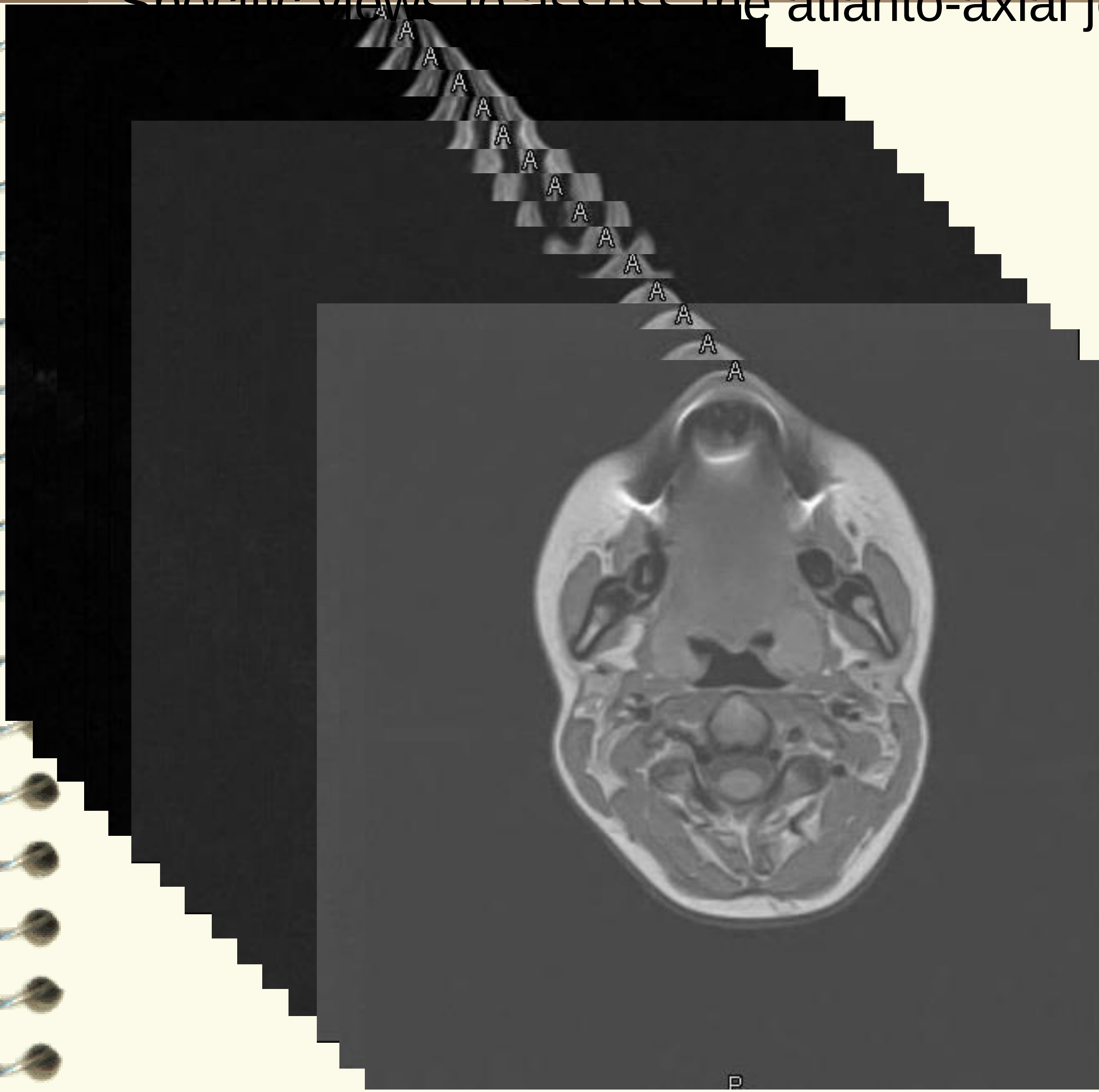

Absent Right
Transverse band of
the cruciate ligament
Normal Left
Transverse band of
the cruciate ligament


Normal Left Alar
Ligament

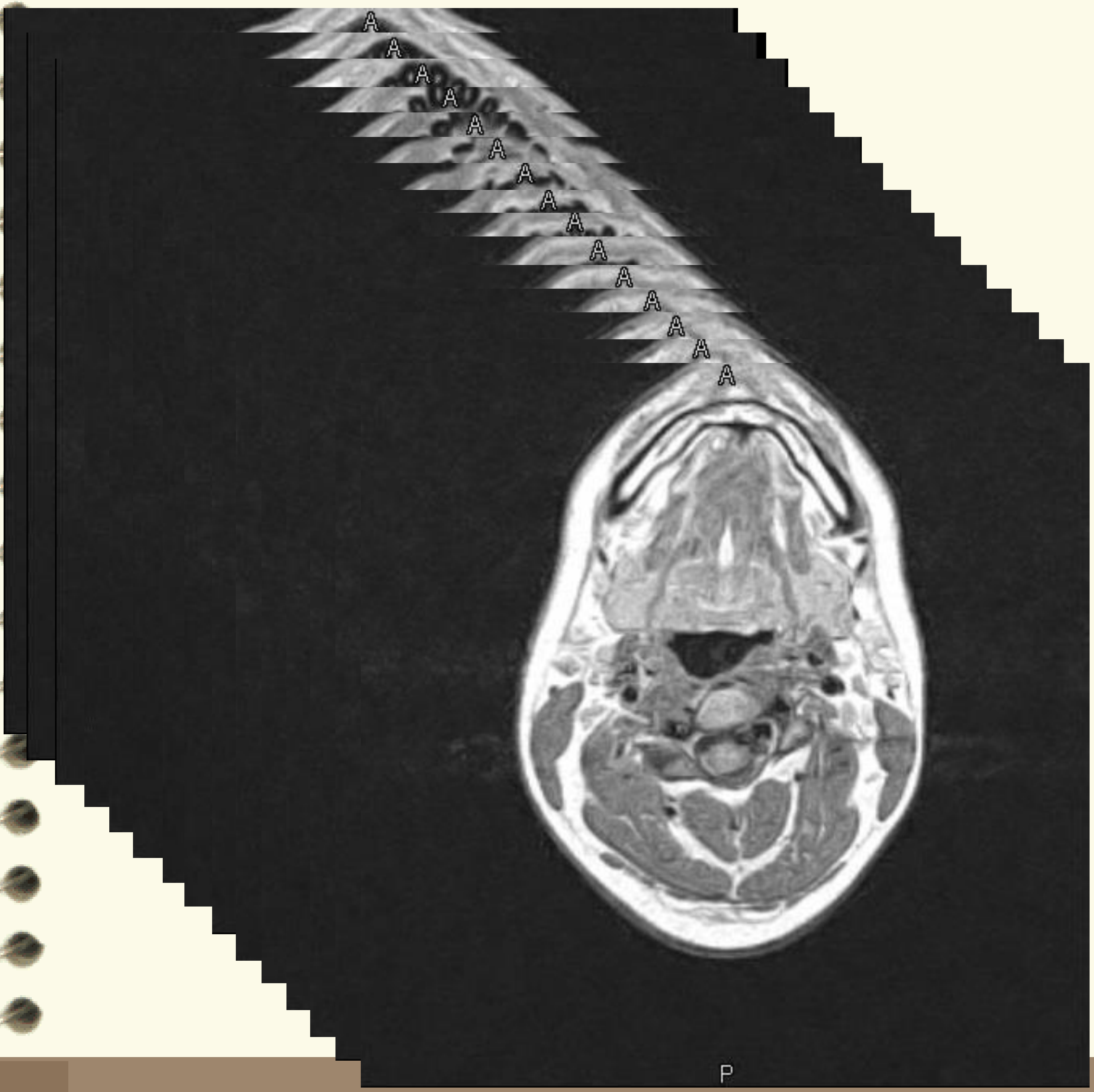

Normal Left Alar
Ligament


Craniovertebral
Ligament Complex
Dura/Tectorial
Membrane Complex
Apical Ligament
(Underneath Superior band of Cruciform)
Anterior
Longitudinal
Ligament
Superior band of
Cruciform Ligament
Alar Ligament(s)
Transverse band of
Cruciform Ligament
Accessory
Ligament(s)
Posterior
Longitudinal
Ligament (PLL)

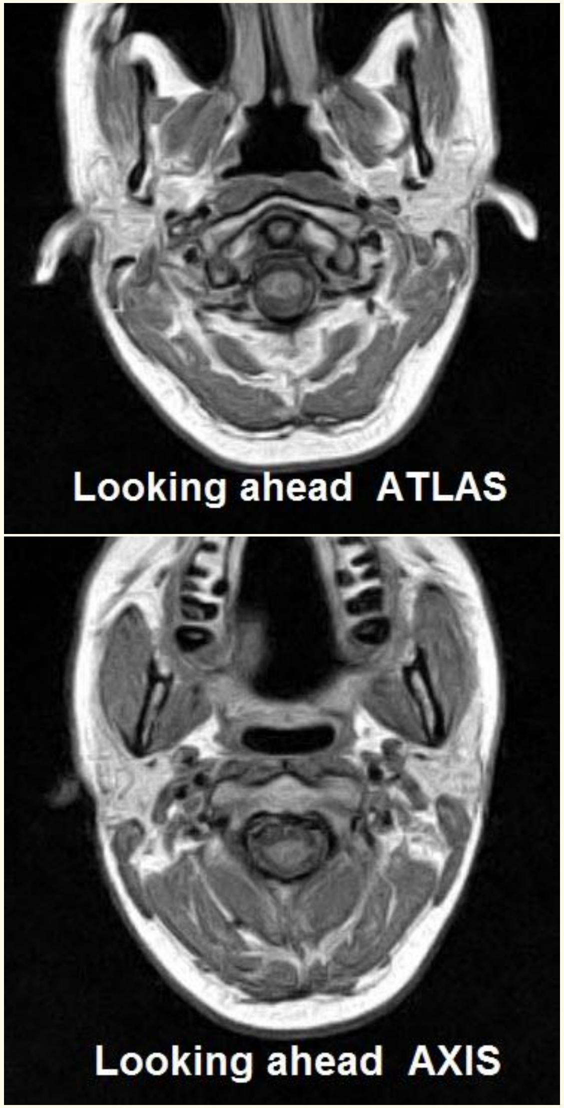
Specific views to assess the atlanto-axial joint.



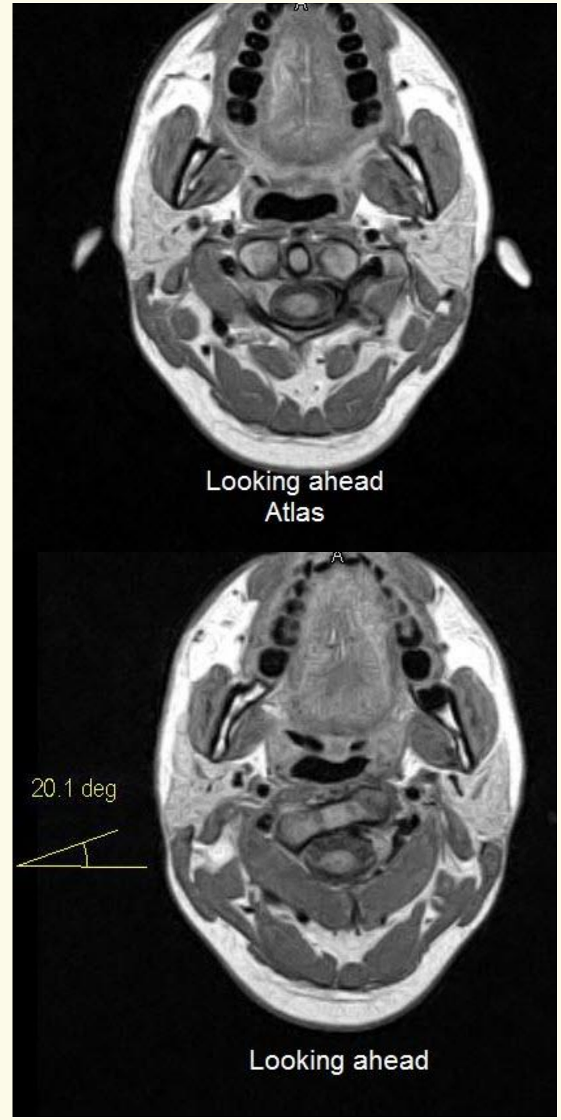
Specific views to assess the atlanto-axial joint



