Imaging of Hard and Soft Tissues

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Oral and Maxillofacial Radiologist

Lecture contents provided through the courtesy of Dr Tom Huang

Imaging Modalities

– Intraoral radiographs
– Extraoral radiographs
– Computed tomography
– Cone beam computed tomography
– Magnetic resonance imaging
– Ultrasound
– Nuclear medicine

Intraoral Radiographs

– Bitewings
– Periapicals
– Occlusographs

- Two dimensional image of a 3D object.
- Limited FOV
- **Dental** pathology
    - i.e. Caries, periodontal disease, peripical inflammatory pathology.
- Bony abnormalities ...?
- CAN NOT fully exclude presence of disease.

“Toothache”

Extraoral Radiographs

- **Panoramic Radiograph (OPG)**
- Cephalometric Radiograph (Lat / PA)
- Other Facial Views
  - Oblique Lateral
  - SMV
  - Waters
  - Reverse Towne …

- Good overview
- Large FOV
- Two dimensional image of a 3D object
- Bony abnormalities
- CAN NOT fully exclude presence of disease.


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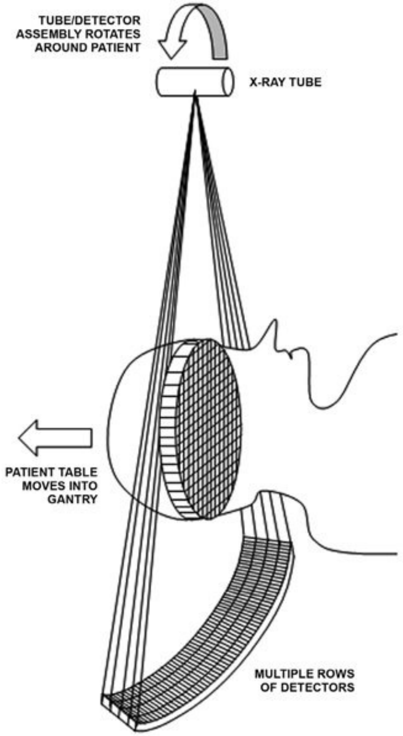
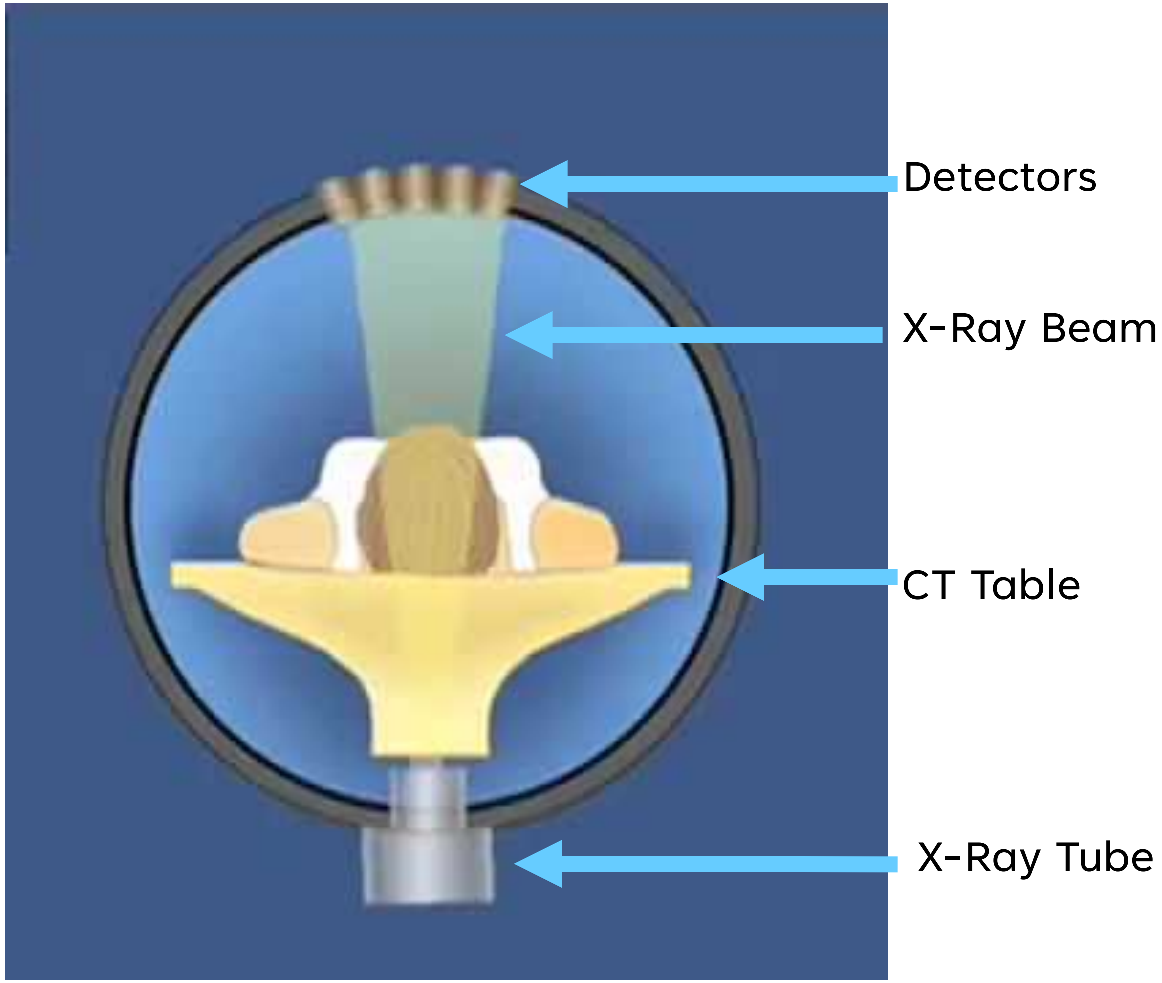
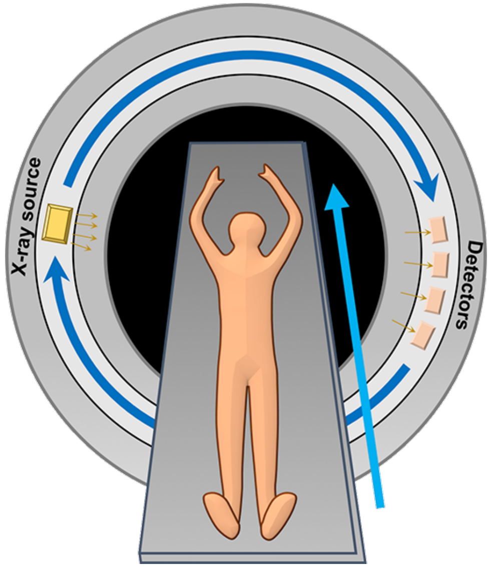
Computed Tomography

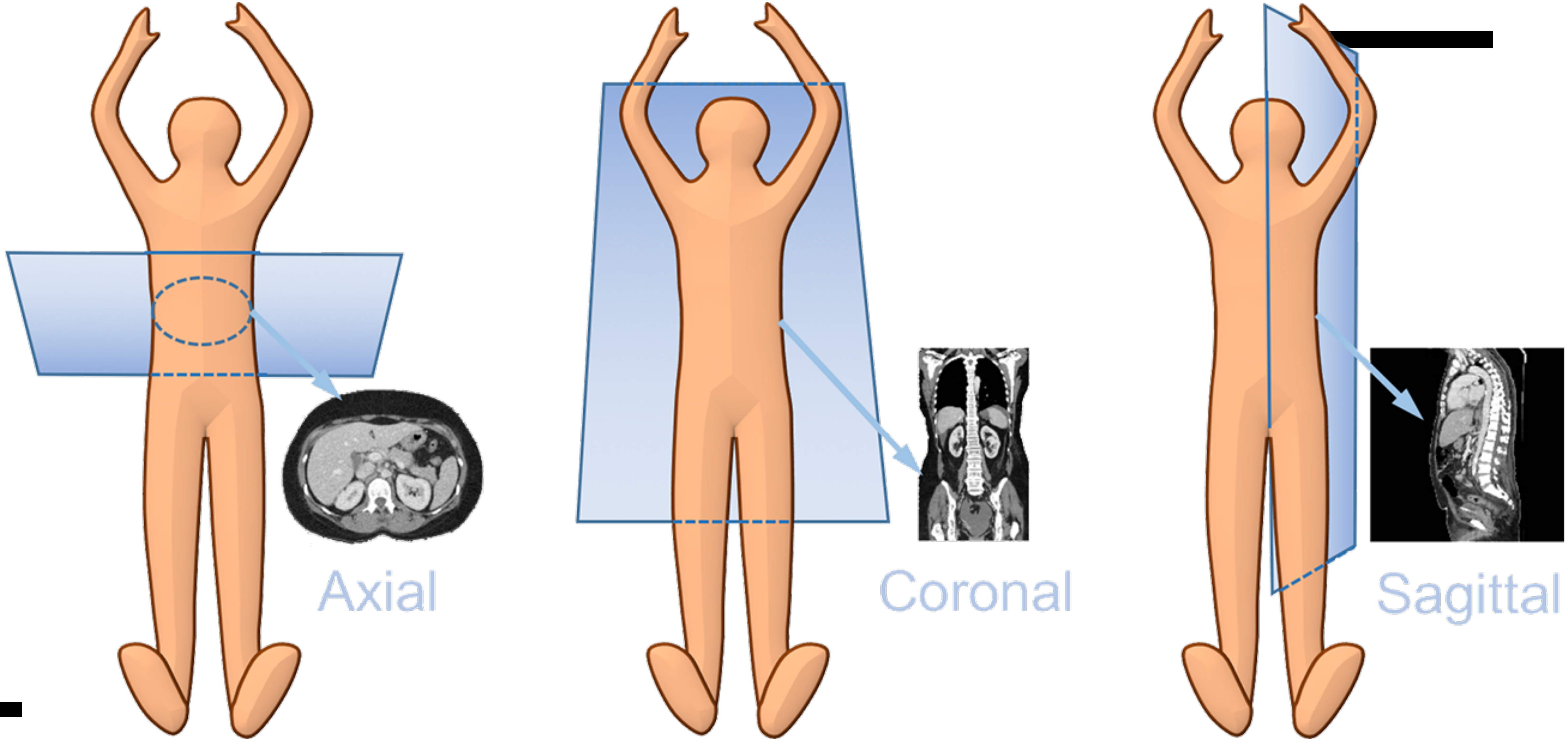
Multislice CT AKA Multidetector CT, Sprial CT…





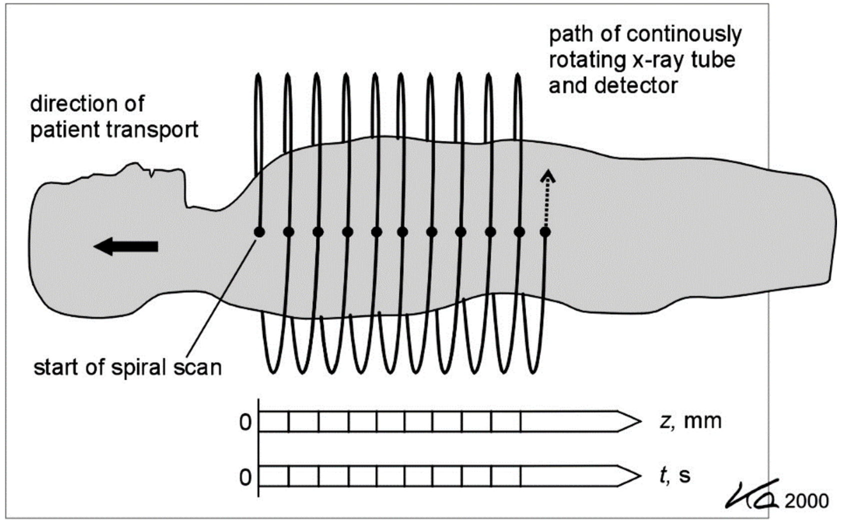

SIEMENS
SOMATOM Force


X-ray source
Detectors

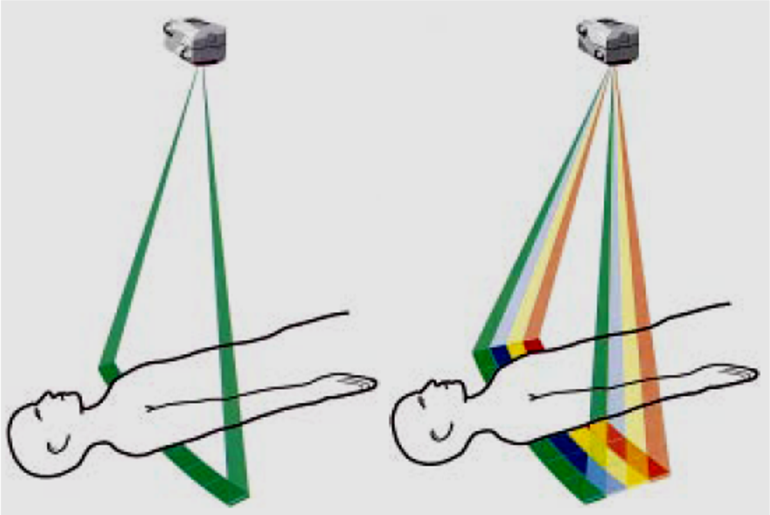

Axial
Coronal
Sagittal

Historical Development of CT

– Sixth Generation CT: Helical (1990's)
  - ✓ Slip-ring technology developed (allows gantry to rotate continuously without wires)
  - ✓ Helical CT scanners acquires data while table is moving