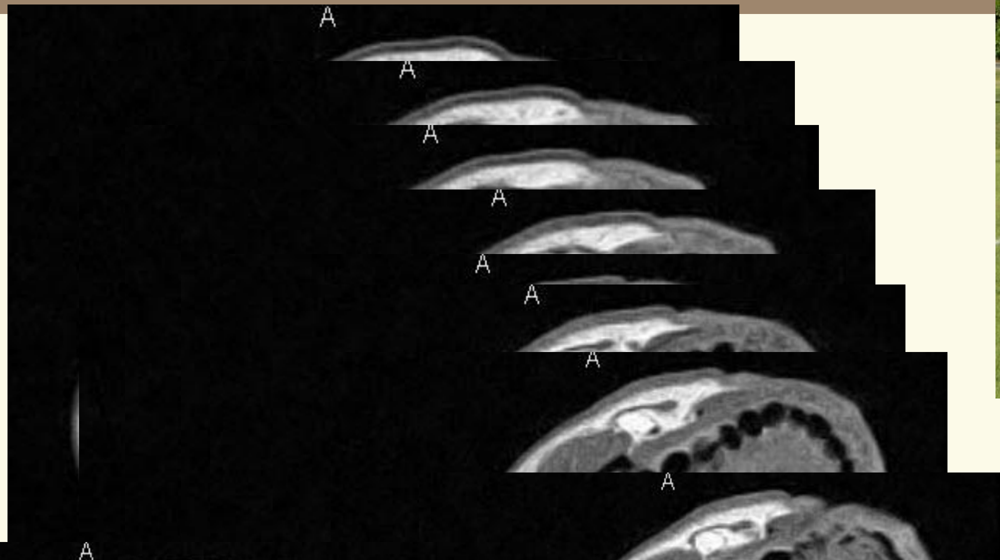
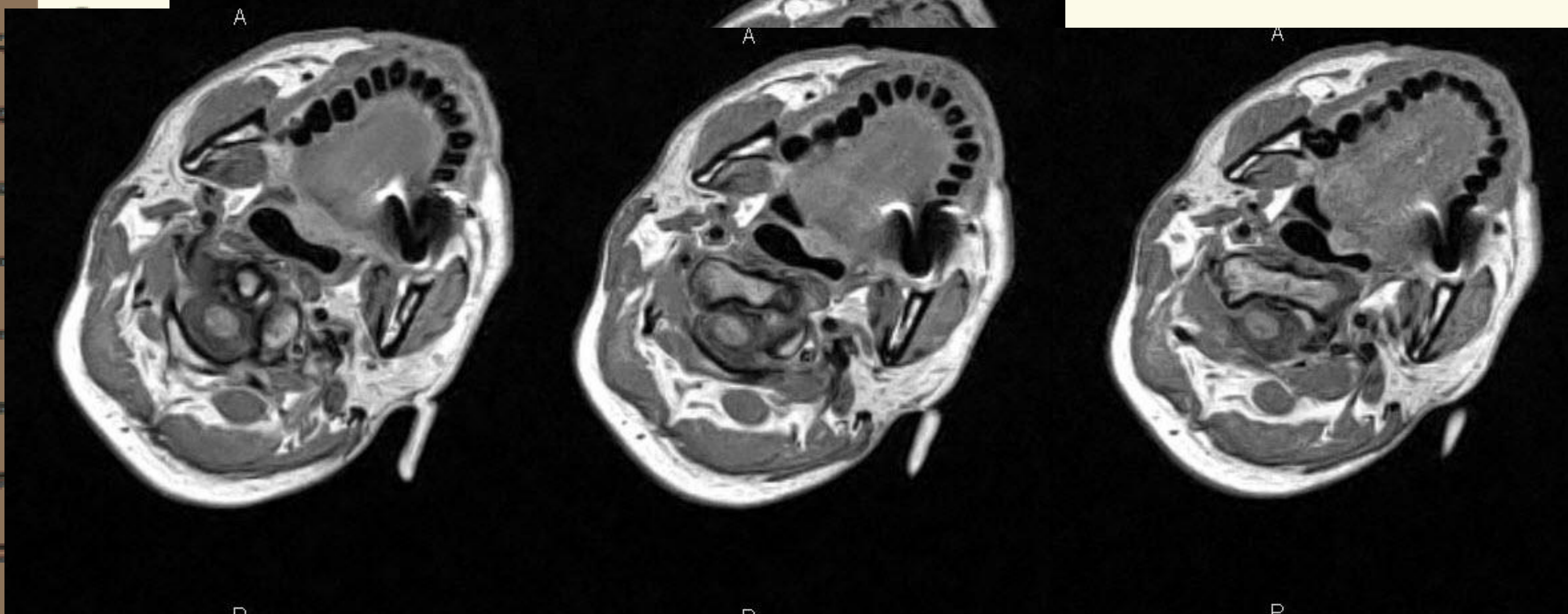
Specific views to assess the atlanto-axial joint



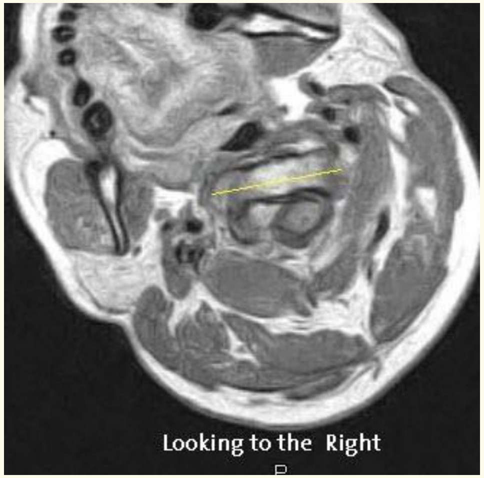
Normal alignment

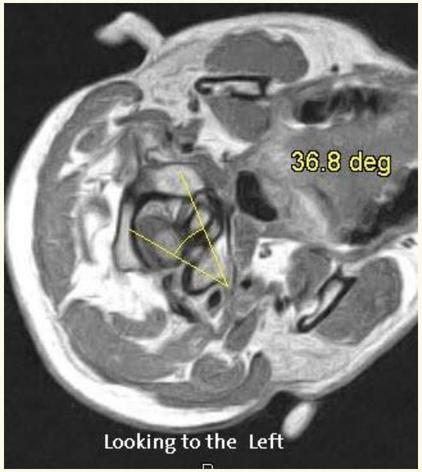


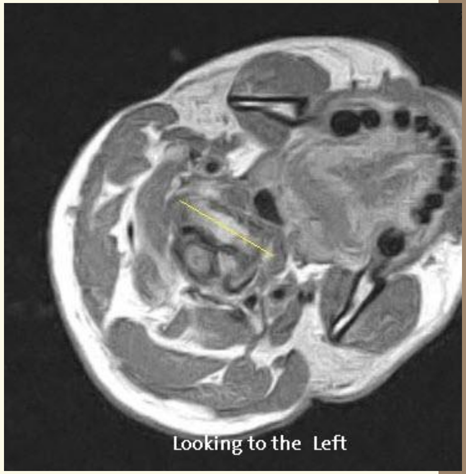
20º of dislocation at the atlanto-axial joint

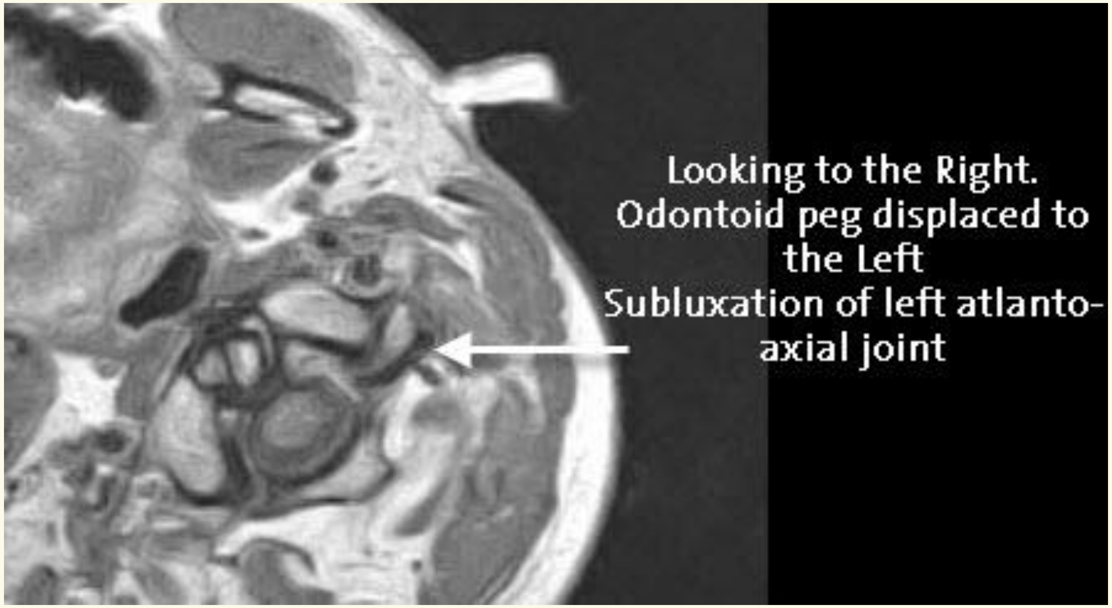


A
A
A
A
A
A
A
A
A
A
A
P
P
P


28.1 deg
Looking to the Right

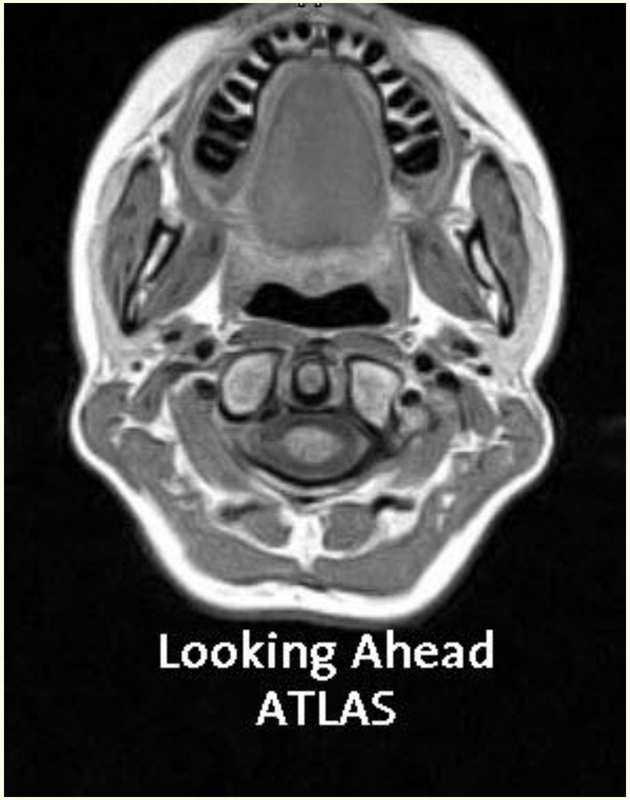

Looking to the Right

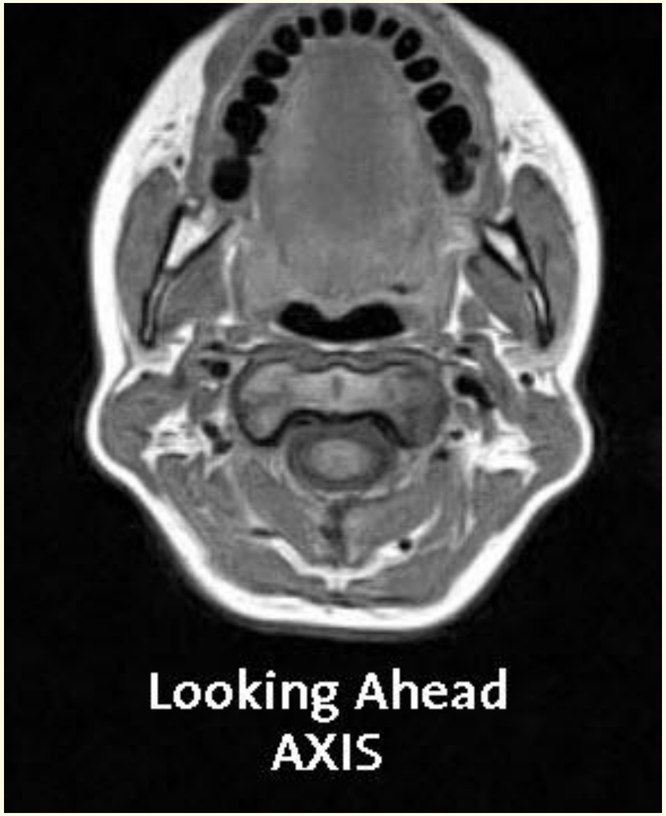

36.8 deg
Looking to the Left


Looking to the Left

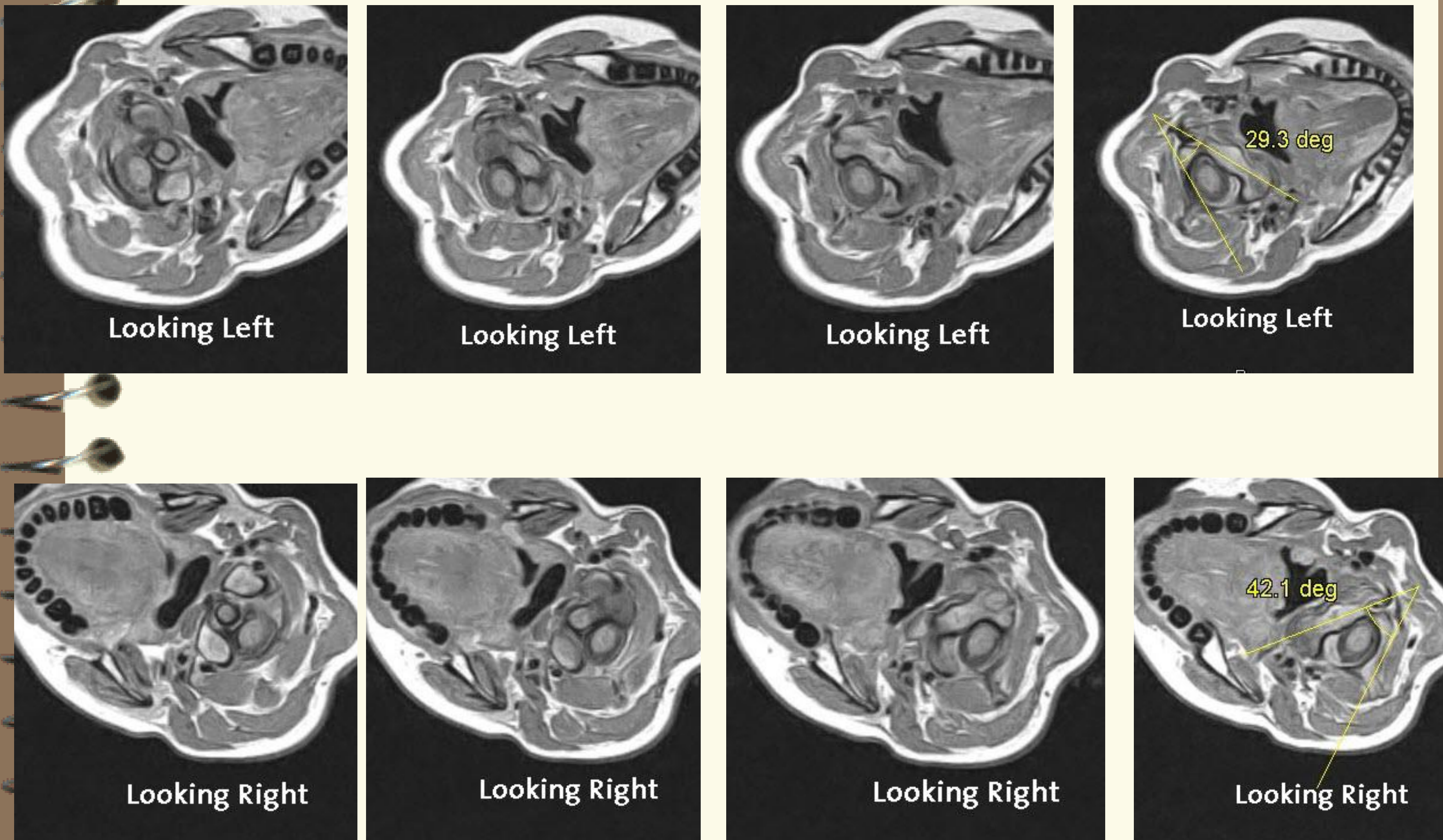

Looking to the Right.
Odontoid peg displaced to the Left
Subluxation of left atlanto-axial joint

39 years old female Whiplash Associated Disorder

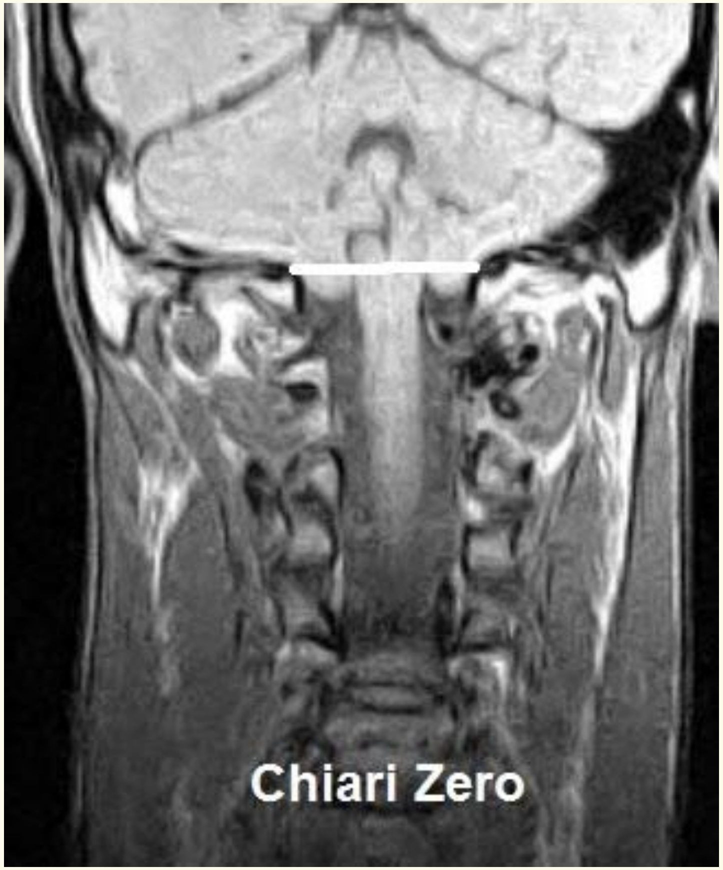




39 years old female Whiplash Associated Disorder



Post-traumatic ectopia of the cerebellar tonsils is best demonstrated when sitting



A case-control study of cerebellar tonsillar ectopia (Chiari) and cervical spine trauma.

Freeman MD, Rosa S, Harshfield D, Smith FW Bennett R, Centano CJ, Kornel E, Nystrom A, Heffez DS, & Kohles SS

Brain Inj. 24 (7-8):988-94. 2010

CLINICAL RELEVANCE/APPLICATION

The cost implications of under diagnosis of mechanical damage at the cranio-cervical junction, both in terms of patient suffering and cost in insurance claims, is very large

We believe it is of paramount importance :

1. To show any dislocation and ligamentous damage when present
2. Also to exclude such damage when it is not present

(Unless it is specifically looked for, any damage at the cranio-cervical junction cannot be excluded a limited cervical spine examination)

Ehlers –Danlos Syndrome

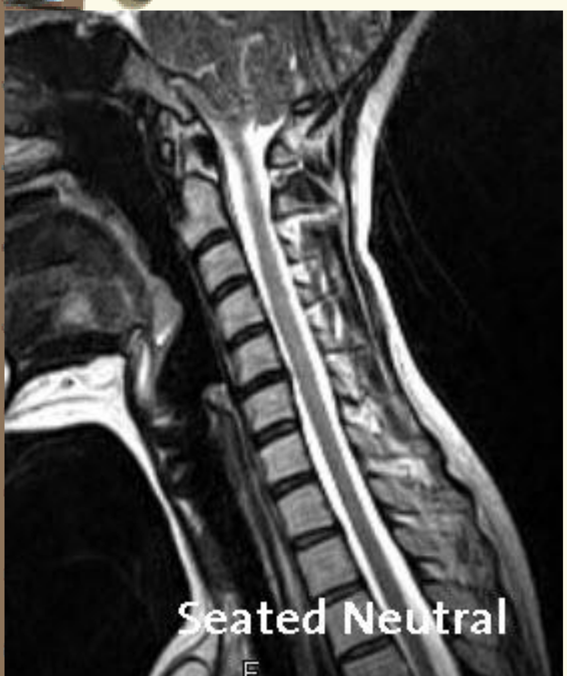
hEDS

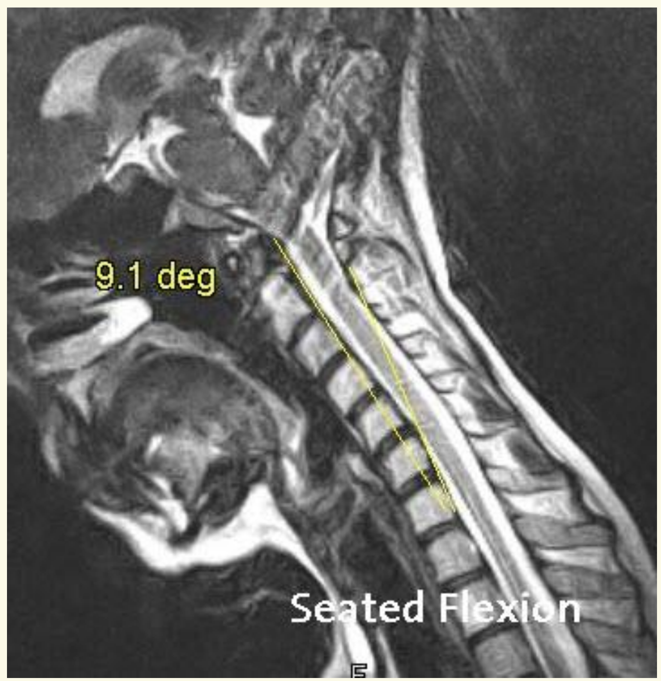
Method and Materials :

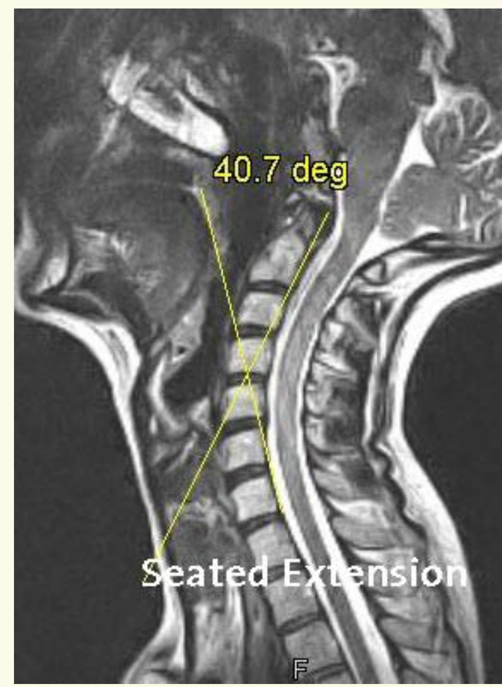
E.D.S.	49	average age	34.5yrs	(11 - 64)	42F	7M
Normal con	58	average age	58yrs	(22 – 78)	42 F	16 M

CERVICAL SPINE ANGLE

	Normal/Control	E.D.S.
Neutral	17.1°	17.7°
Flexion	-11.5°	-18.1°
Extension	32.1°	50.1°







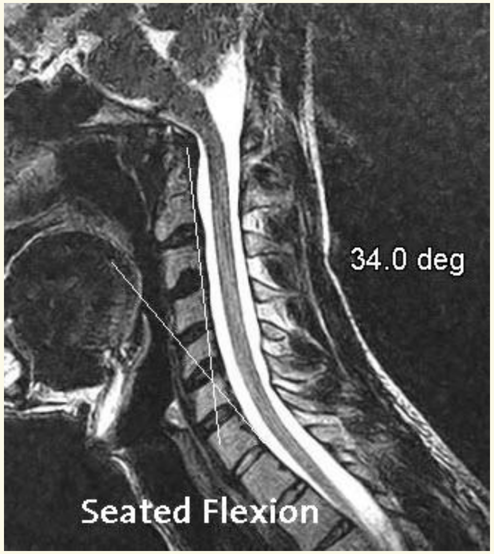
CERVICAL SPINE ANGLE

	Normal/Control	E.D.S.	E.D.S.Type1	E.D.S. Type 2
Neutral	17.1^o	17.7^o	21^o	13.5^o
Flexion	11.5^o	18.1^o	12^o	25.5^o
Extension	32.1^o	50.1^o	48^o	51.6^o

Type 1	27	average age	36.6yrs	(11 - 64)	21F 5M
Type 2	22	average age	31.7yrs	(15 - 46)	20F 1M

TYPE 1

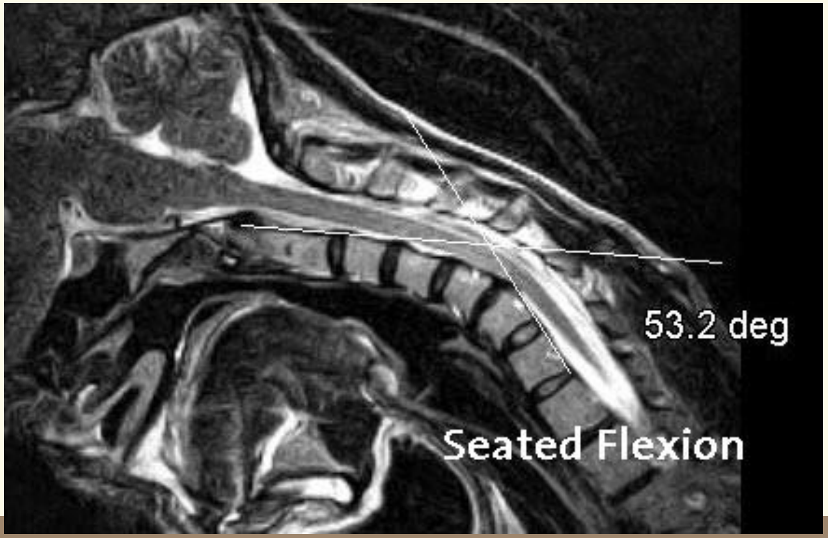

39.0 deg
Seated Neutral


34.0 deg
Seated Flexion

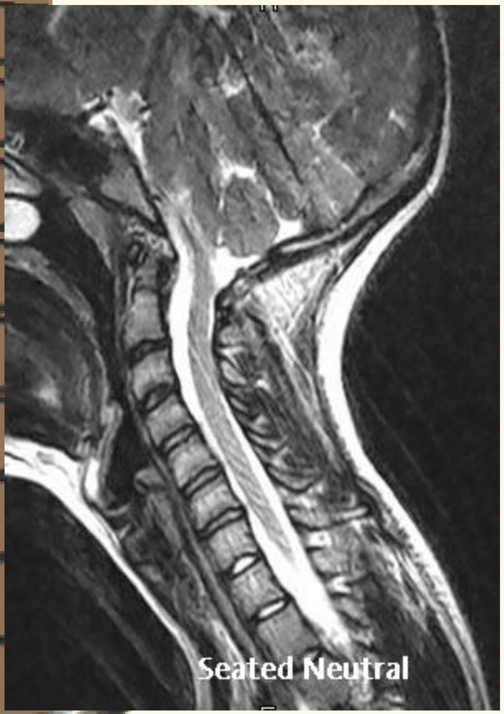

70.5 deg
Seated extension

TYPE 2


2.3 deg
Seated Neutral


53.2 deg
Seated Flexion


31.3 deg
Seated extension


Seated Neutral


Seated Flexion


H
Seated Extension
F

CLIVO-AXIAL ANGLE

Clivo-axial angle.	Normal	E.D.S.	E.D.S.Type1	E.D.S. Type 2
Neutral	154^o	146^o	139^o	146^o
Flexion	148^o	143^o	136^o	143^o
Extension	160^o	158^o	154^o	157^o

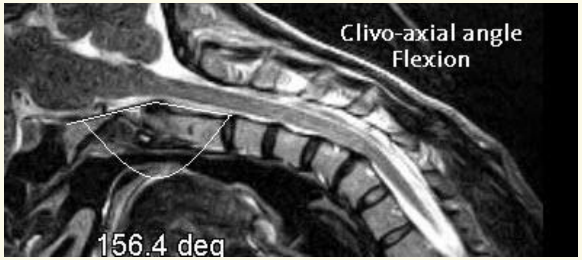
GRABB OAKES INTERVAL All within normal.