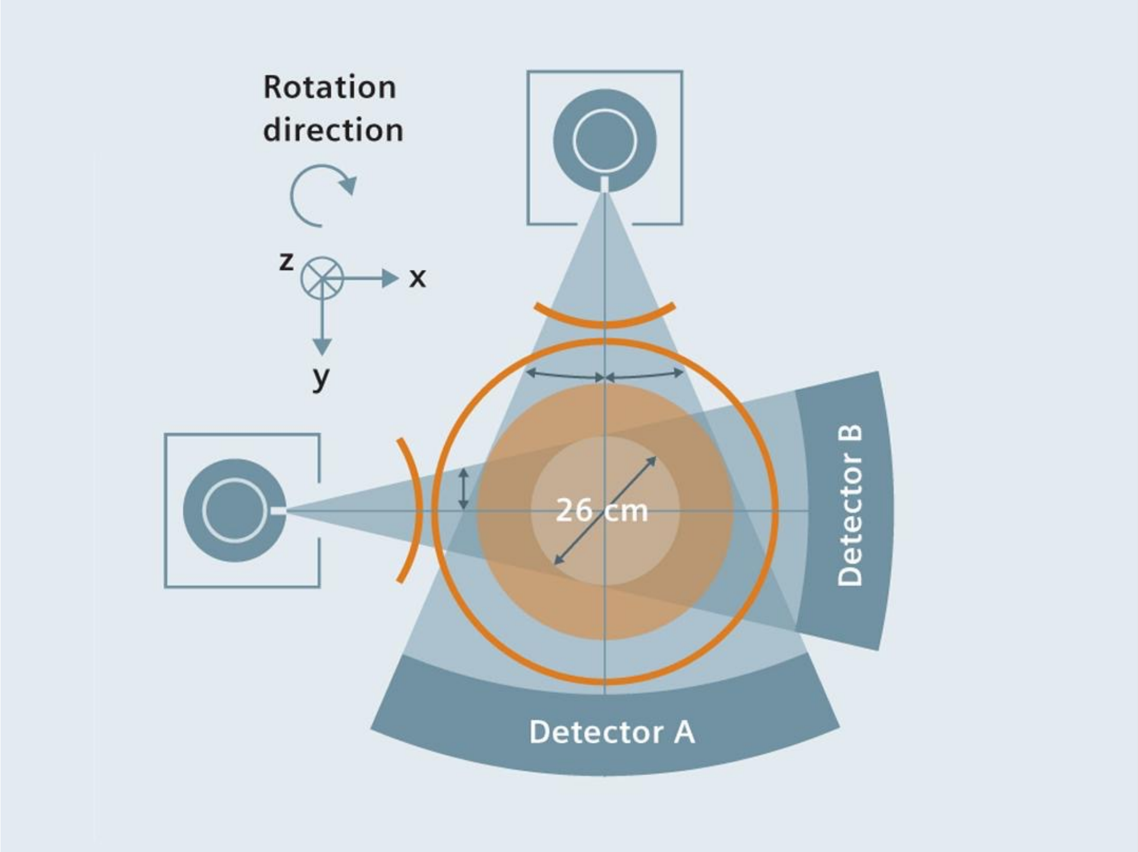
c.f. Kalendar WA, Computed Tomography, Second Edition, pg. 79, 2005



❖ Seventh Generation CT (late 1990's – 2000)
  - ✓ Multiple Detector Array

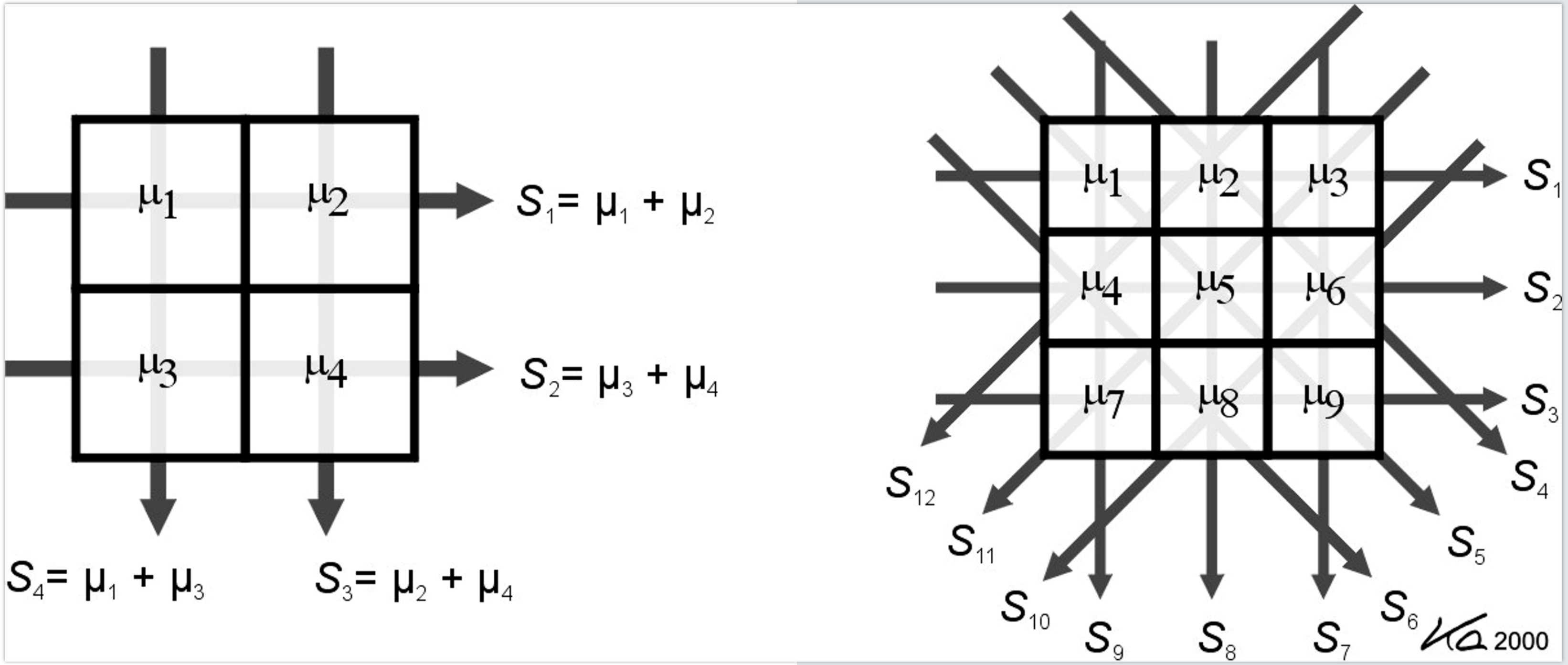
c.f. www.impactscan.org

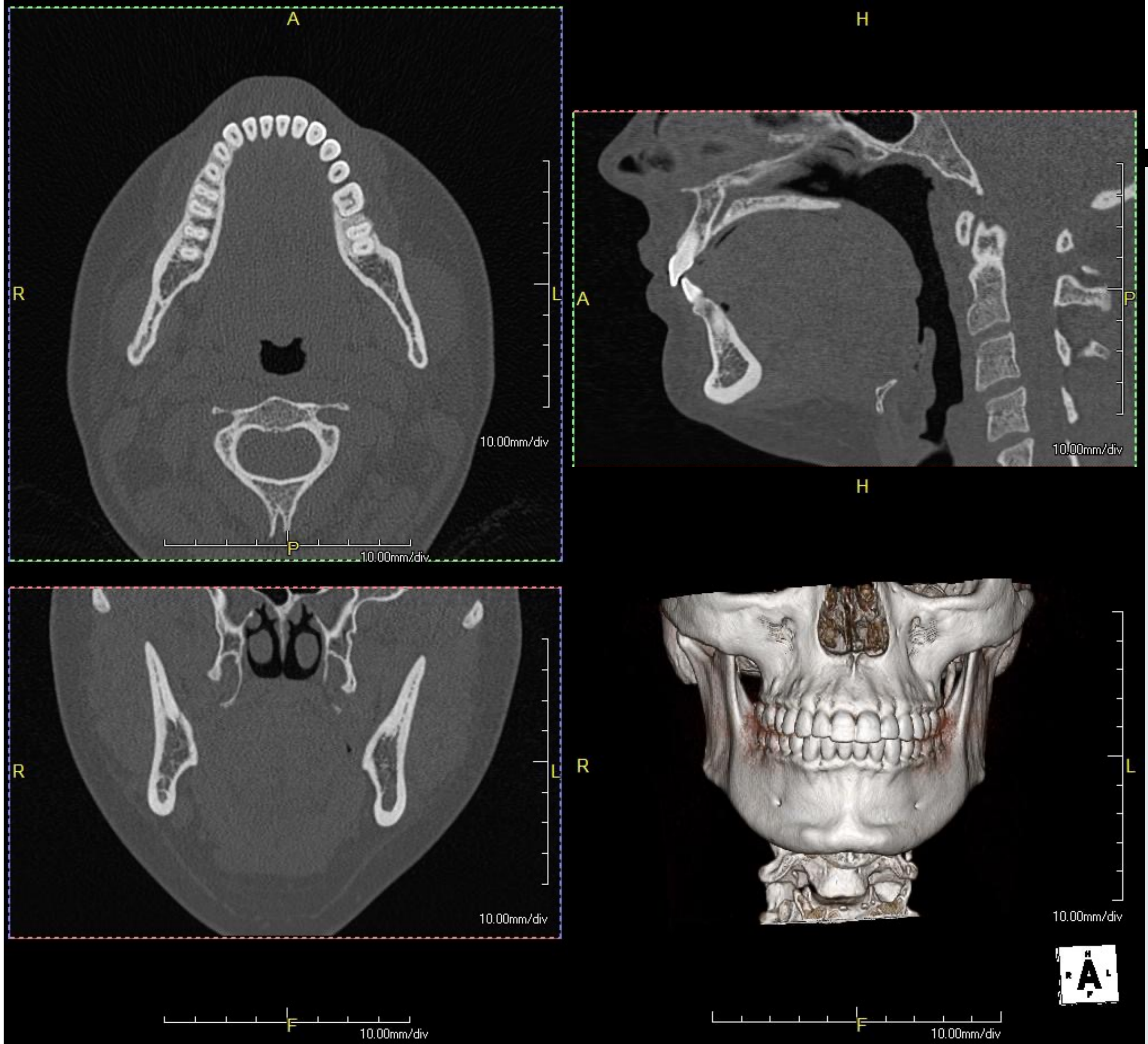
Dual Source CT



Tomographic Reconstruction

– An algorithm is used to produce the CT image (attenuation coefficient map)
– Filtered back projection is most widely used in clinical CT scanners

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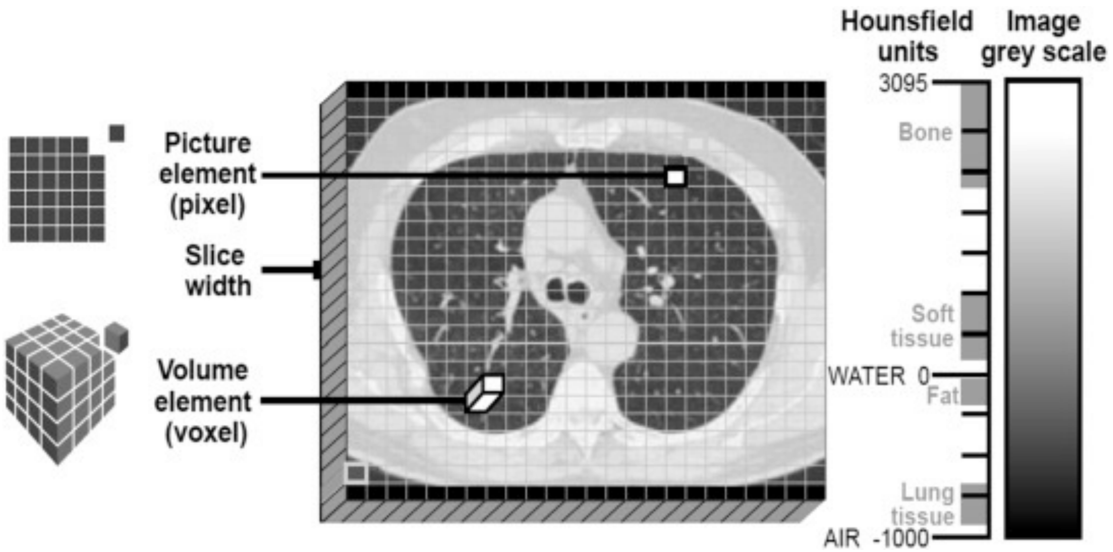
Hounsfield unit (HU)

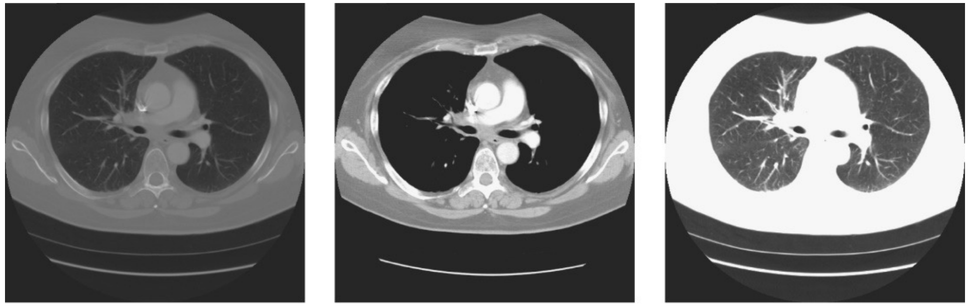
- The **Hounsfield unit (HU)** is a quantity commonly used in CT scanning to express CT numbers in a standardised and convenient form.
- Hounsfield units, created by and named after Sir Godfrey Hounsfield, are obtained from a linear transformation of the measured attenuation coefficient.
- This transformation is based on the arbitrary definitions of air and water.