HARRIS MEASUREMENTS

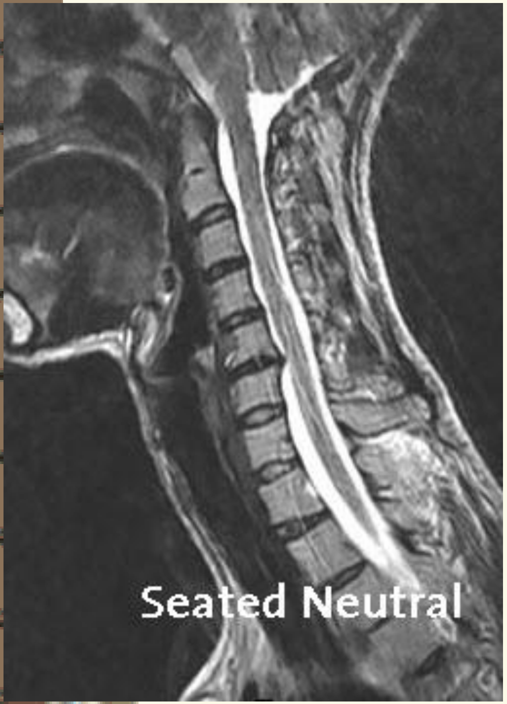
Basion-axial & Basion-dental lines. All within normal

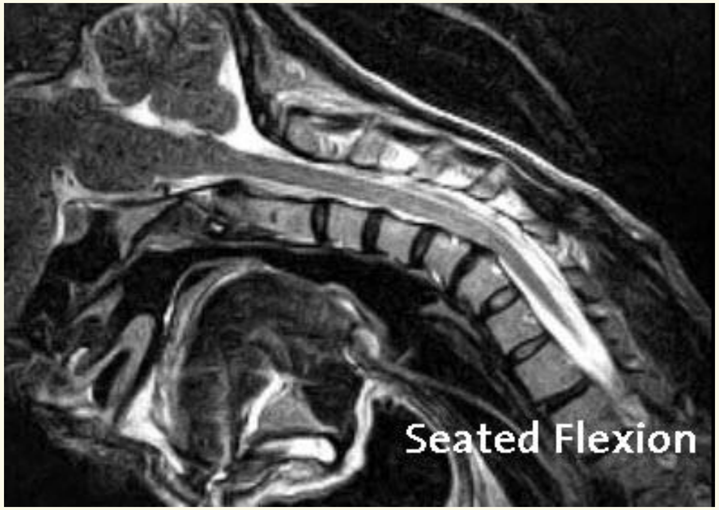
Type 2


146.6 deg
Clivo-axial angle
Neutral

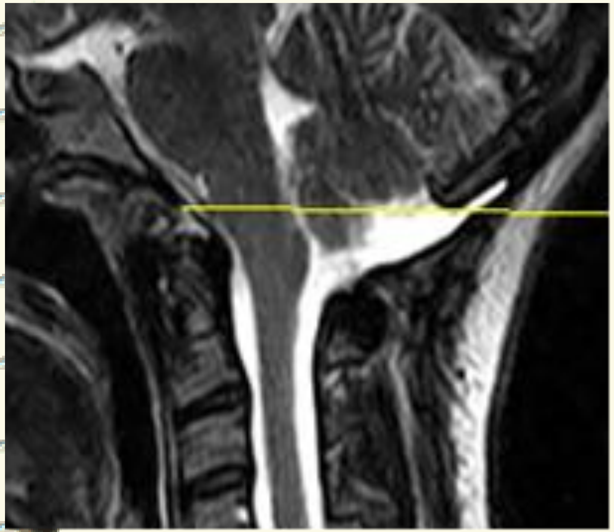

Clivo-axial angle
Flexion
156.4 deg

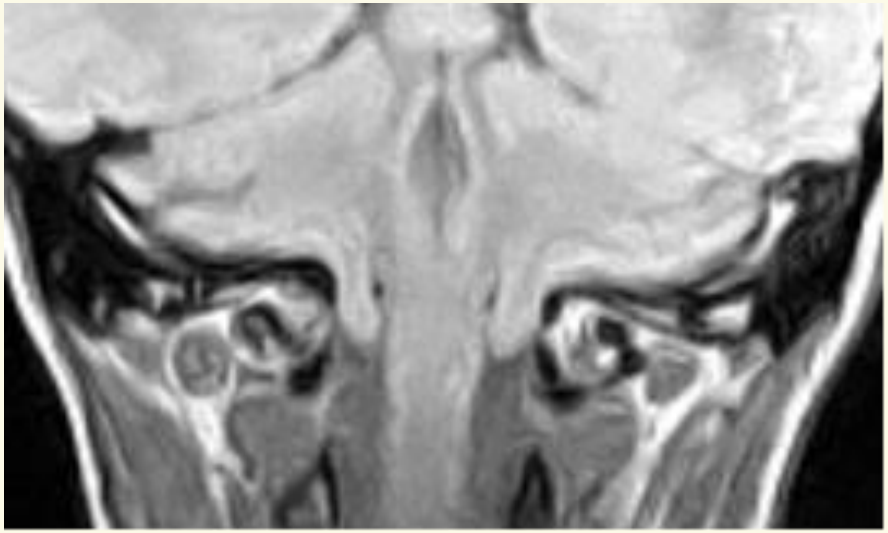

175.1 deg
Clivo-axial angle
Extension

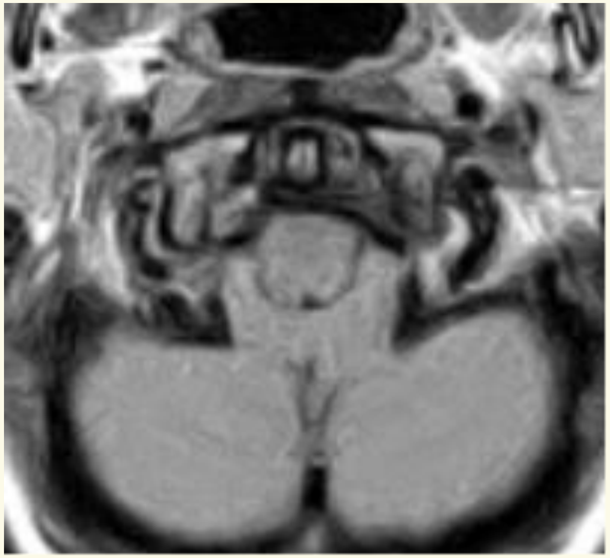

Seated Neutral


Seated Flexion


H
Seated extension

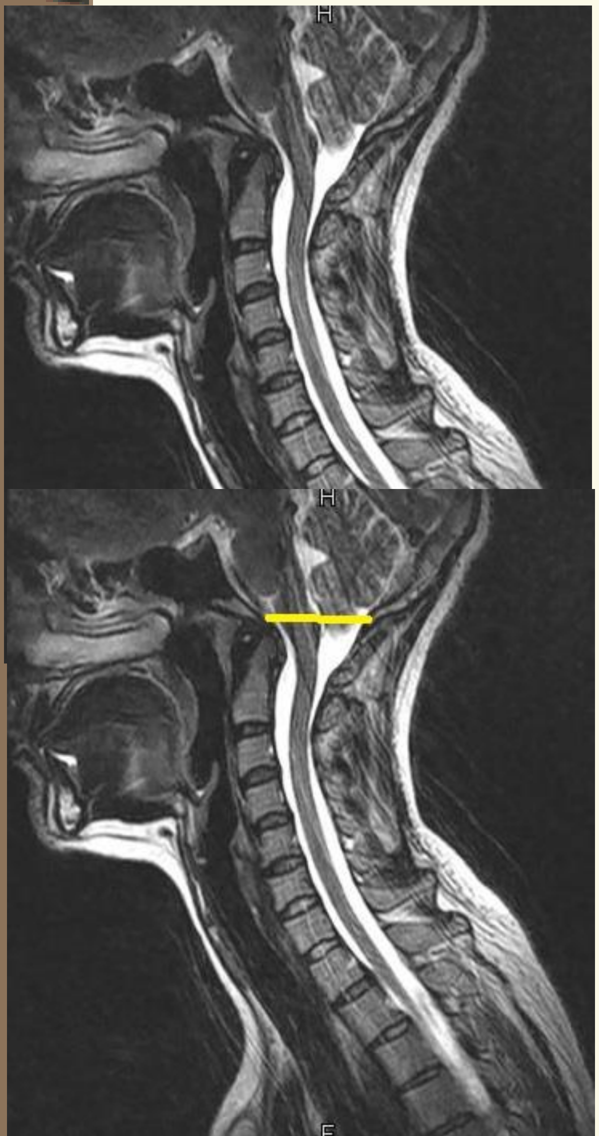


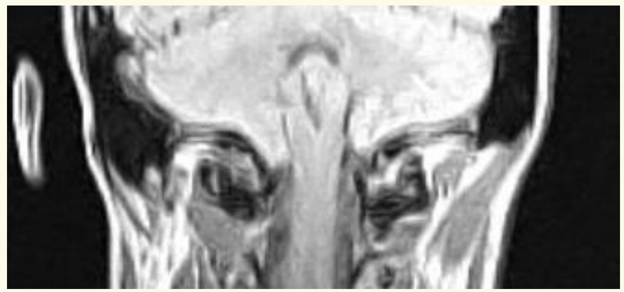


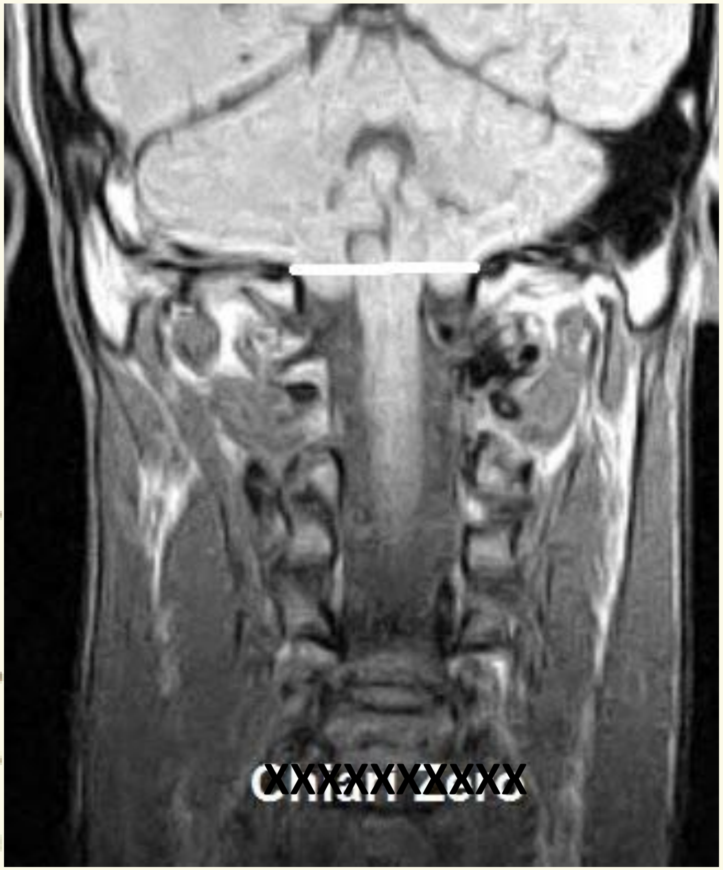


NC

Assessment oCerebellar Tonsillar ectopia. in 55%






XXXXXXXXXX

Atlanto-axial joint:

E.D.S.	49	average age	34.5yrs	(11 - 64)	42F	7M
Normal control	58	average age	58yrs	(22 – 78)	42 F	16 M

Stable joint	13/49	26%
Laxity of ligaments	25/49	51%
Dislocation	11/49	23%

CONCLUSIONS:

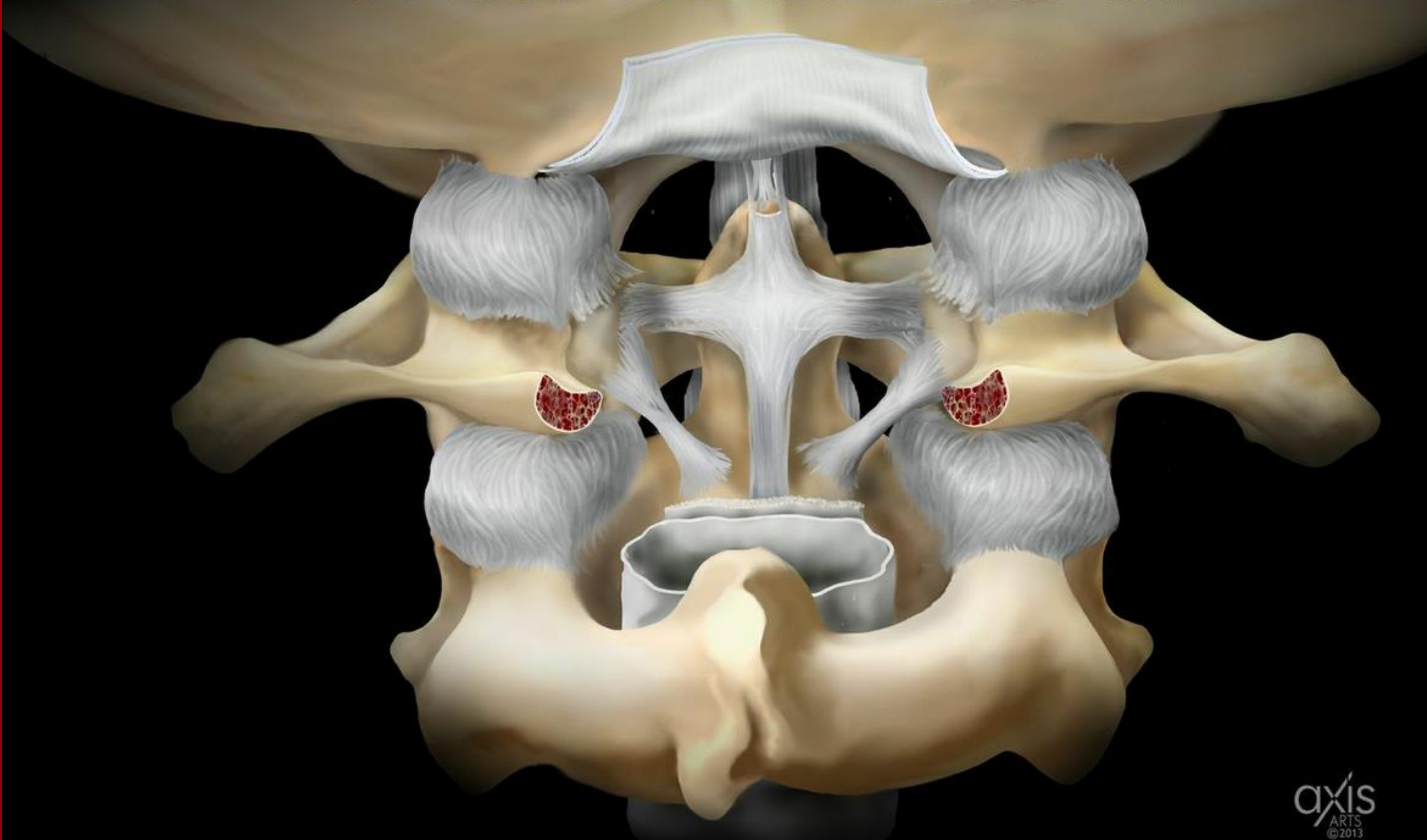
- **Cervical spine** Two types
  Type 1 associated with an element of basilar invagination
  Type 2 associated with Cerebellar tonsillar ectopia

- **Atlanto -axial joint** only 26% stable
  51% abnormal range of movement due to ligamentous laxity
  23% show a degree of dislocation.

- **Cerebellar Tonsillar ectopia** present in 55%

- A lot more work to do

DEEP LIGAMENTS of the CRANIOVERTEBRAL JUNCTION



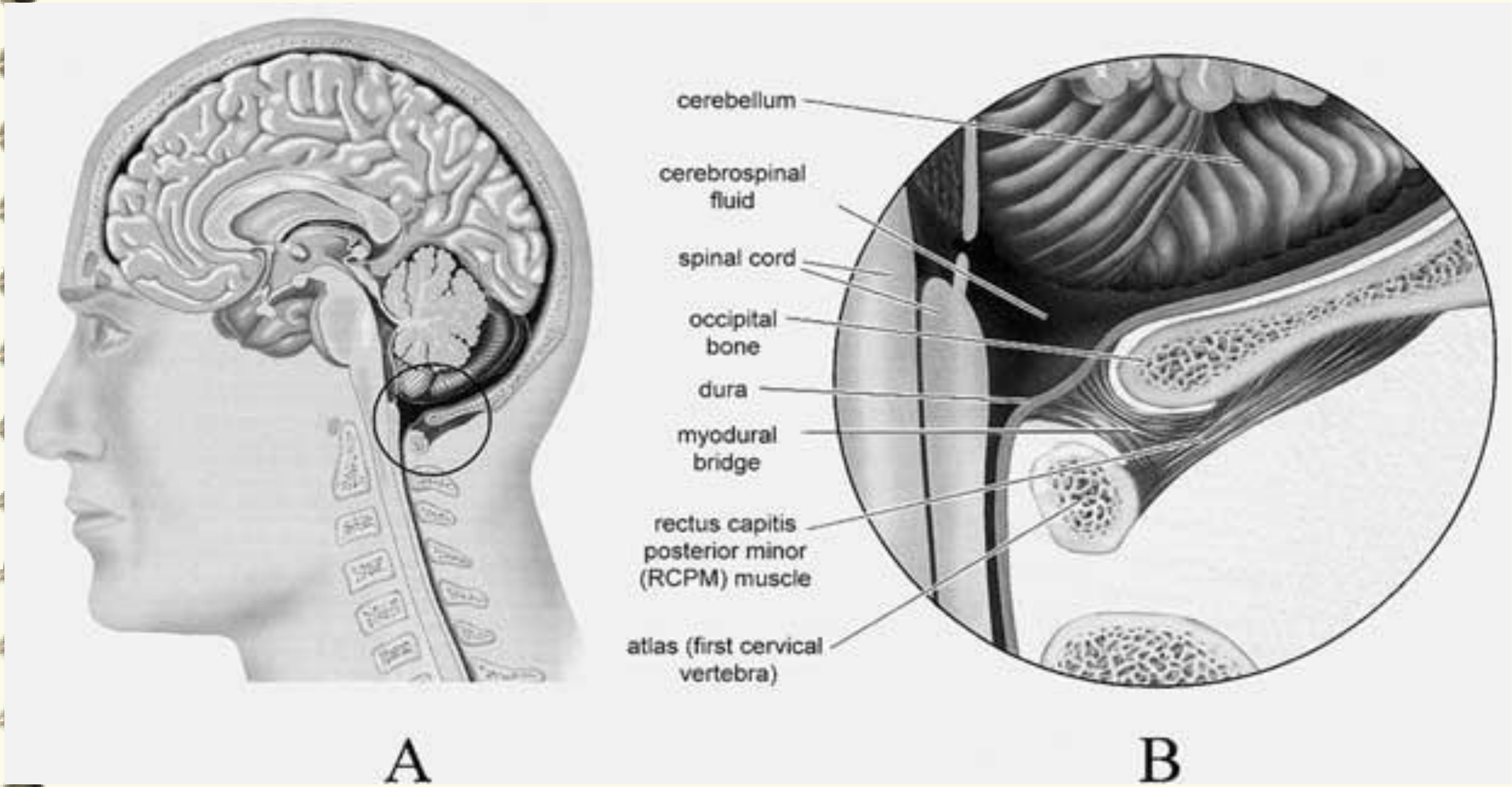
Cervical Myodural Bridge

Nowhere in early editions of Gray's Anatomy is a functional relationship described between the Rectus capitis posterior minor muscle and the dura mater.

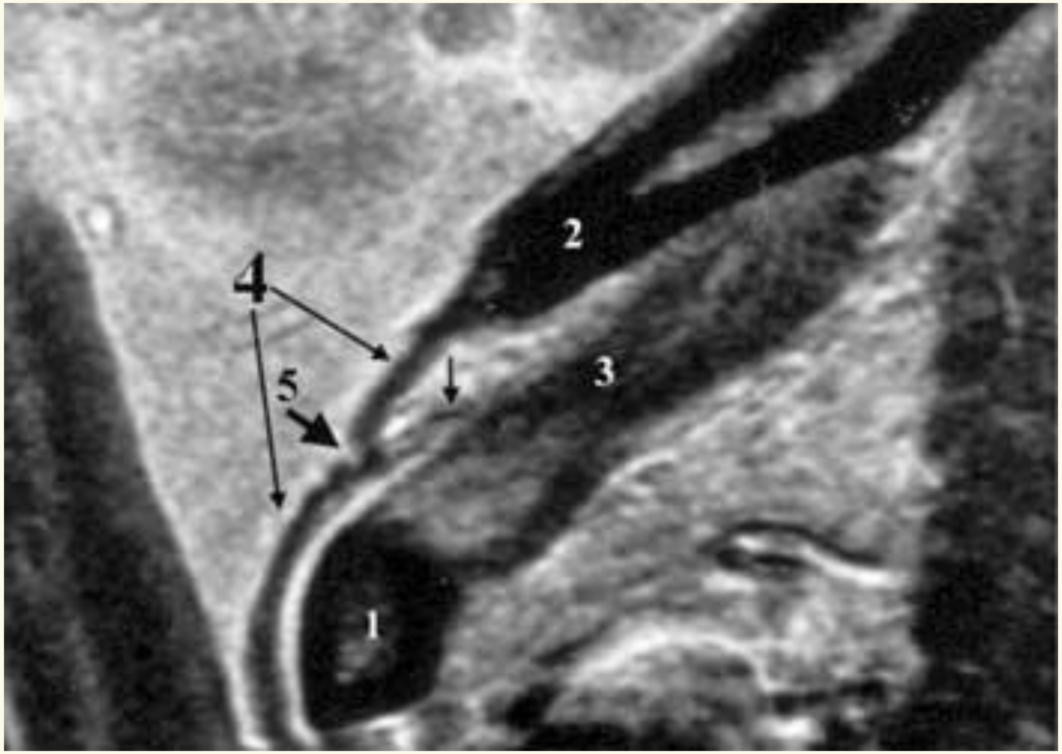
The naturally occurring physical connection between suboccipital muscles and the dura mater at the atlanto-occipital junction has been described in recent studies.

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

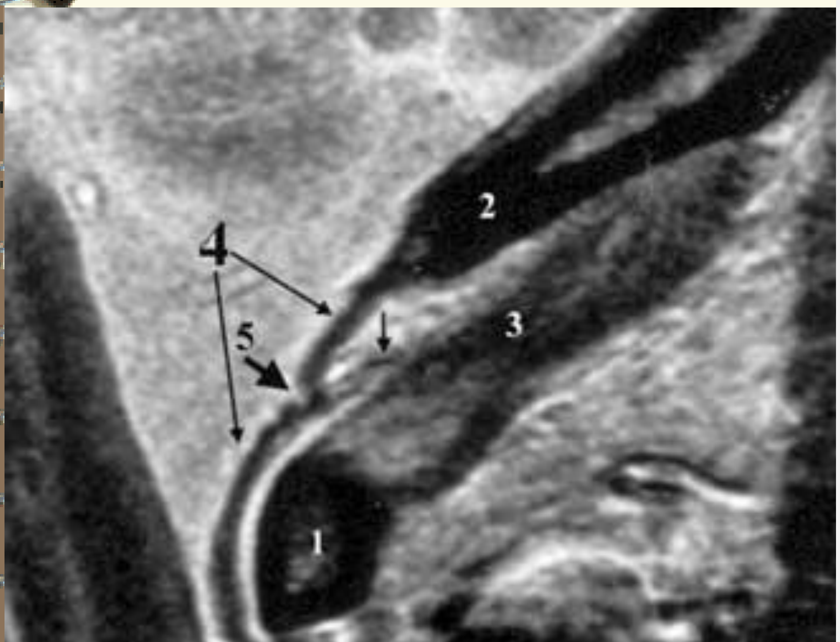


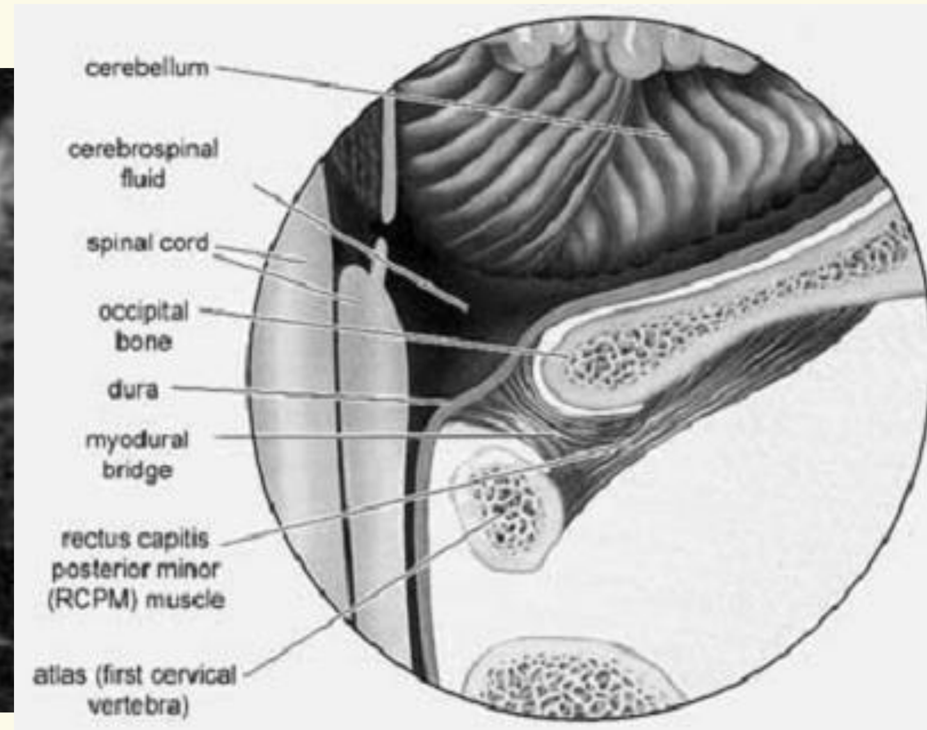
Magnetic Resonance Imaging of the atlanto-occipital junction..