CT numbers / Hounsfield Unit

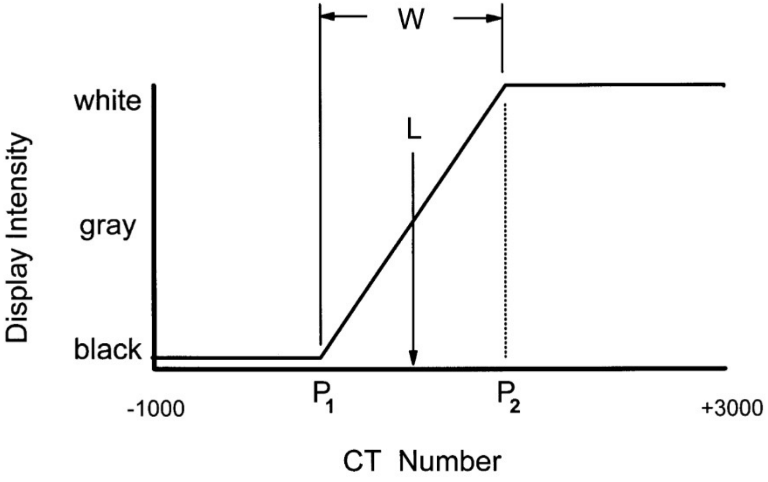


Substance	HU
Air	−1000
Lung	−500
Fat	−100 to −50
Water	0
CSF	15
Kidney	30
Blood	+30 to +45
Muscle	+10 to +40
Grey matter	+37 to +45
White matter	+20 to +30
Liver	+40 to +60
Soft Tissue, Contrast	+100 to +300
Bone	+700 (cancellous bone) to +3000 (dense bone)

Digital Image Display: Window/Level



W = 4095, L = 1048 | W = 600, L = –100 | W = 700, L = –650



$P_1 = L - \frac{1}{2} W$
$P_2 = L + \frac{1}{2} W$

– Computer monitors and laser imagers for printing have about 8 bits of display fidelity (2^8=256)

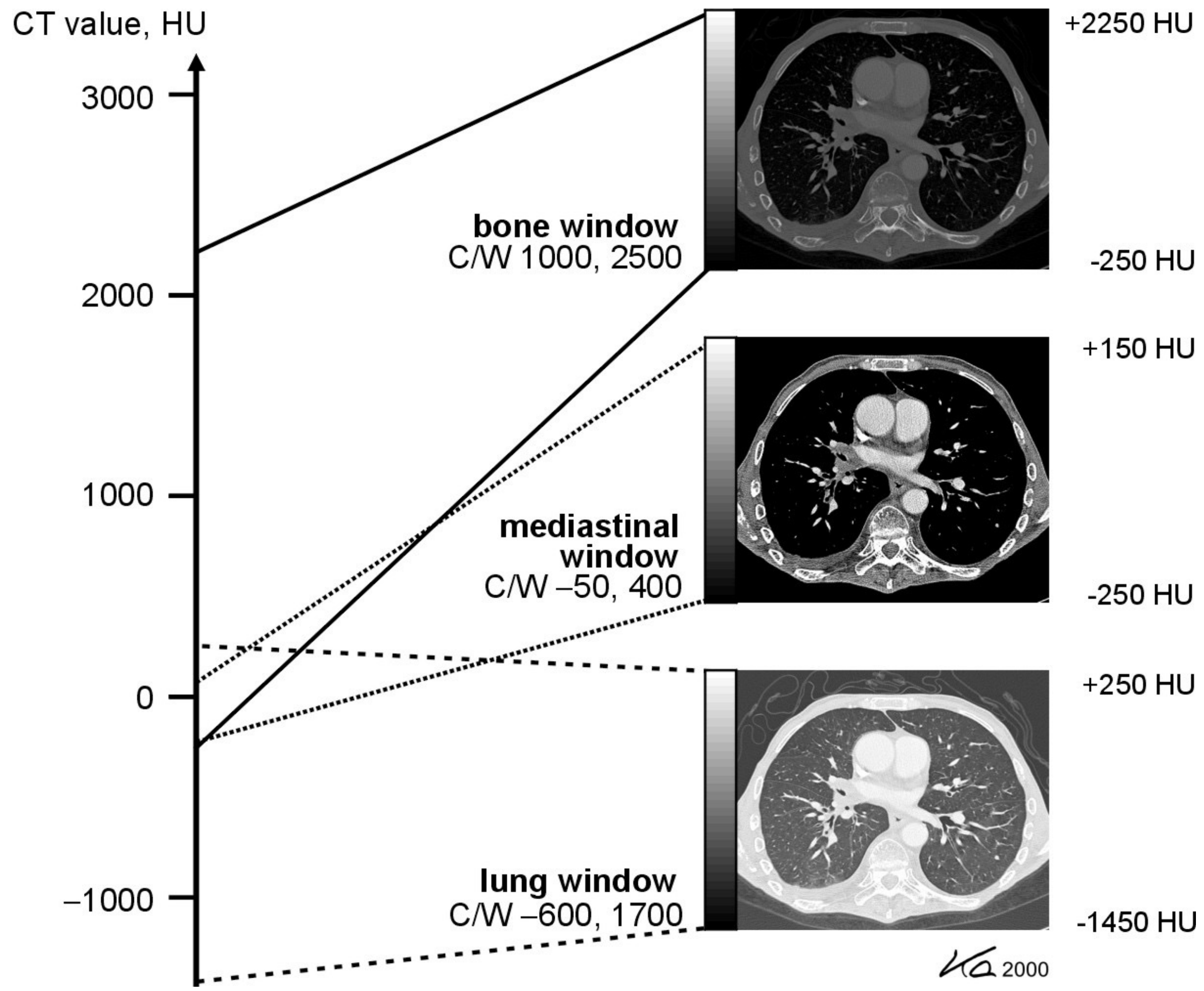
– The 12-bit CT images must be reduced to 8 bits to accommodate most image display hardware

– The window width (W) determines the contrast of the image, with narrower windows resulting in greater contrast

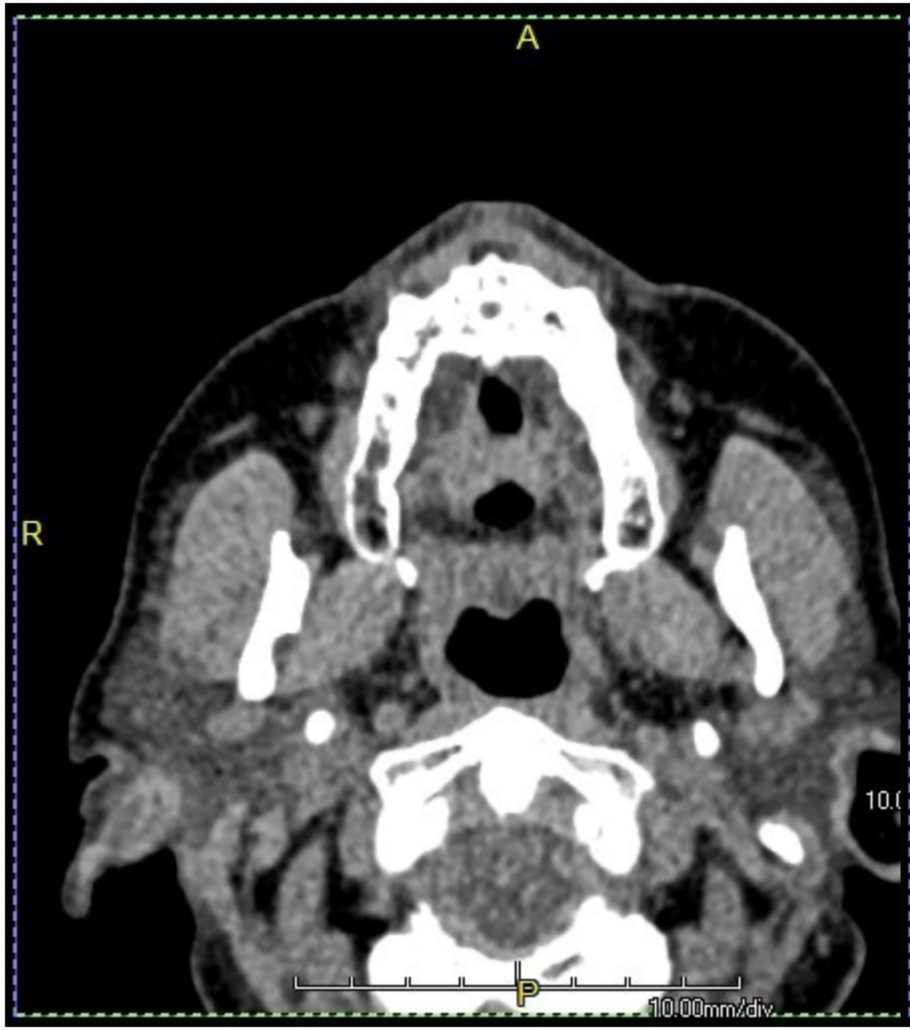
– The level (L) is the CT number at the center of the window

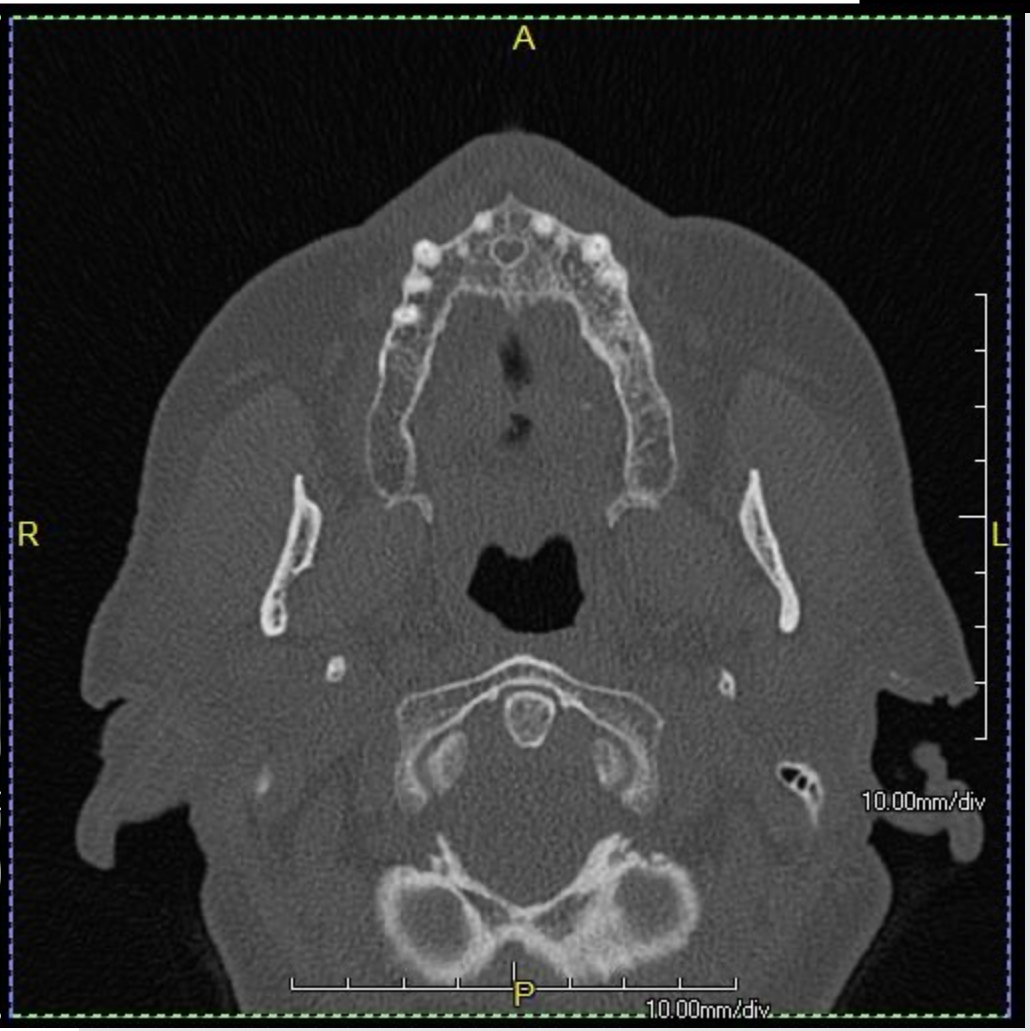
c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 359.