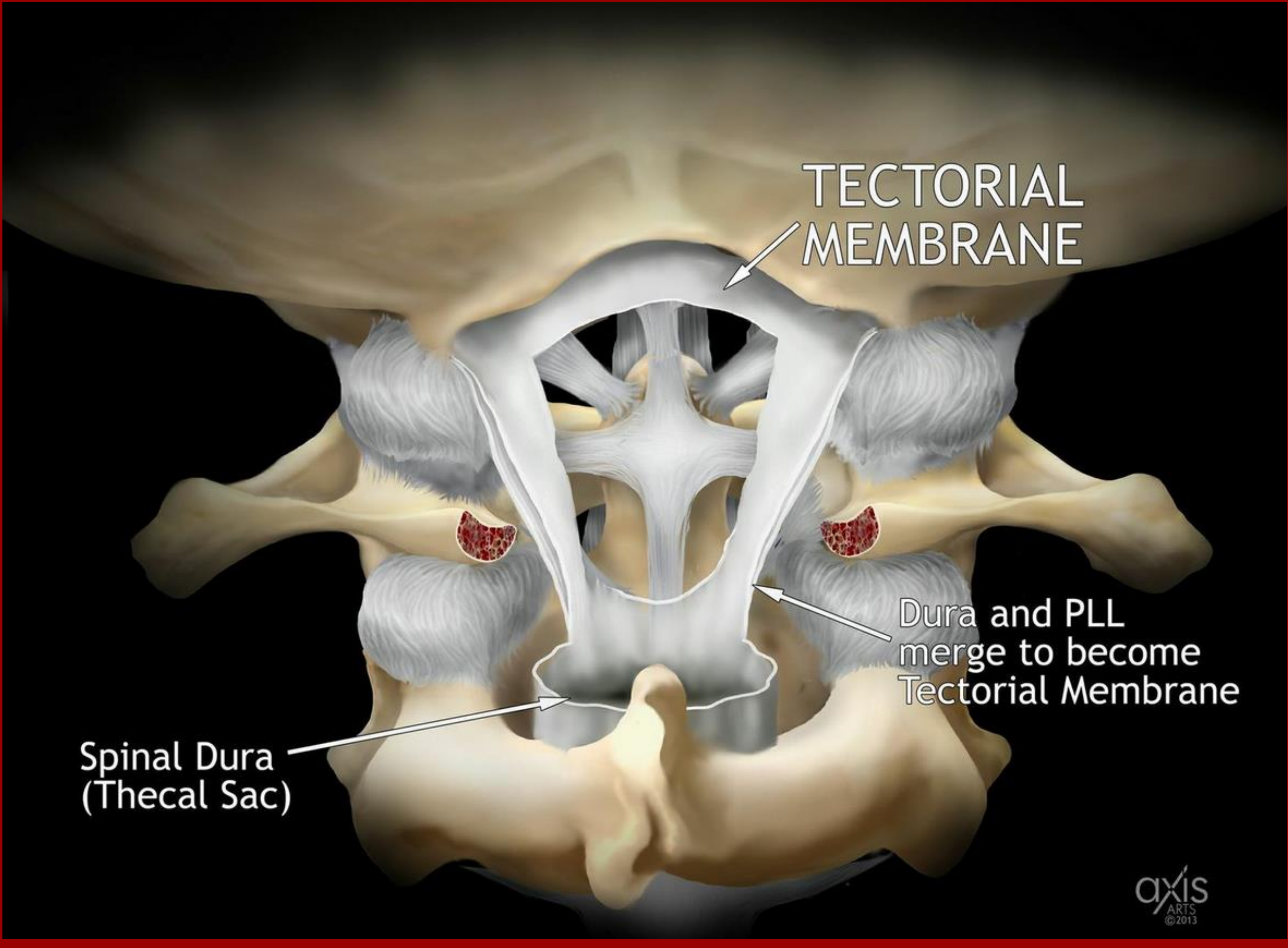


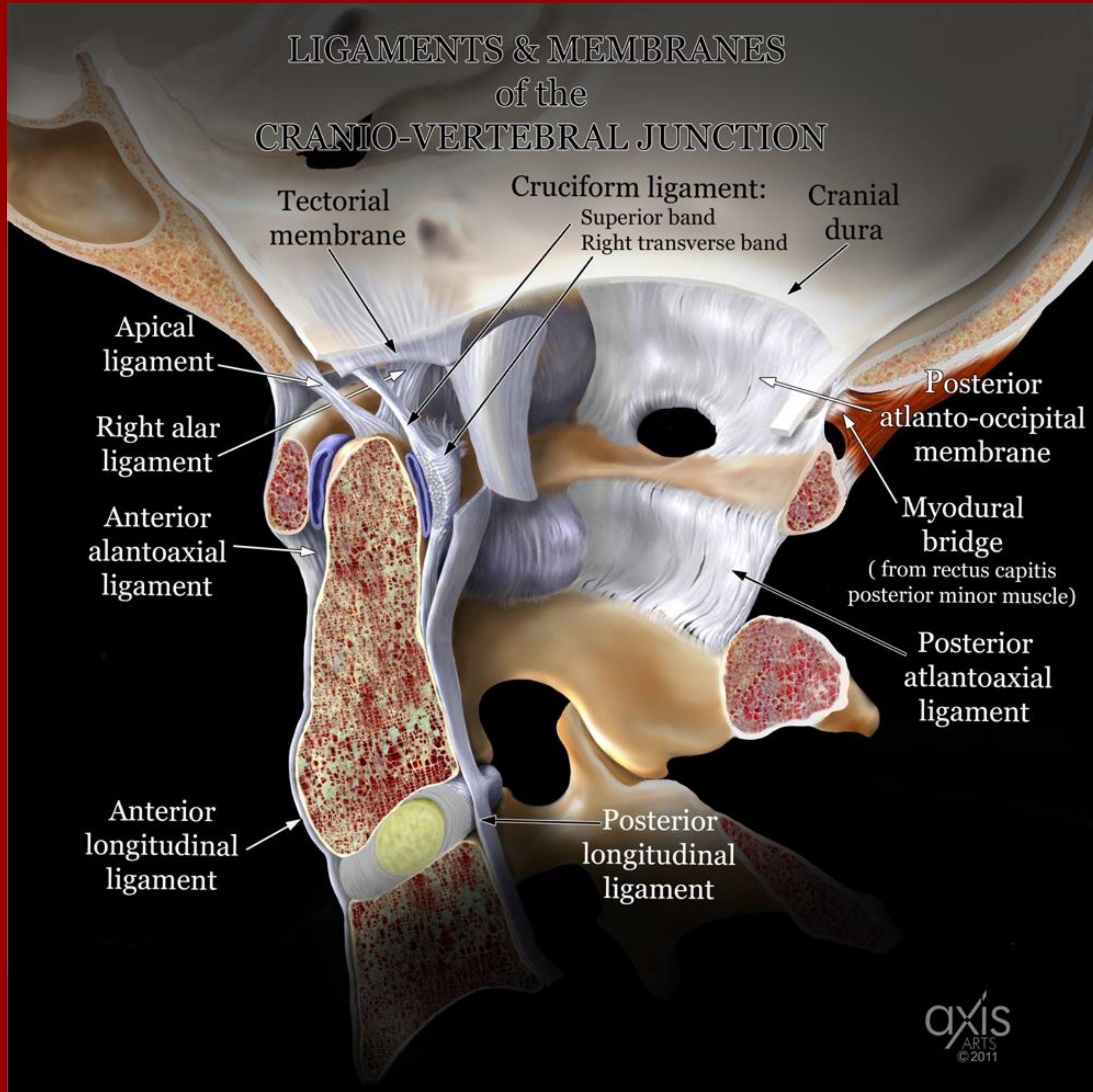
1. First cervical vertebra.
2. Occiput
3. Suboccipital musculature
4. Dura mater
5. Dural fold

Cervical Myodural Bridge



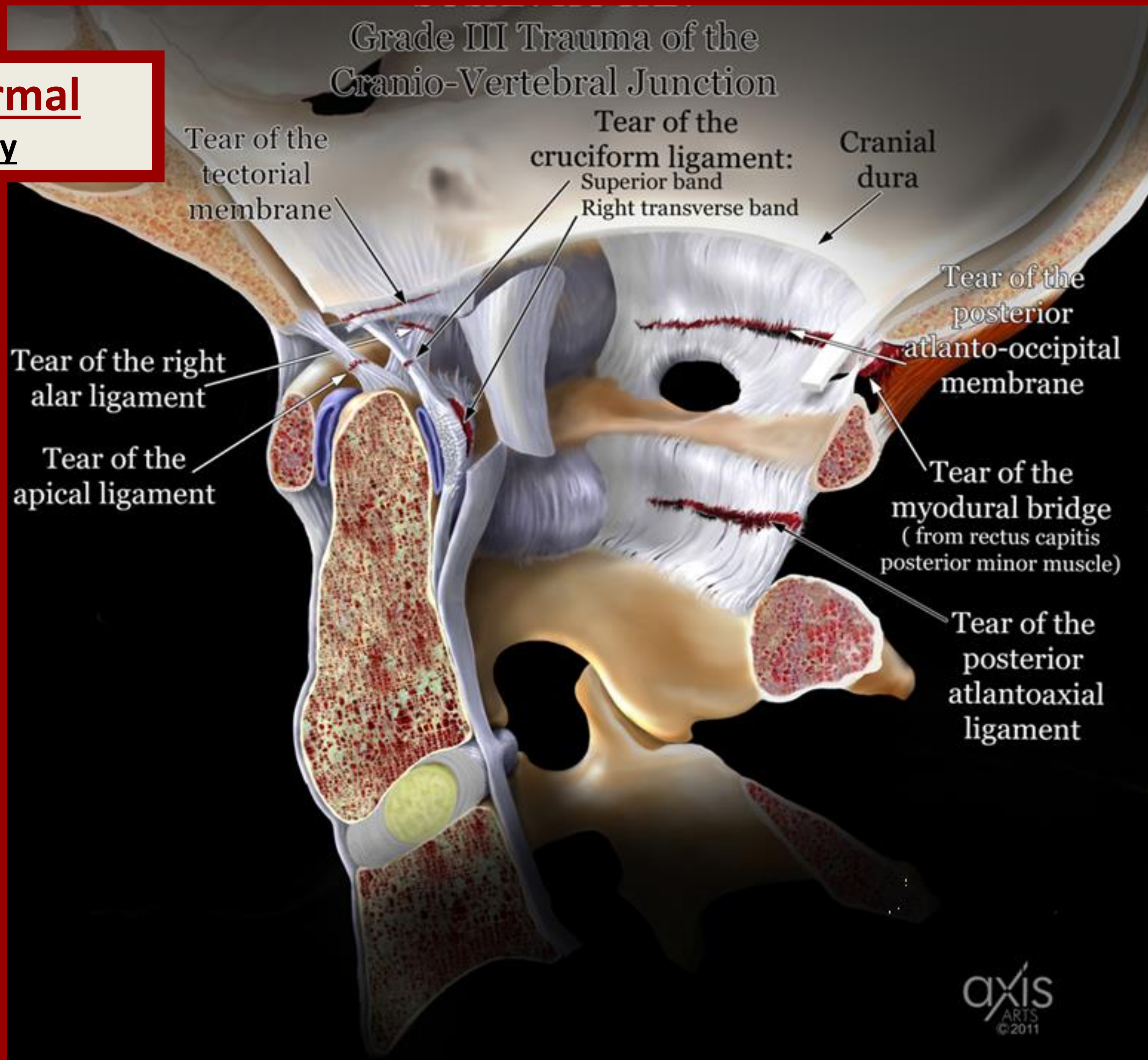



TECTORIAL
MEMBRANE
Dura and PLL
merge to become
Tectorial Membrane
Spinal Dura
(Thecal Sac)
axis
ARTS
©2013


LIGAMENTS & MEMBRANES
of the
CRANIO-VERTEBRAL JUNCTION
Tectorial membrane
Cruciform ligament:
Superior band
Right transverse band
Cranial dura
Apical ligament
Right alar ligament
Anterior alantoaxial ligament
Posterior atlanto-occipital membrane
Myodural bridge
(from rectus capitis posterior minor muscle)
Posterior atlantoaxial ligament
Anterior longitudinal ligament
Posterior longitudinal ligament
axis ARTS ©2011

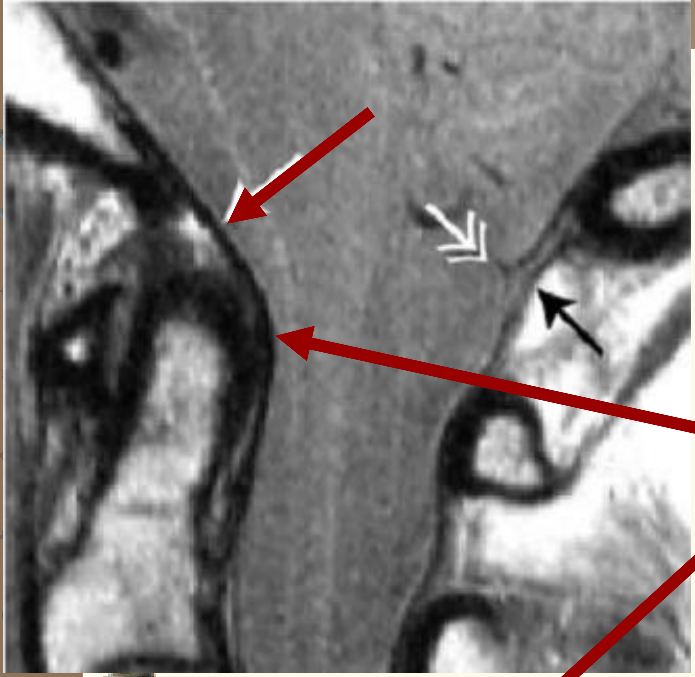
Abnormal

Anatomy



Normal Anatomy

Mid-sagittal view of the tectorial membrane.

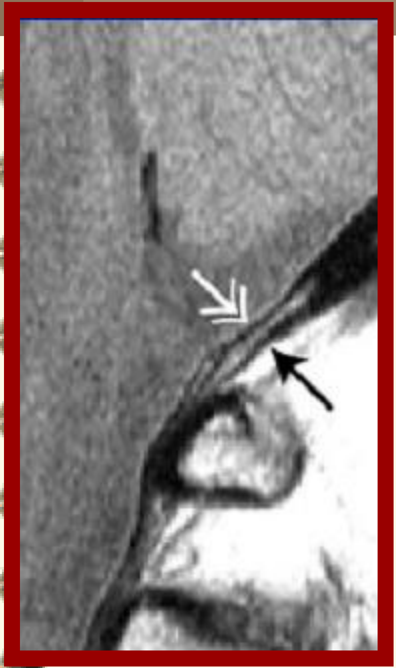


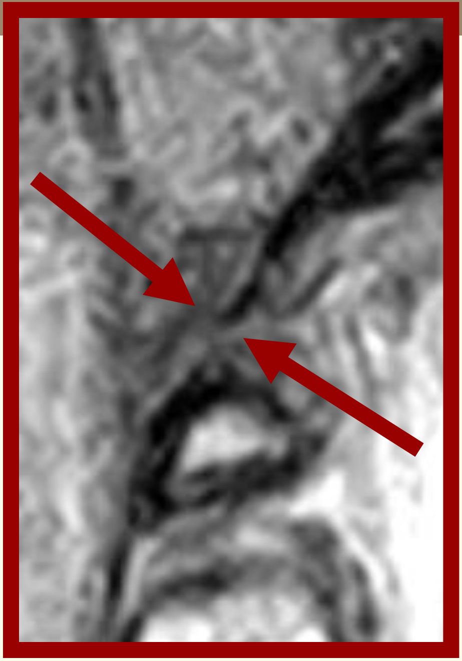
Normal tectorial membrane (red arrows).

Normal tectorial membrane from the literature (**upper left image** depicted by a single white arrow).

Abnormal tectorial membrane from the literature **upper middle image**.

Patient's Abnormal Tectorial Membrane
with near complete disruption (**upper right image** red line), classified as a grade 3 lesion involving greater than 2/3rds of the width of the membrane. Only the dura mater is remaining.





Normal posterior atlanto-occipital membrane (upper left image-black arrow) and the dura mater (double white arrow), which is separated from the membrane in this particular case, is normal.

Abnormal posterior atlanto-occipital membrane is gray and ill-defined (upper middle image-black arrow). The dura mater shows an anterior flap (infolding indicated by double arrow) indicating a transverse rupture, classified as grade 3.

Patient's Abnormal Posterior Atlanto-Occipital Membrane (upper right image-red arrow), high-grade 3 lesion.

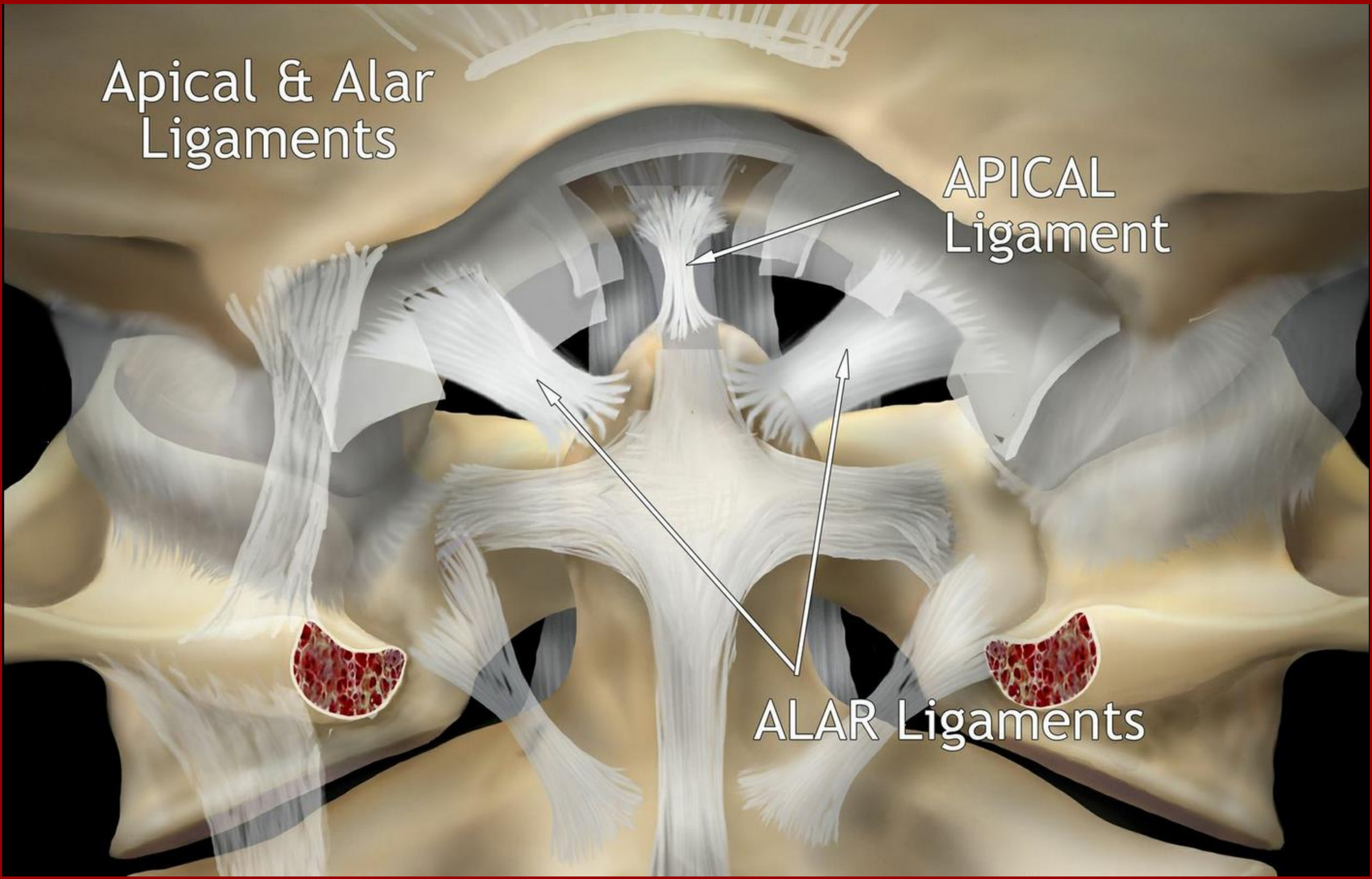
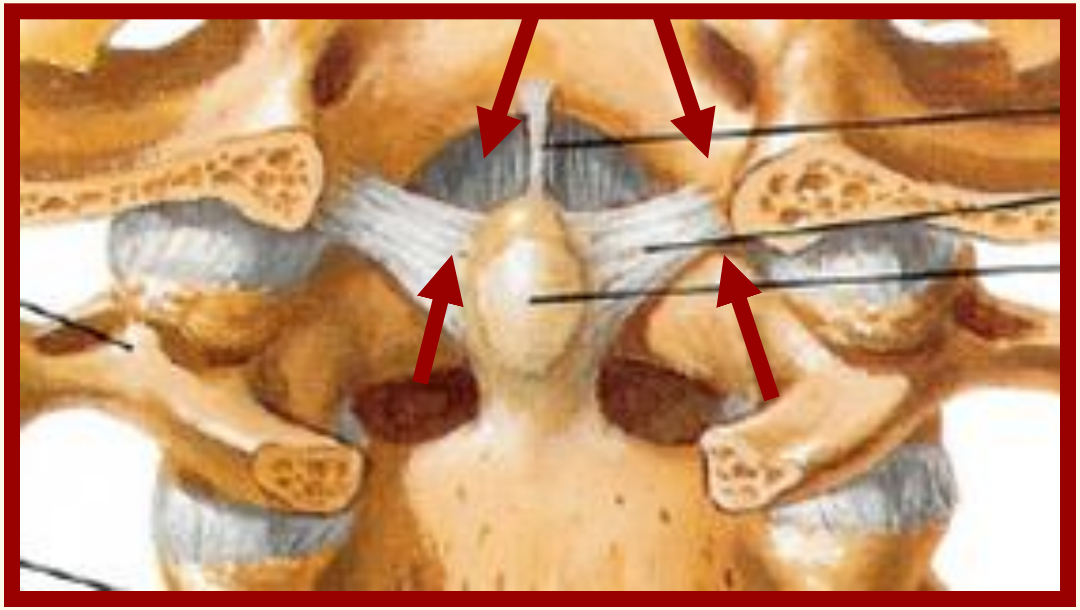
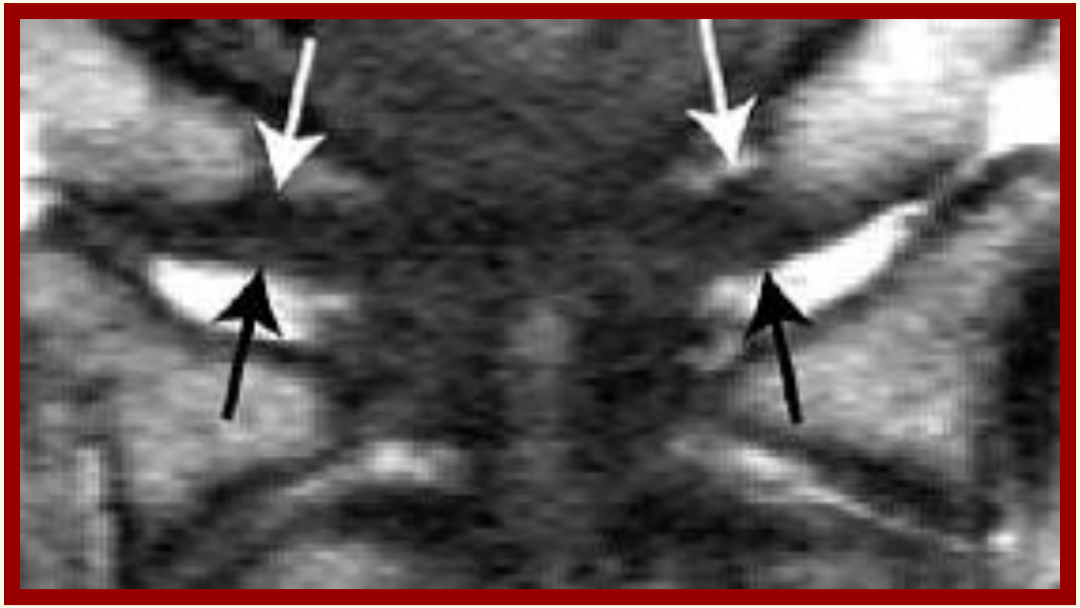
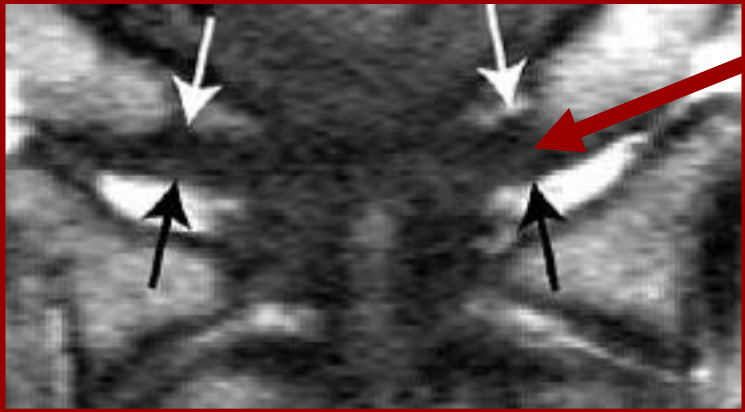