Digital Image Display: Window/Level



c.f. Kalendar WA, Computed Tomography, Second Edition, pg. 32, 2005





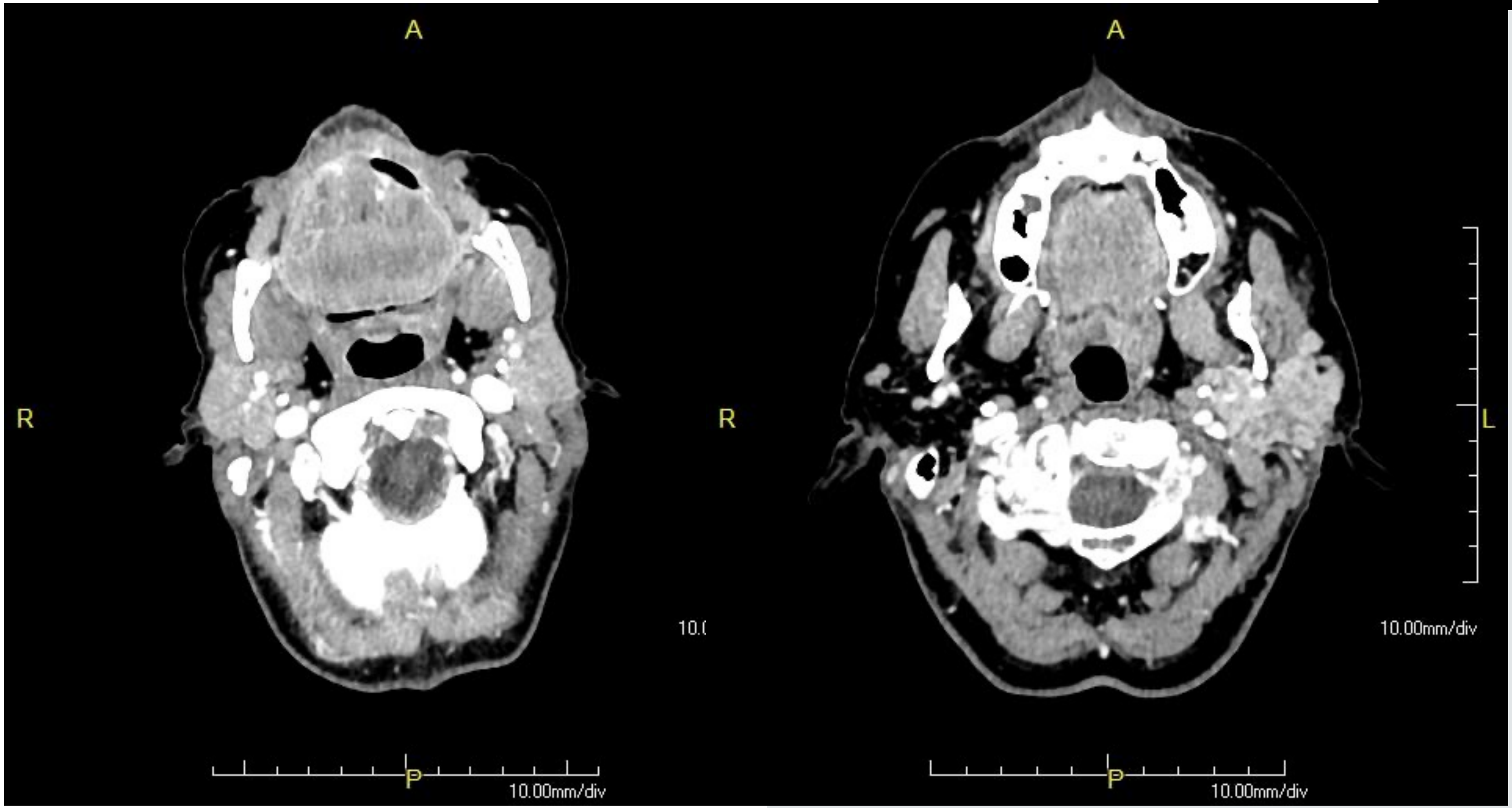
W:300, L:50

W:3000, L:500

Contrast Agents

– Frequently Iodine

– Help better visualize structures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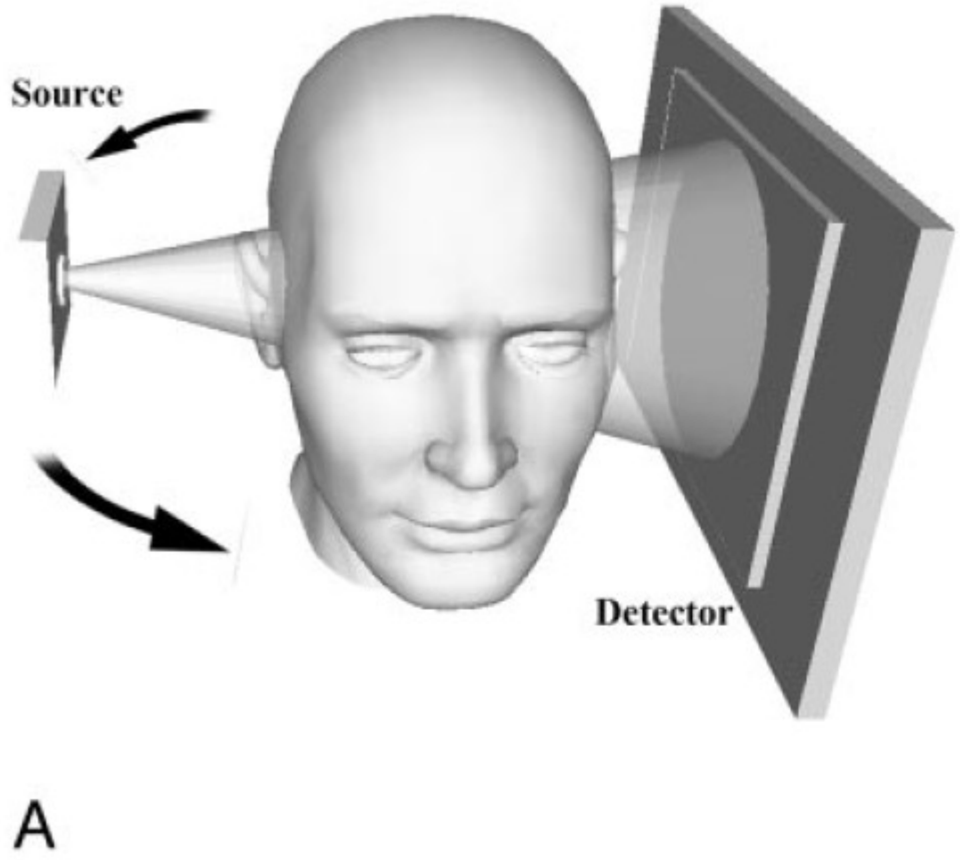
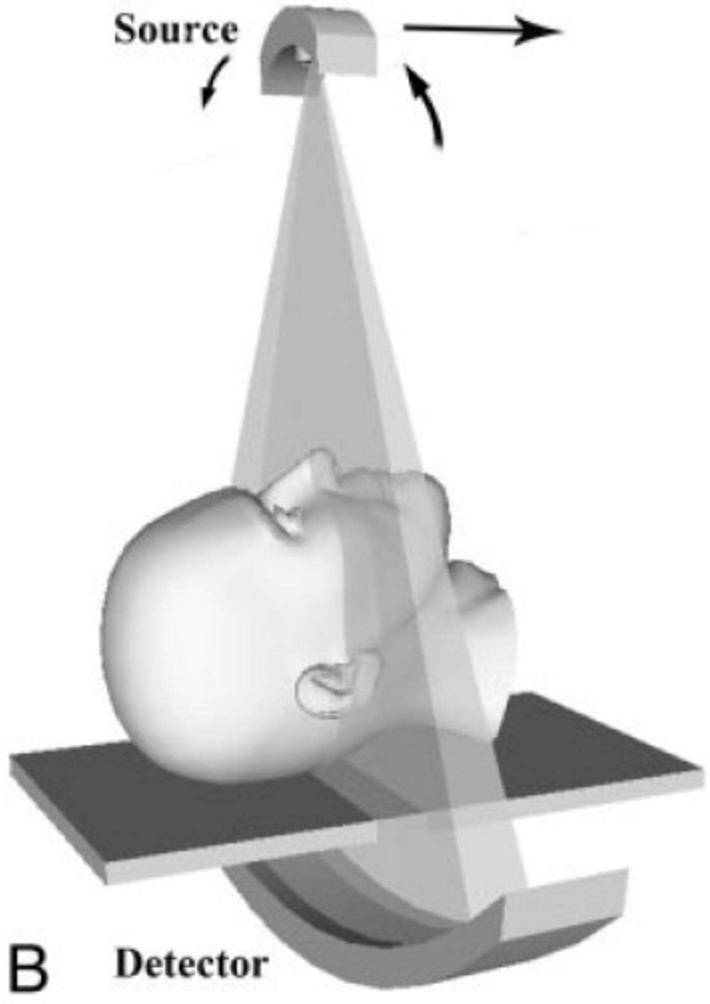
MSCT Take Home

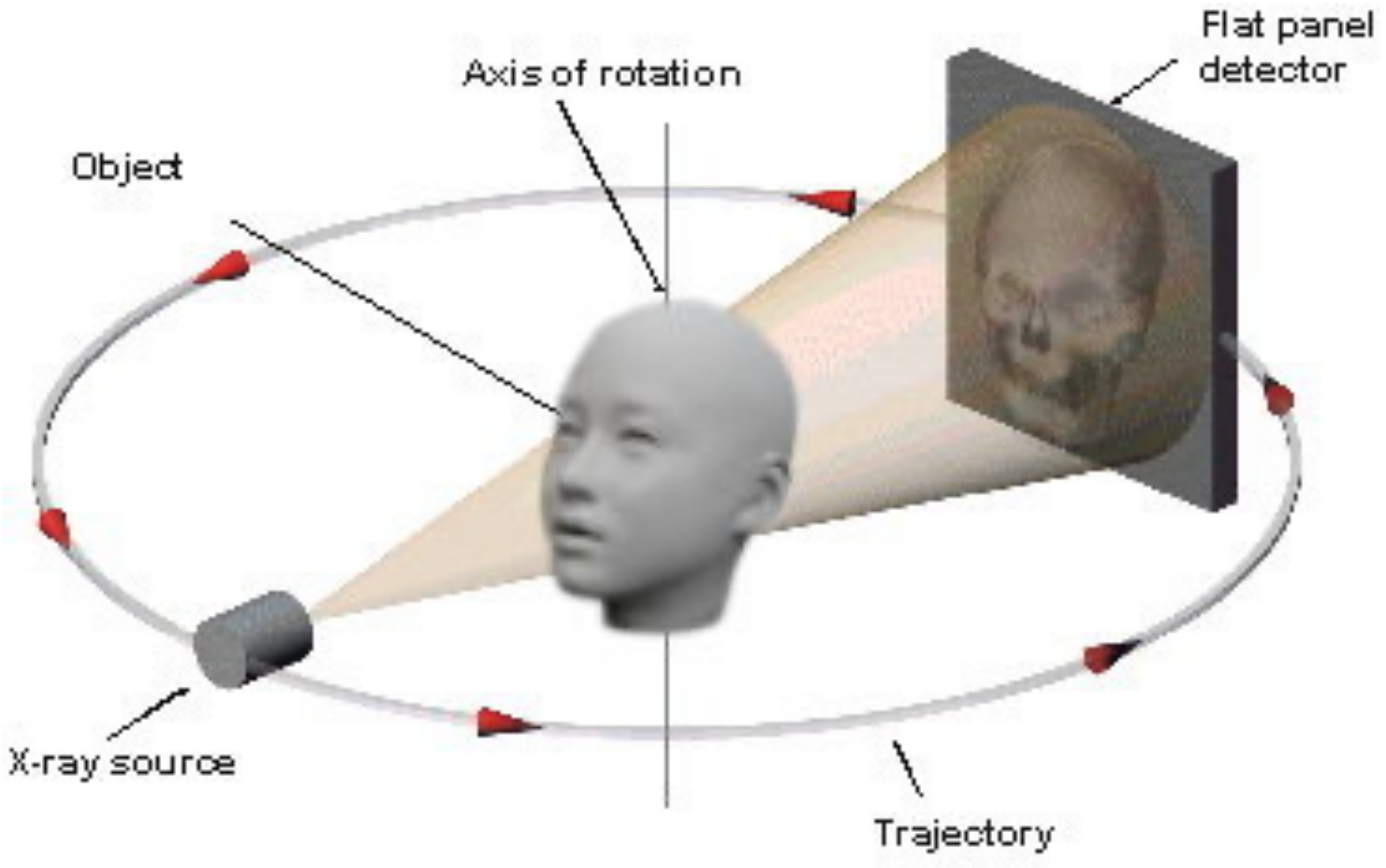
- 3D Imaging & Dimensionally accurate
- Multiplanar reformatting
- **Bony pathology**
- **Shows soft tissue but not as well as MRI**
- Contrast use
- Superior Speed
- Supine position
- Hounsfield Units → Tissue density
  - Air: -1000, Water: 0