Apical & Alar Ligaments
APICAL Ligament
ALAR Ligaments

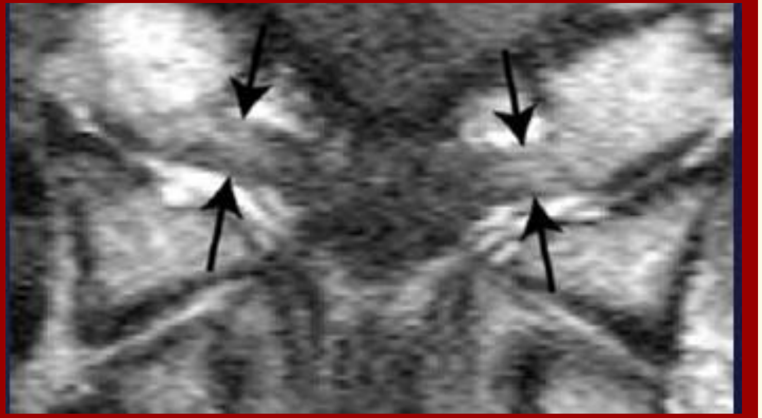
Diagram of the Alar ligaments



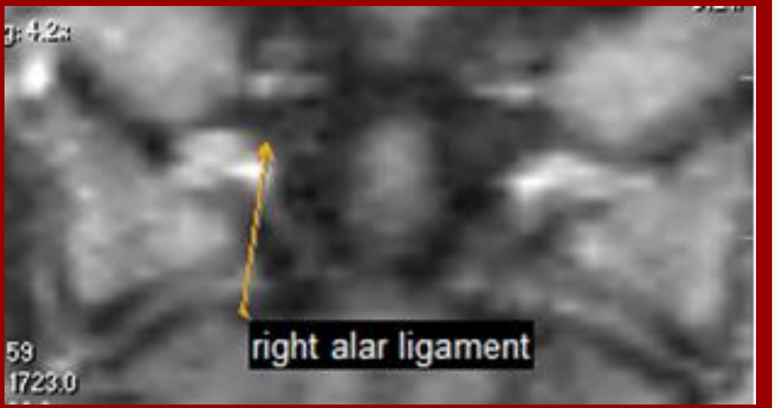




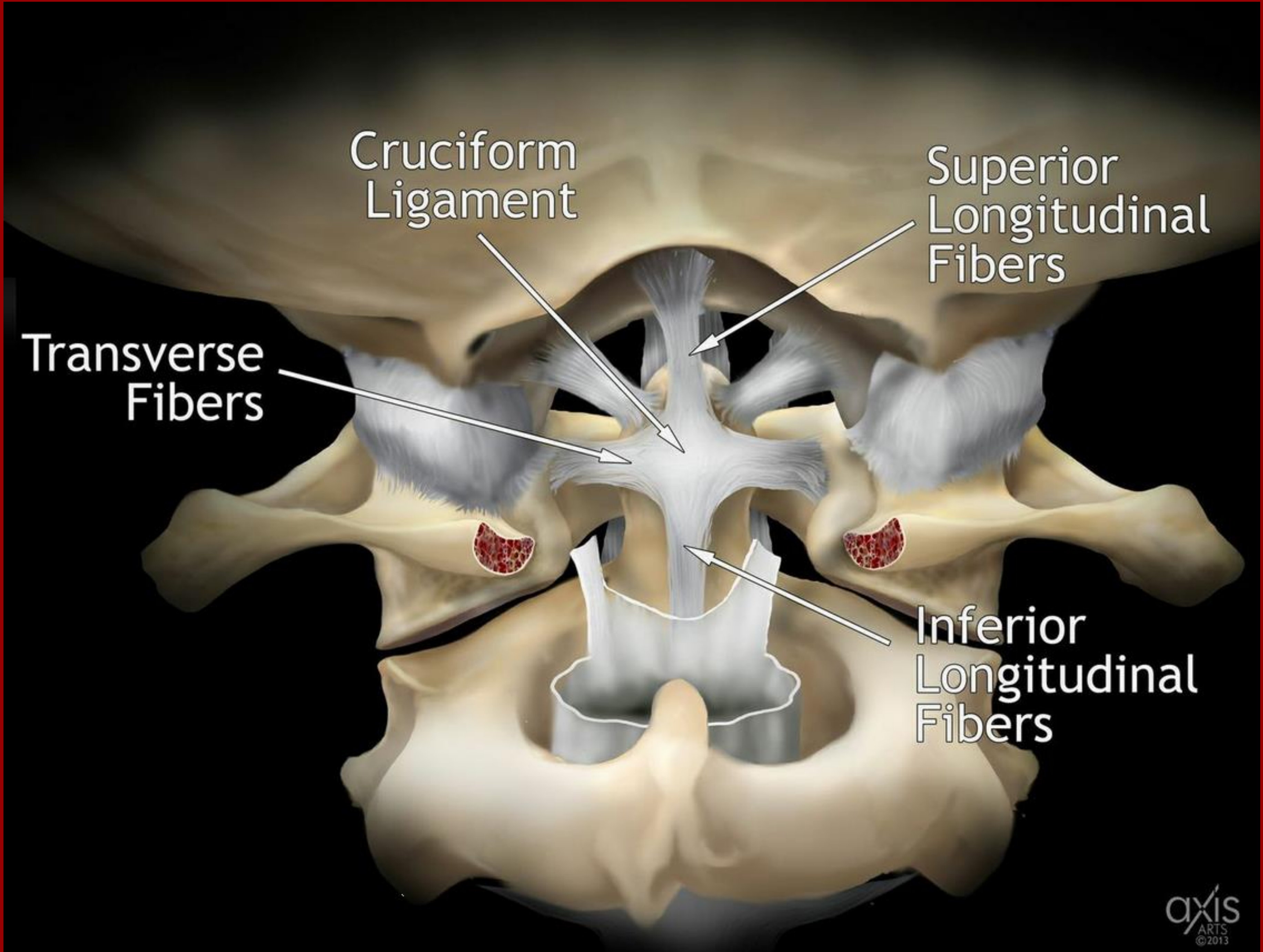
<u>Normal Alar ligaments</u> from the literature are well defined, appearing dark, and can be followed from the posterior part of the dens axis to the occipital condyles (arrows).



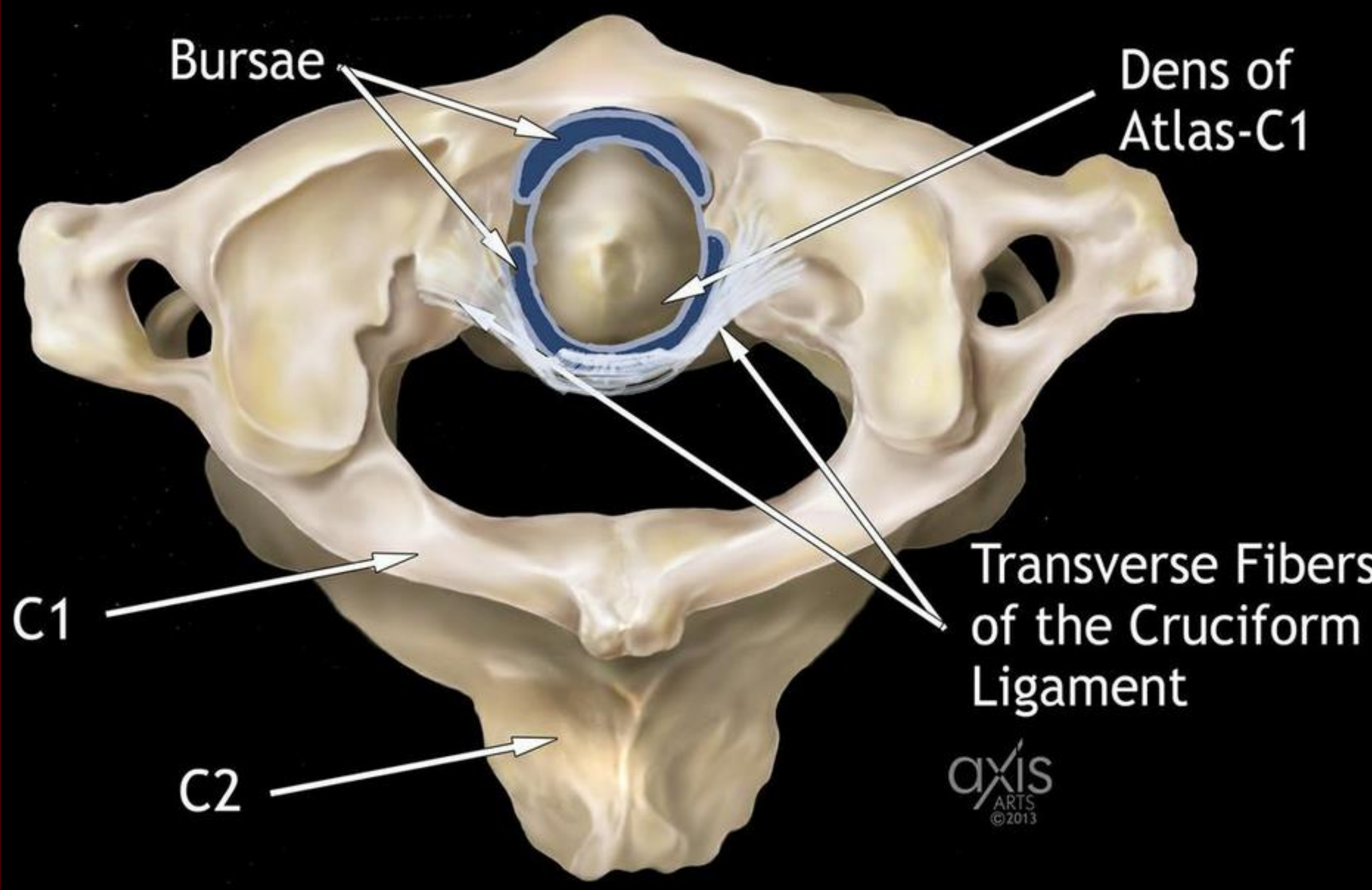
Abnormal Alar ligaments from the literature show high signal intensity, appearing light-gray, on both sides, most prominent in the lateral parts (arrows).

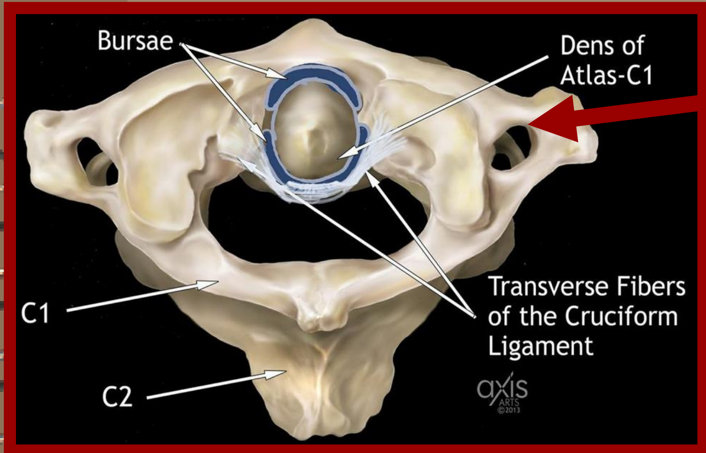


<u>Patient's Abnormal Alar ligaments</u> show high signal intensity, appearing light-gray, on both sides, most prominent in the lateral parts

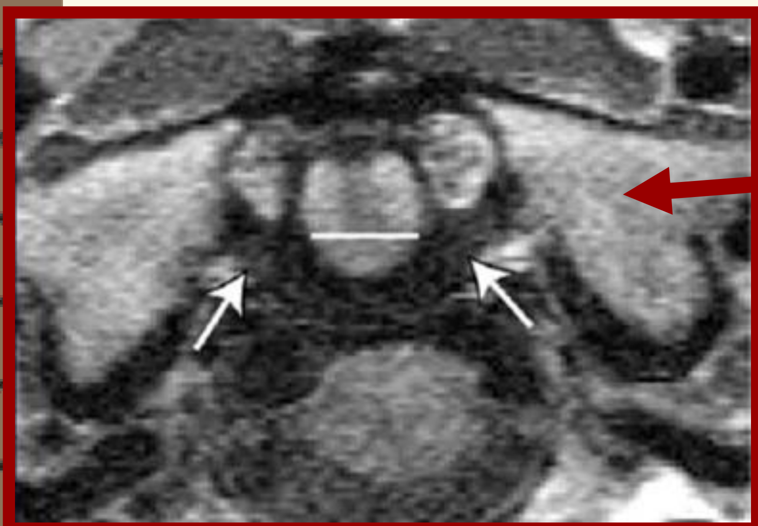

Cruciform
Ligament
Superior
Longitudinal
Fibers
Transverse
Fibers
Inferior
Longitudinal
Fibers
axis
ARTS
©2013

TRANSVERSE BANDS of the CRUCIFORM LIGAMENT



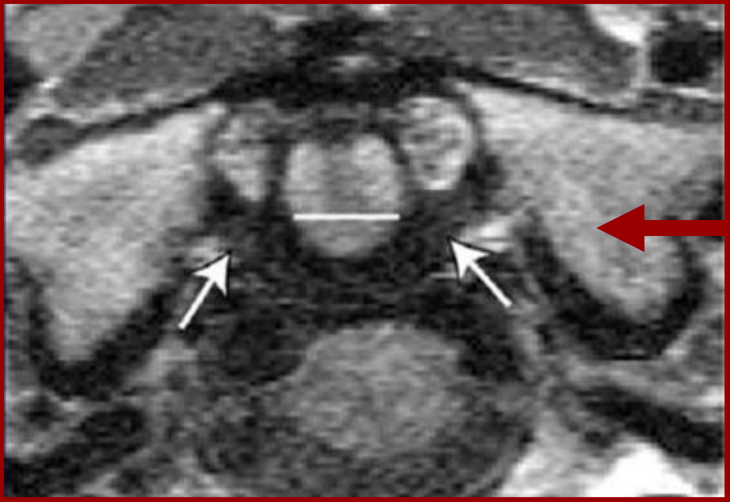


<u>Diagram of the transverse bands</u> of the cruciform ligament of the Atlas.



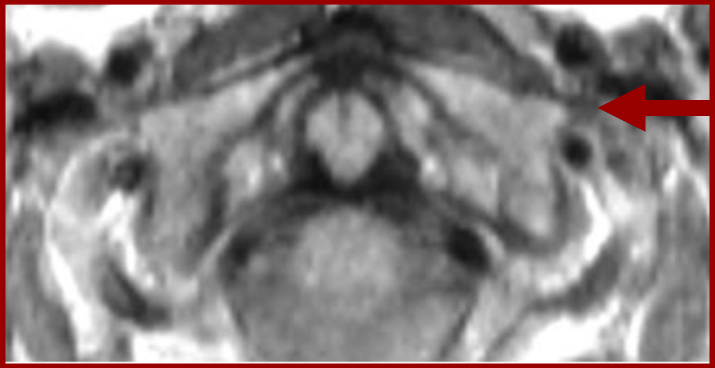
Transverse image from the literature shows low signal intensity indicating a **<u>Normal ligament</u>** appearing dark (arrows).

<u>Patient's Abnormal</u> asymmetry of the transverse bands of the cruciform ligament. The cruciform ligament is ill defined and shows generally increased signal intensity, appearing gray.



Proton-weighted images (TR/TE 2200/15) of a normal transverse ligament.

Normal transverse bands of cruciform ligament with low signal intensity indicating a normal ligament appearing dark (arrows).



Abnormal transverse bands of the cruciform ligament is ill defined and shows generally increased signal intensity (arrows), appearing gray.

Patient’ s Abnormal disrupted transverse bands of the cruciform ligament.

Clinical evaluation/missed injuries

1. The reported ***frequency of missed injuries in the cervical spine varies from 4% to 30%.***

2. The most common reason cited for missed injuries is an ***inadequate radiographic examination.***

3. **It has been recognized that even in the absence of fractures, clinically significant instability can exist.** Spinal cord injury without radiographic abnormality has been found to occur in 0.8% of adults with blunt cervical spine trauma.

4. When injuries are missed on initial assessment, a delay in diagnosis occurs that puts the patient at risk for progressive instability and neurologic deterioration. In one series by Davis *et al.*, ***29% of patients with missed injuries developed permanent neurologic sequelae.***

1. It is clear that a systematic approach to the evaluation of suspected cervical spine injuries is important to avoid these pitfalls.

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