CONE BEAM VOLUMETRIC TOMOGRAPHY



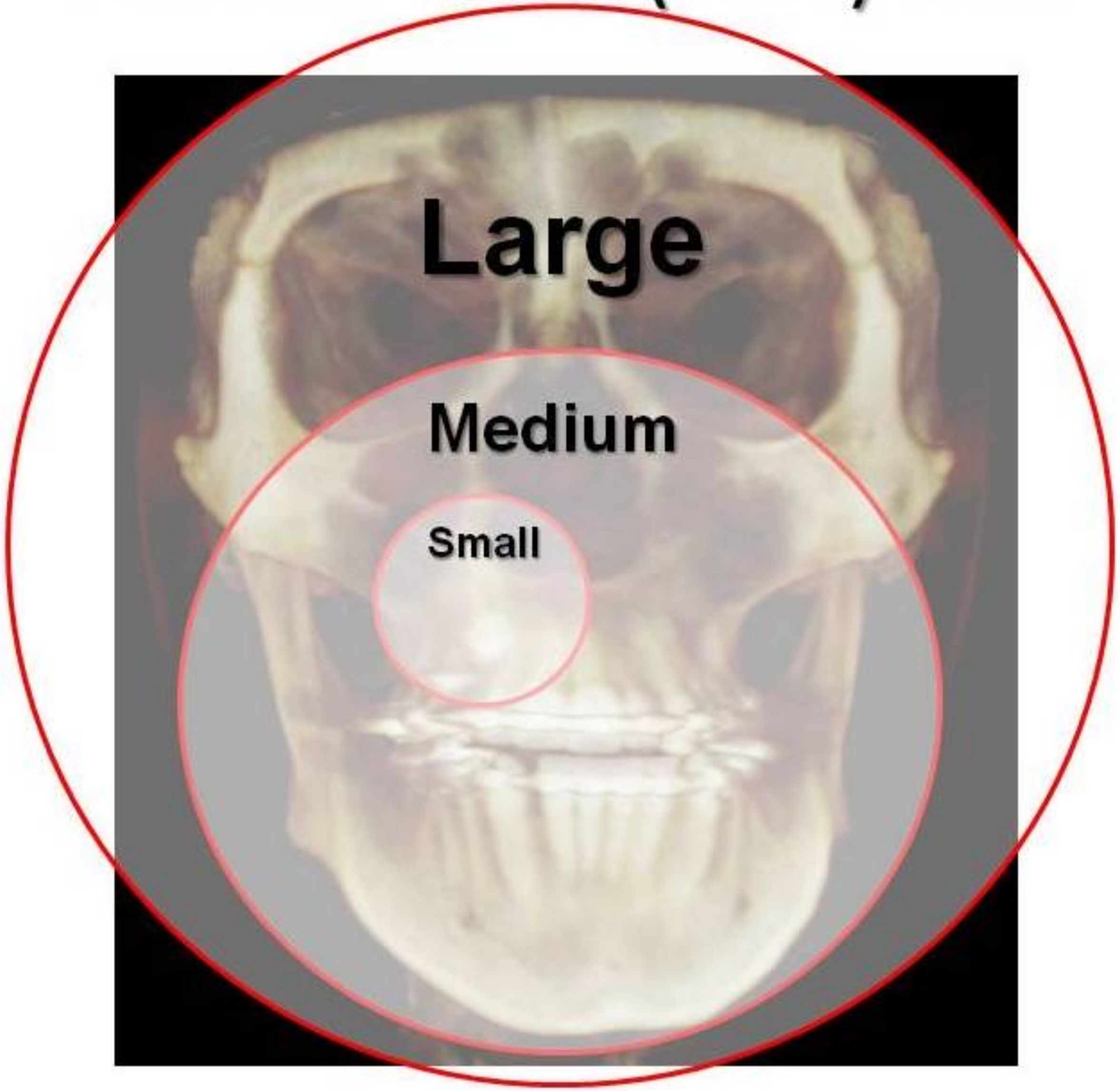


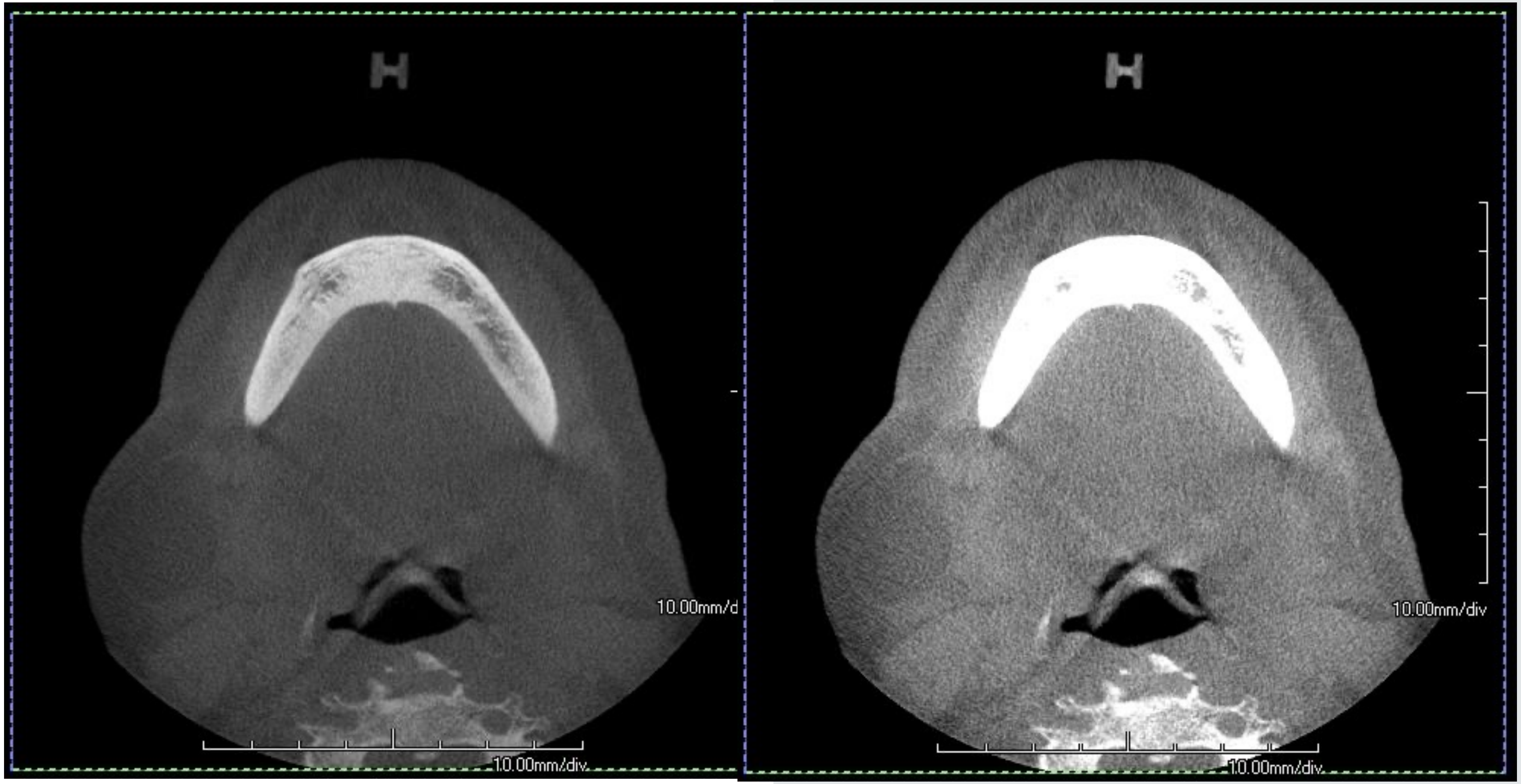

GALILEOS



Flat panel detector
Axis of rotation
Object
X-ray source
Trajectory

Field of View (FOV) Size

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Radiation Dose Levels

Type of Examination	Effective Dose (ICRP 2007) MICROSIEVERTS
Bitewing (E)	5-9
OPG	4.7-54
CBCT	27-1073
CT	180-1160

Ludlow et al. 2008, Ludlow et al. 2008, Ngan et al. 2003, Loubele et al. 2009, Gavala et all. 2008, Gihbell et al. 2005, Visser et al. 2000, Loubele 2005, Wuomalainen et al. 2009, Okano et al. 2009, Roberts et al. 2009, Kumar et al. 2007, Schultze et al. 2004.

Table 3

Effective doses for Adult phantom by exposure protocol and field of view - ANOVA p value and Tukey HSD maxilla dentition mandible

	maxila	dentition	mandible	both arches	arches + TMJ	standard ceph	average	ANOVA p=.0055 Tukey HSD*
Quick Scan +	4	5	8	8	9	11	8	C
Quick Scan	20	23	34	39	43	54	36	BC
Standard	32	44	61	70	79	85	62	B
High Resolution	65	85	127	148	159	171	126	A
average	30	39	58	66	73	81	58	
ANOVA p<.0001 - Tukey HSD*	C	BC	ABC	ABC	AB	A		

Ludlow and Walker 2013

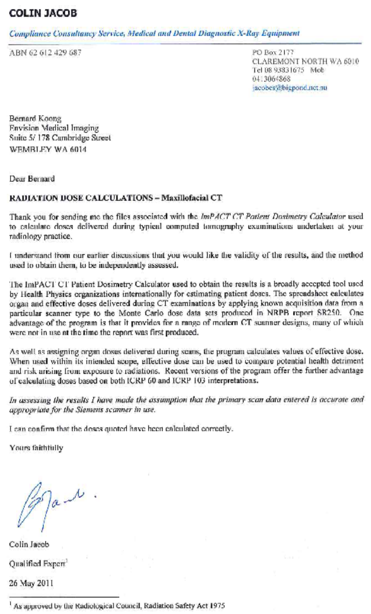
Multislice CT doses are very much protocol dependent –ie Radiologist dependent

The accuracy and validity of these dose calculations have been confirmed by an independent Qualified Expert as approved by the Radiological Council (Radiation Safety Act 1975) – May 2011

Multislice CT doses at Envision:

2007 ICRP 103 tissue weights

- Mandible: 40-99 µSv
- Maxilla: 31-77 µSv
- Orofacial Glabella-chin: 100-180 µSv



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Envision Medical Imaging
Suite 5/ 178 Cambridge Street
WEMBLEY WA 6014

Dear Bernard

RADIATION DOSE CALCULATIONS – Maxillofacial CT

Thank you for sending me the files associated with the *ImPACT CT Patient Dosimetry Calculator* used to calculate doses delivered during typical computed tomography examinations undertaken at your radiology practice.

I understand from our earlier discussions that you would like the validity of the results, and the method used to obtain them, to be independently assessed.

The ImPACT CT Patient Dosimetry Calculator used to obtain the results is a broadly accepted tool used by Health Physics organizations internationally for estimating patient doses. The spreadsheet calculates organ and effective doses delivered during CT examinations by applying known acquisition data from a particular scanner type to the Monte Carlo dose data sets produced in NRPB report SR250. One advantage of the program is that it provides for a range of modern CT scanner designs, many of which were not in use at the time the report was first produced.

As well as assigning organ doses delivered during scans, the program calculates values of effective dose. When used within its intended scope, effective dose can be used to compare potential health detriment and risk arising from exposure to radiations. Recent versions of the program offer the further advantage of calculating doses based on both ICRP 60 and ICRP 103 interpretations.

In assessing the results I have made the assumption that the primary scan data entered is accurate and appropriate for the Siemens scanner in use.

I can confirm that the doses quoted have been calculated correctly.

Yours faithfully

Colin Jacob

Qualified Expert[1]

26 May 2011

[1] As approved by the Radiological Council, Radiation Safety Act 1975

Radiation Dose Levels

MDCT:

- Variation between different types of scanners
- Imaging protocols substantially alter the doses delivered.

CBCT:

- Dependent on the type of unit and the protocols
- Not all CBCT scans deliver low radiation dose
- A smaller field of view (FOV) in one unit may not necessarily deliver less radiation than a larger FOV in another unit

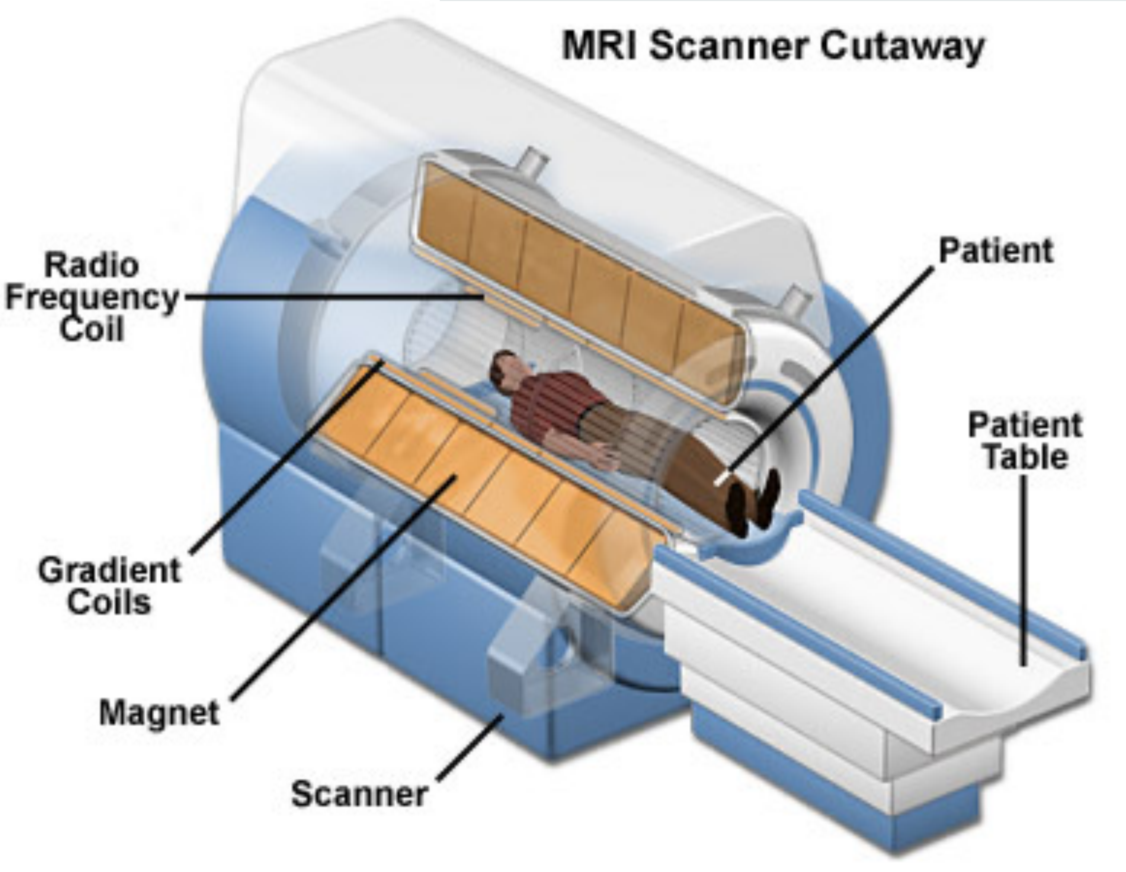
- CBCT may deliver doses greater than low-dose MDCT

- Significant challenges in comparisons:
  - between CBCT units
  - between the different imaging modalities

CBCT Take Home

- 3D Morphologic Study
- Dimensionally accurate
- Multiplanar reformatting
- **Dentoalveolar disease**
- Bony lesions but CT is preferred
- Poor soft tissue depiction
- Density measurements **not reliable**
  - No Hounsfield units
  - Scattered radiation
  - Artefacts

MAGNETIC RESONANCE IMAGING



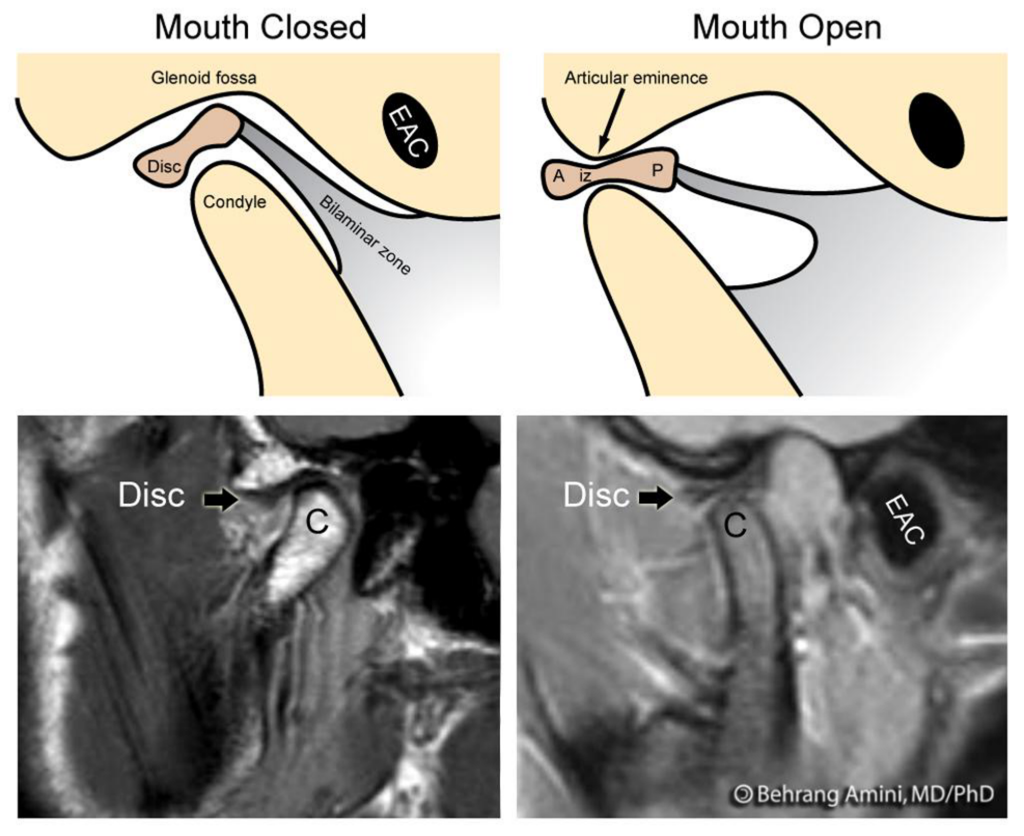

MAGNETOM ESSENZA
SIEMENS

MRI

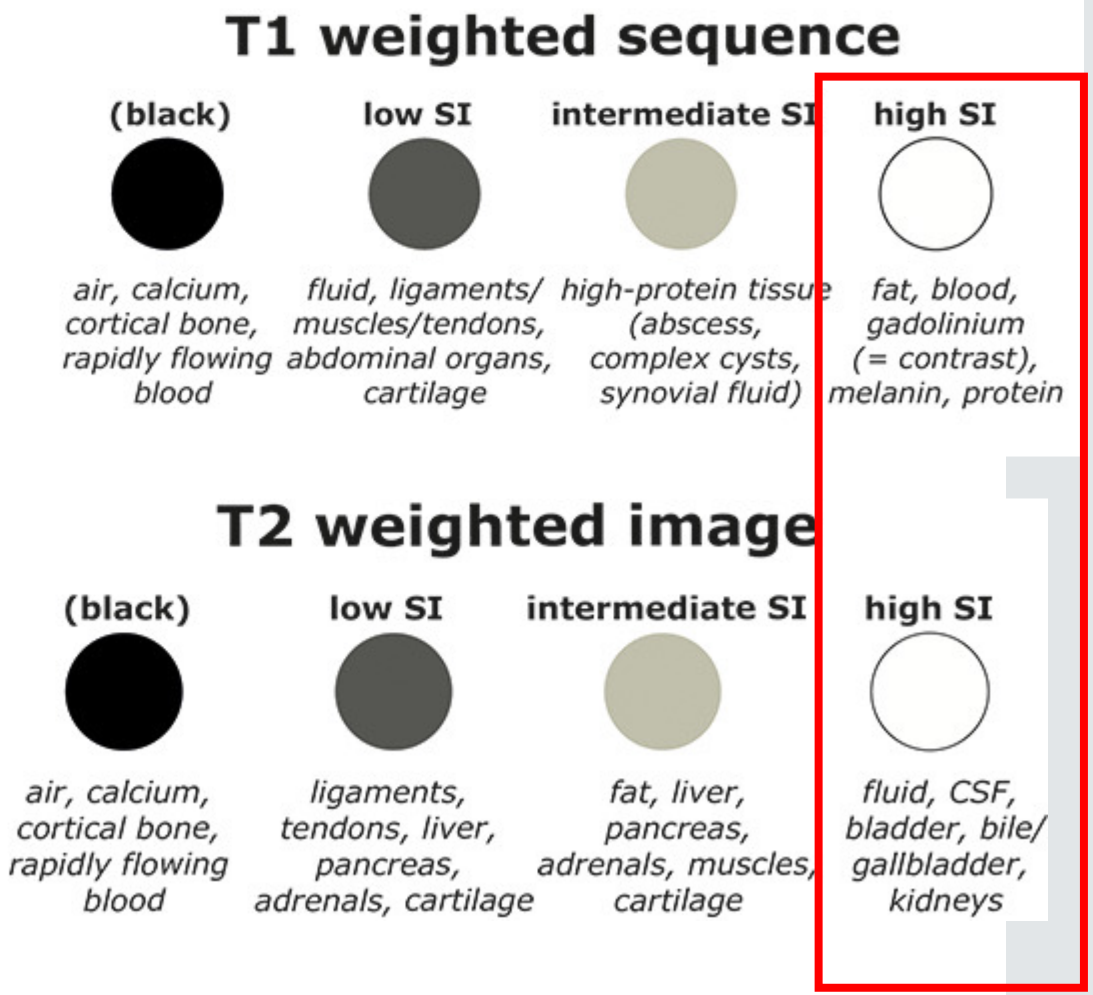
- **Magnetic field and radiofrequency pulses**
- Patient in relatively strong magnetic field
- Nuclei of many atoms (mainly **hydrogen**) align with magnetic field
- Apply radiofrequency signal – several pulses – protons rotate away from direction induced by imaging magnet
- At the end of pulse sequence – relaxation – signal detected by receiver coil
- Larger number of nuclei of loosely bound Hydrogen atoms – larger intensity of recovered signal
- Fourier transform and reconstruction techniques used to produce images

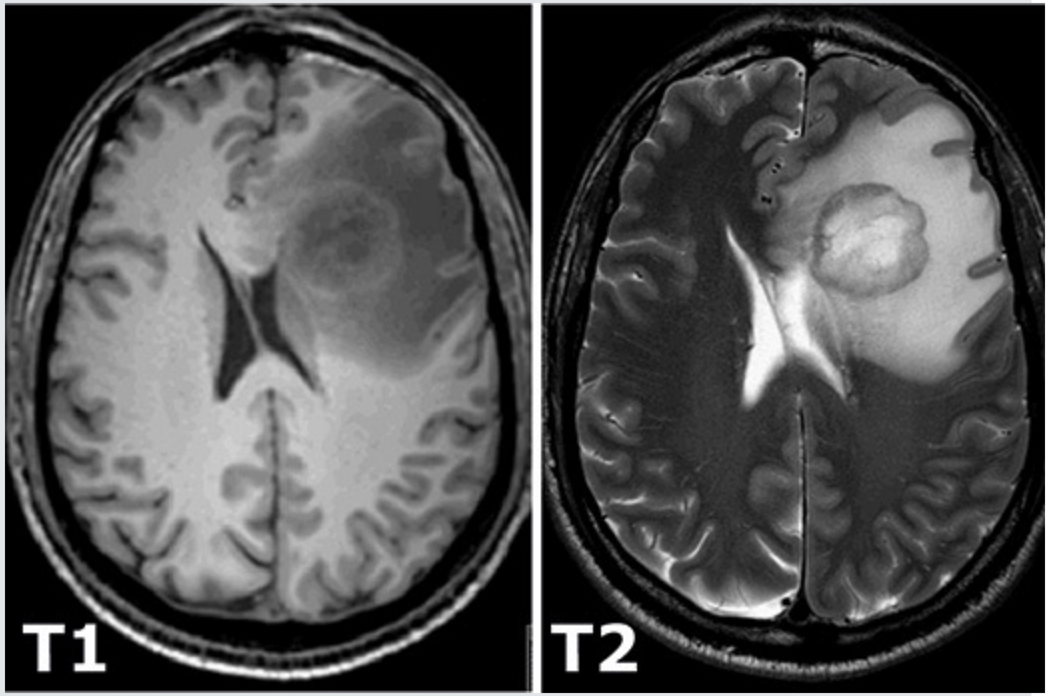
MRI Applications in DMFR

- TMJ disorders
- Tumours and cysts in the head and neck
  - Jaw lesions
  - Salivary gland lesions
  - Paranasal sinus lesions
- Assessment of IDN
- Infection / inflammation eg. osteomyelitis
- Vascular lesions



Understanding MRI Signals





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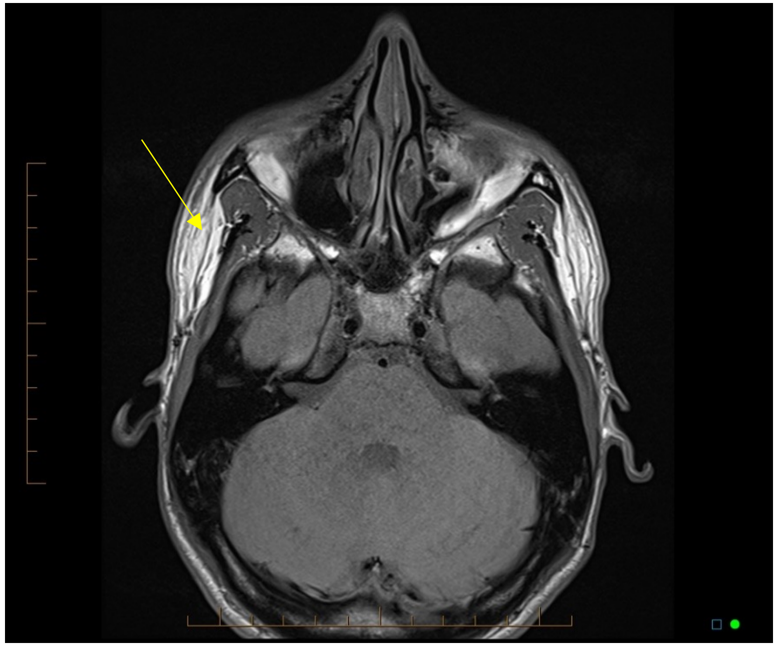
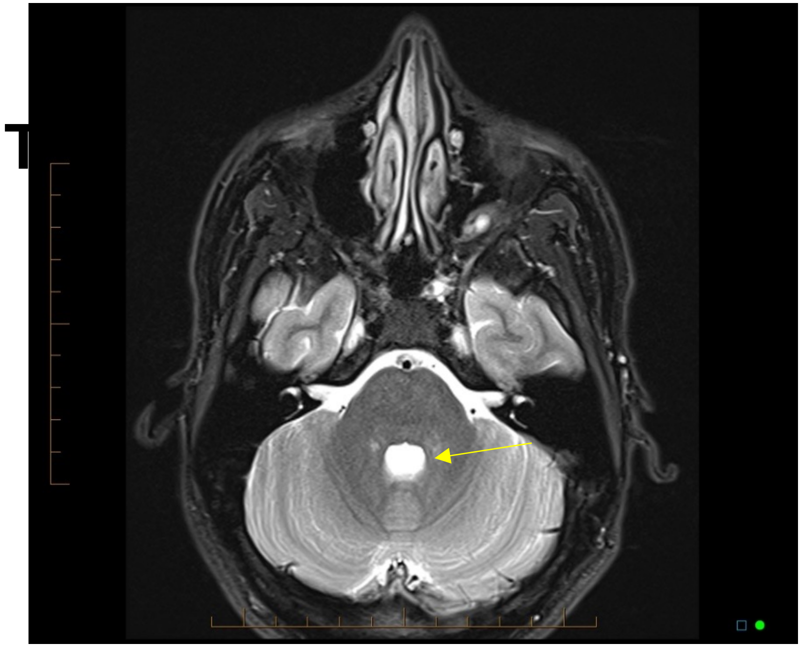


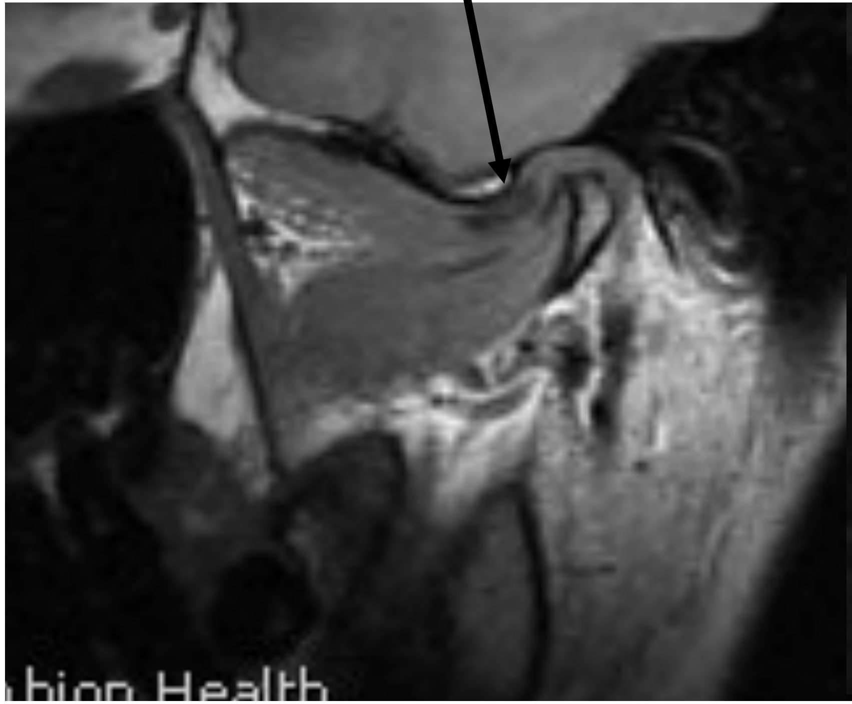
Fat is bright

T



Fluid is bright

DISC



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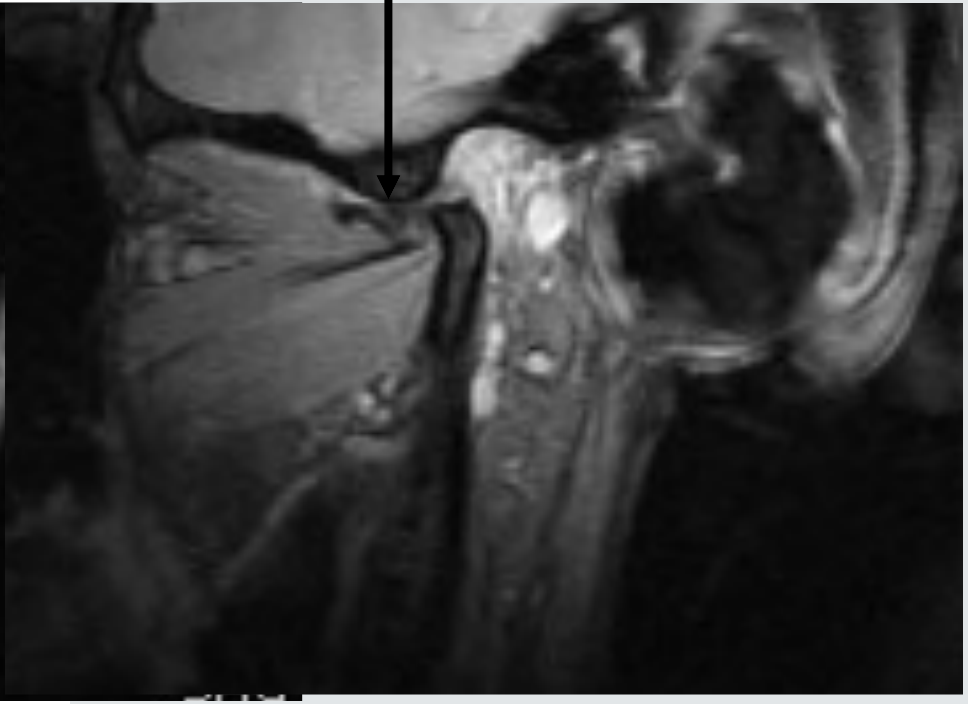

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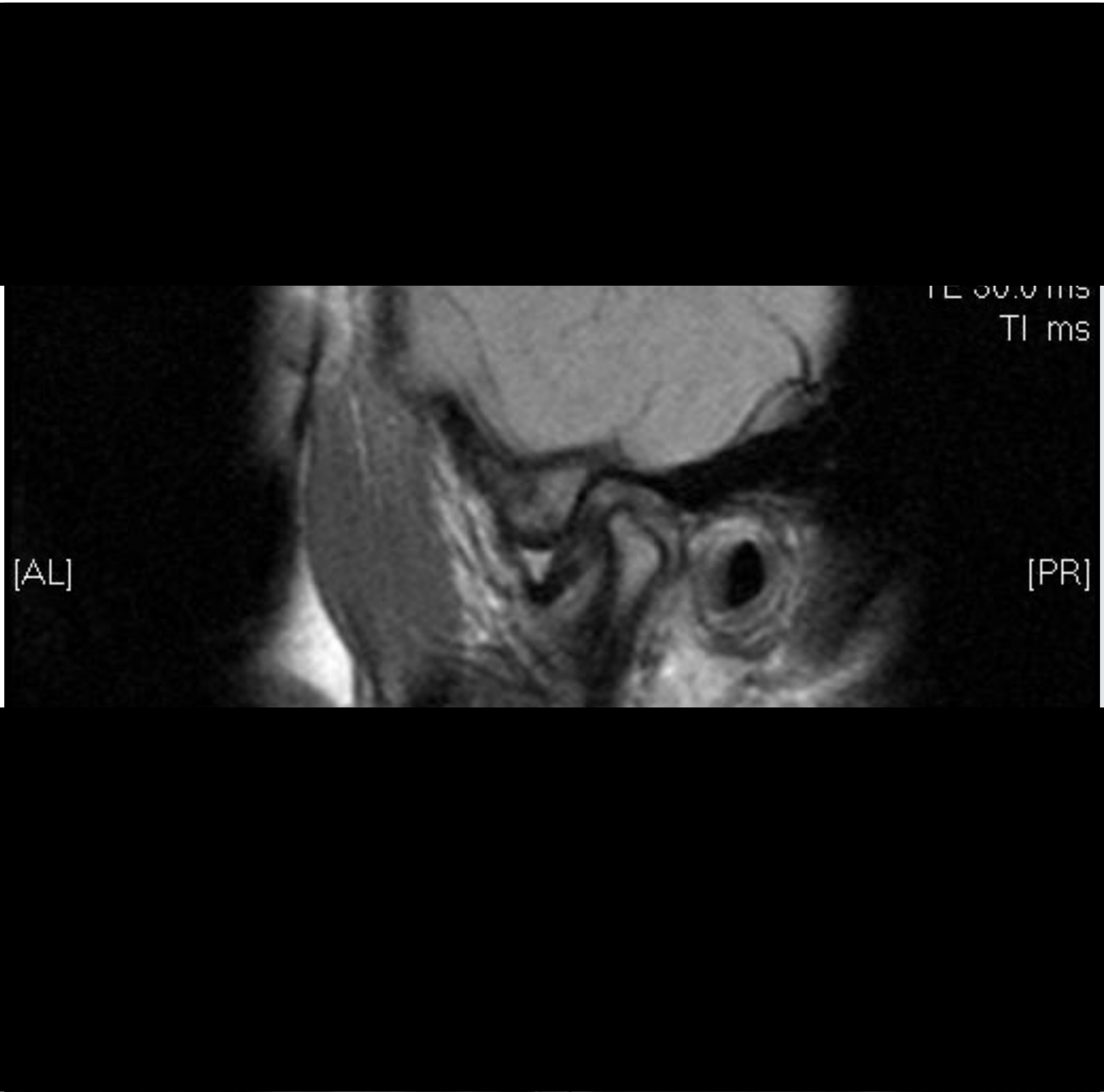

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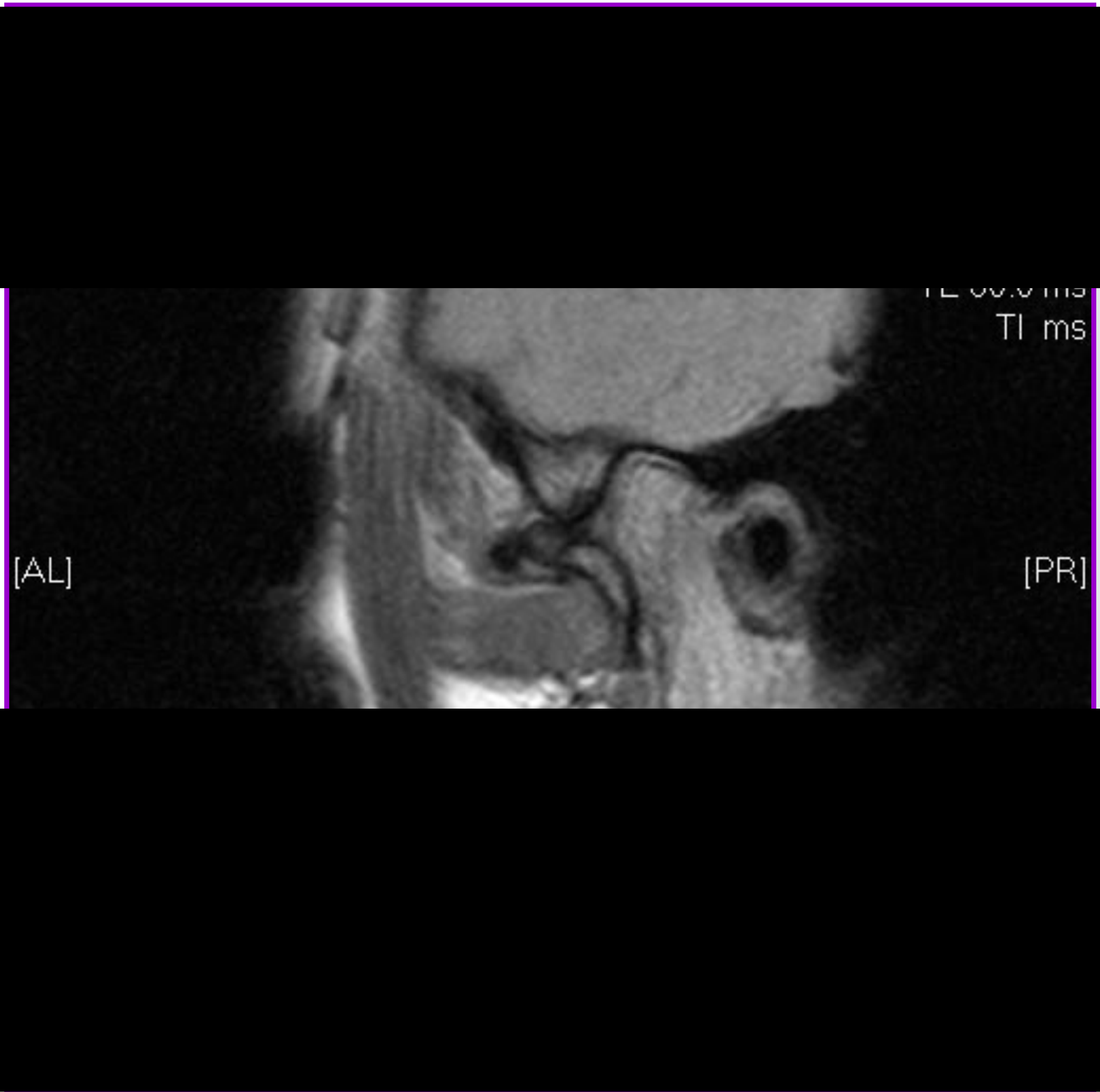

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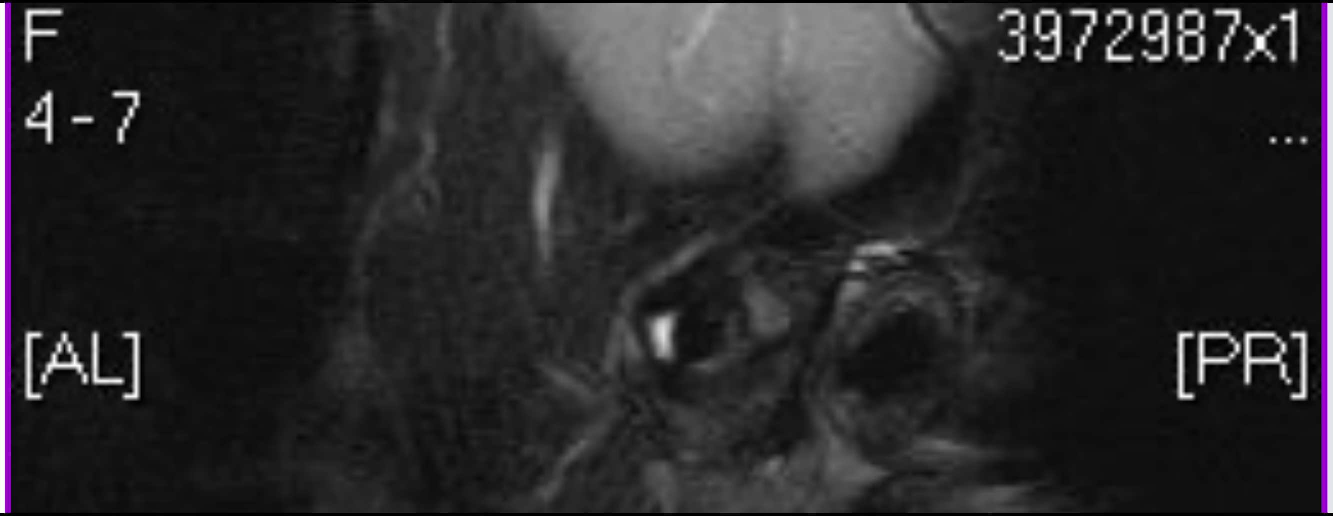

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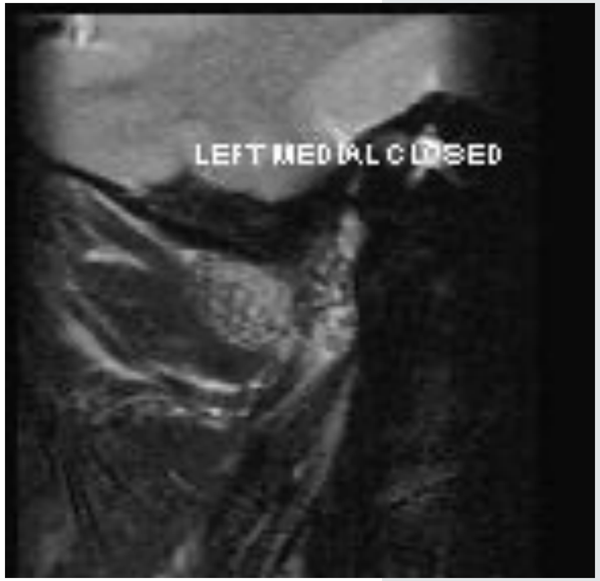
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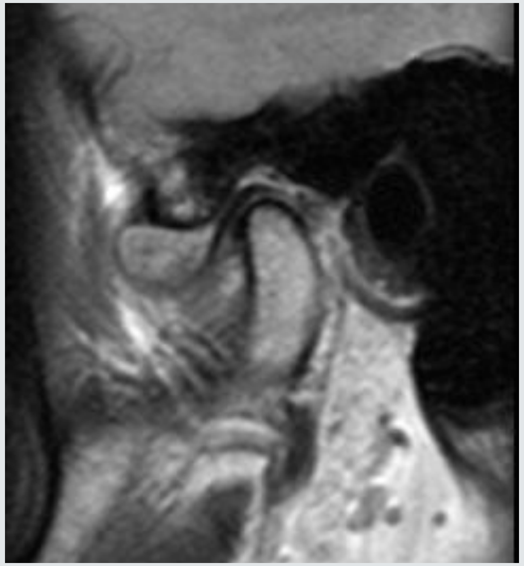


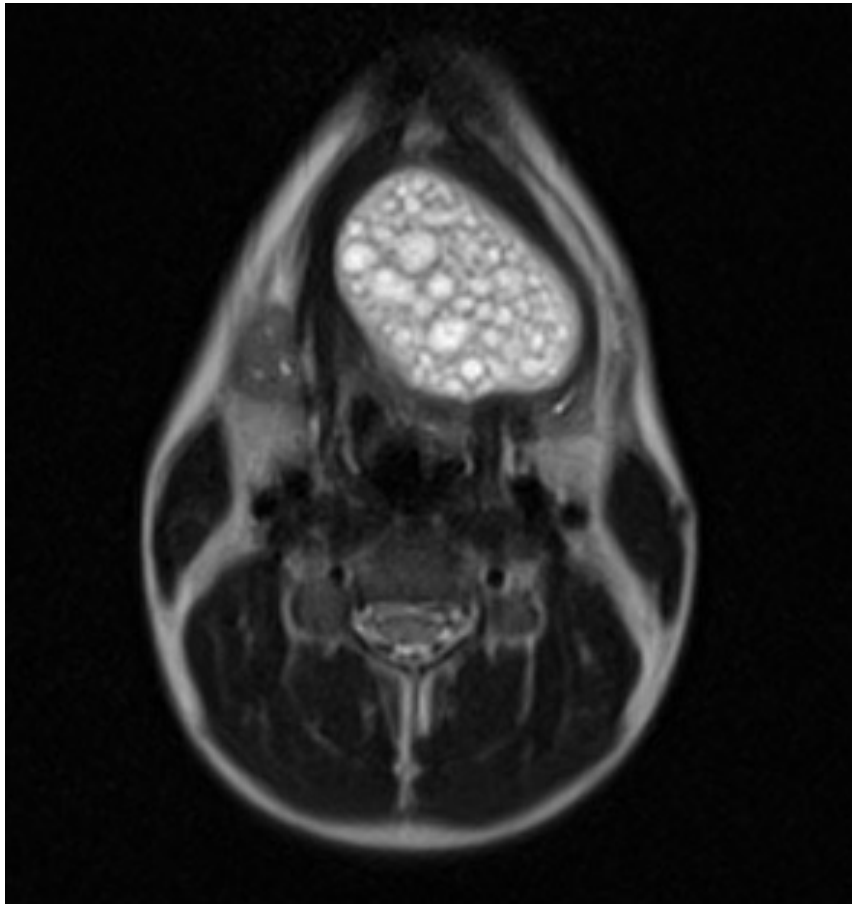

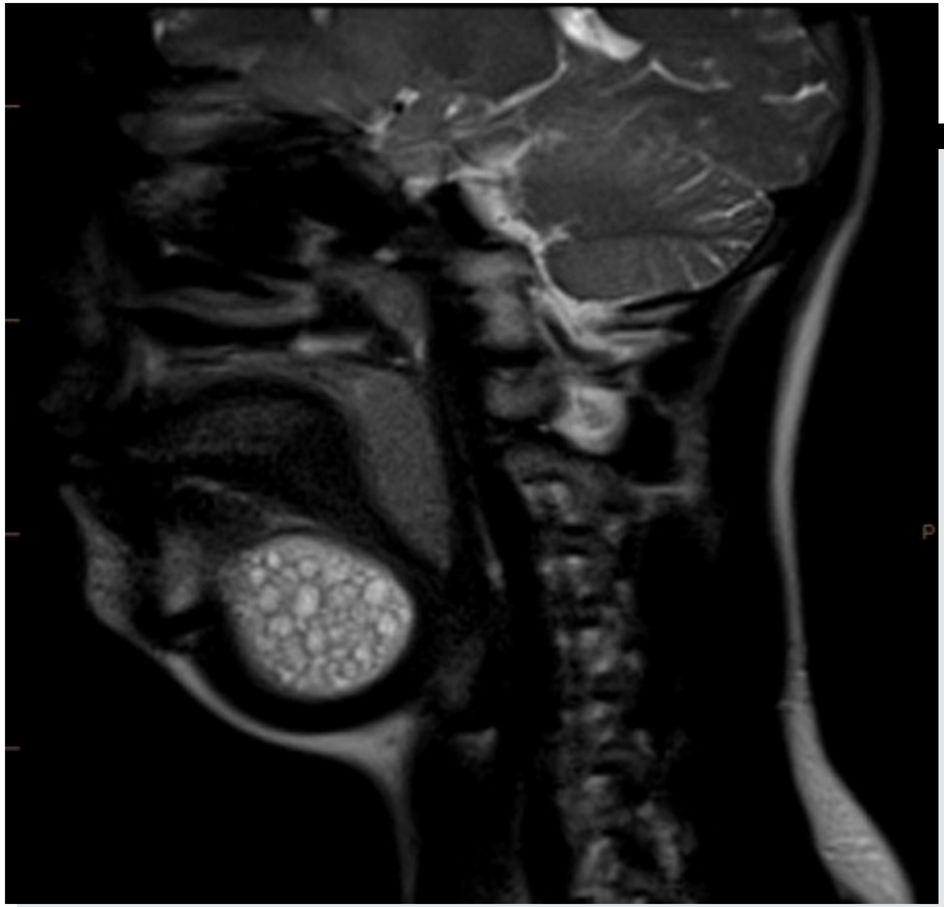
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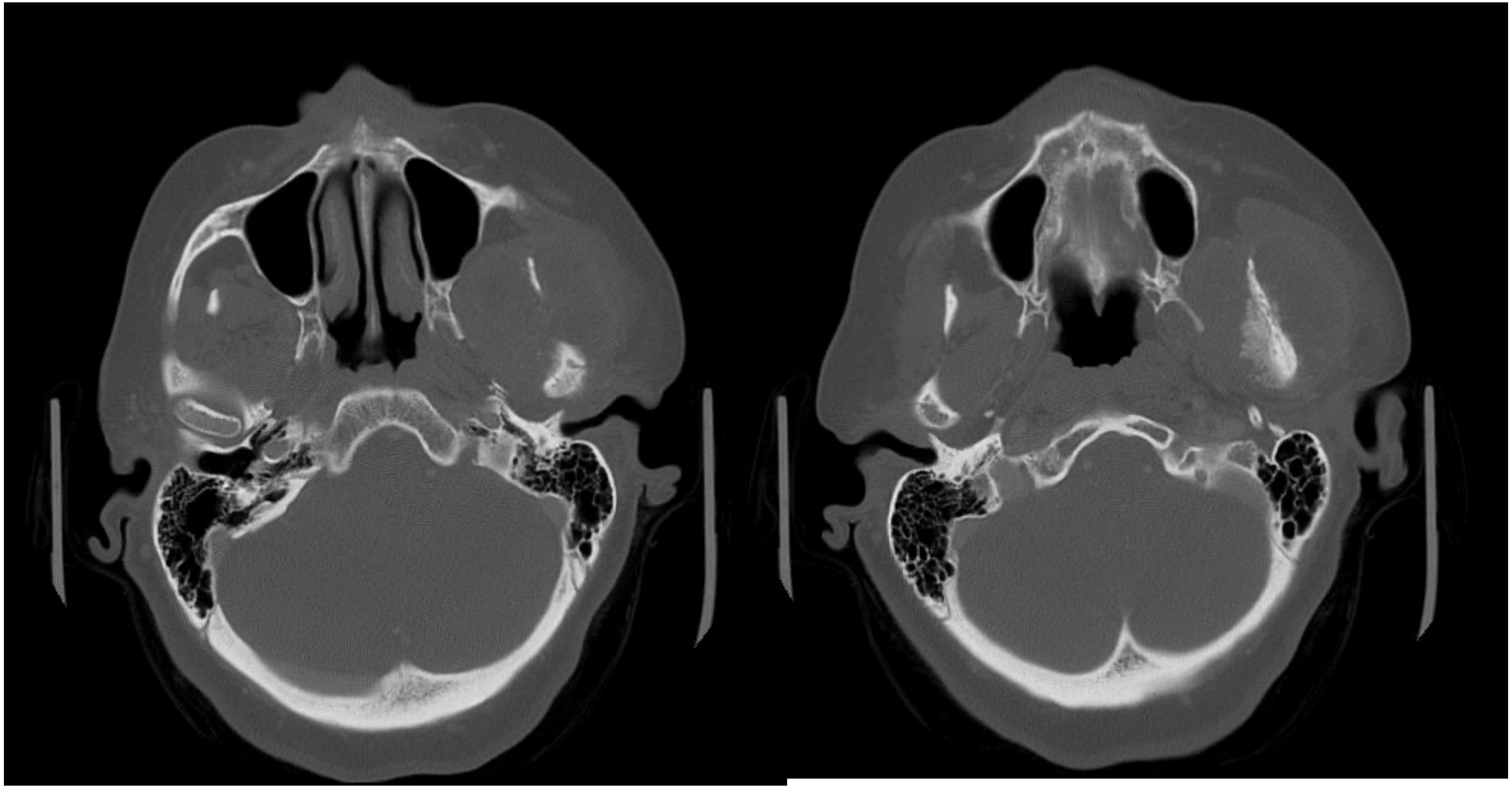
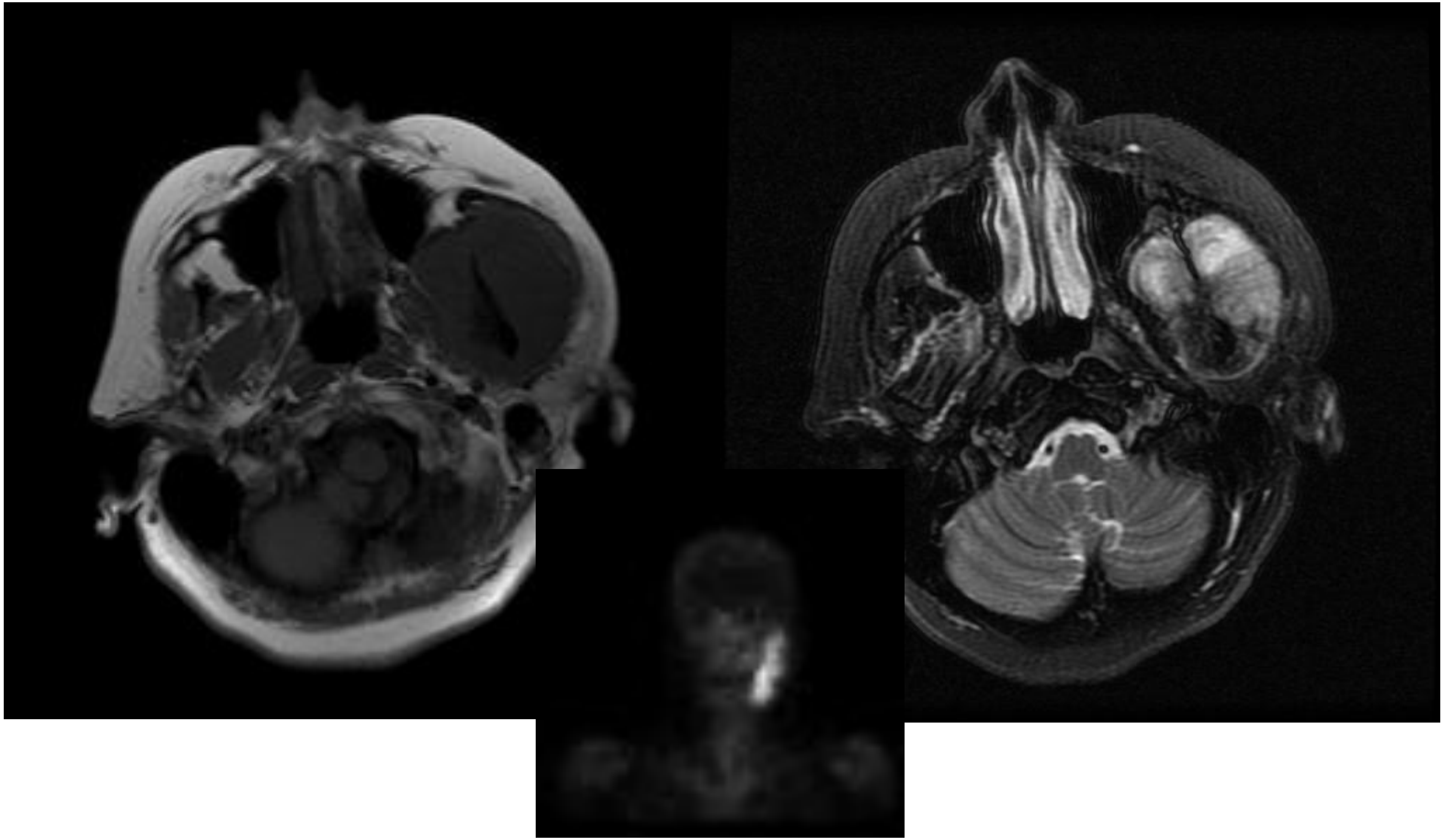




MRI Take Home

Features

- **No ionising radiation** and no known biological side effects
- Superior soft tissue contrast – **soft tissue lesions, articular disc of TMJ**
- Various sequences can be utilised to visualise different tissues
- IV paramagnetic contrast agents eg. Gadolinium
  - Certain anatomical and pathological structures with greater vascularity and permeability can be enhanced.

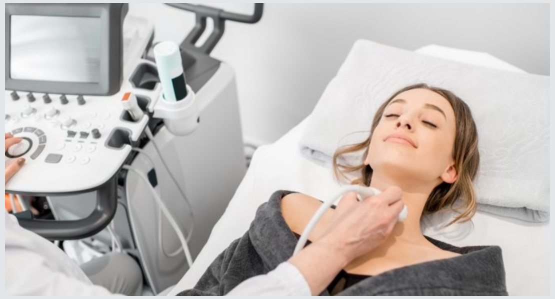
Weaknesses

- Claustrophobia – “non-claustrophobic” MRI
- Long imaging times
- Ferromagnetic metals contraindicated eg cardiac pacemakers, cerebral aneurysmal clips
- May not detect osseous changes visualised in CT
- Calcific deposits may be undetected
- Can over estimate extent of tumours due to response of adjacent tissues
- Gadolinium-based contrast media must be used with caution in those with renal impairment - has been associated with nephrogenic systemic fibrosis
- Gadolinium deposition with regions of the brain has recently been discovered and is currently being investigated.

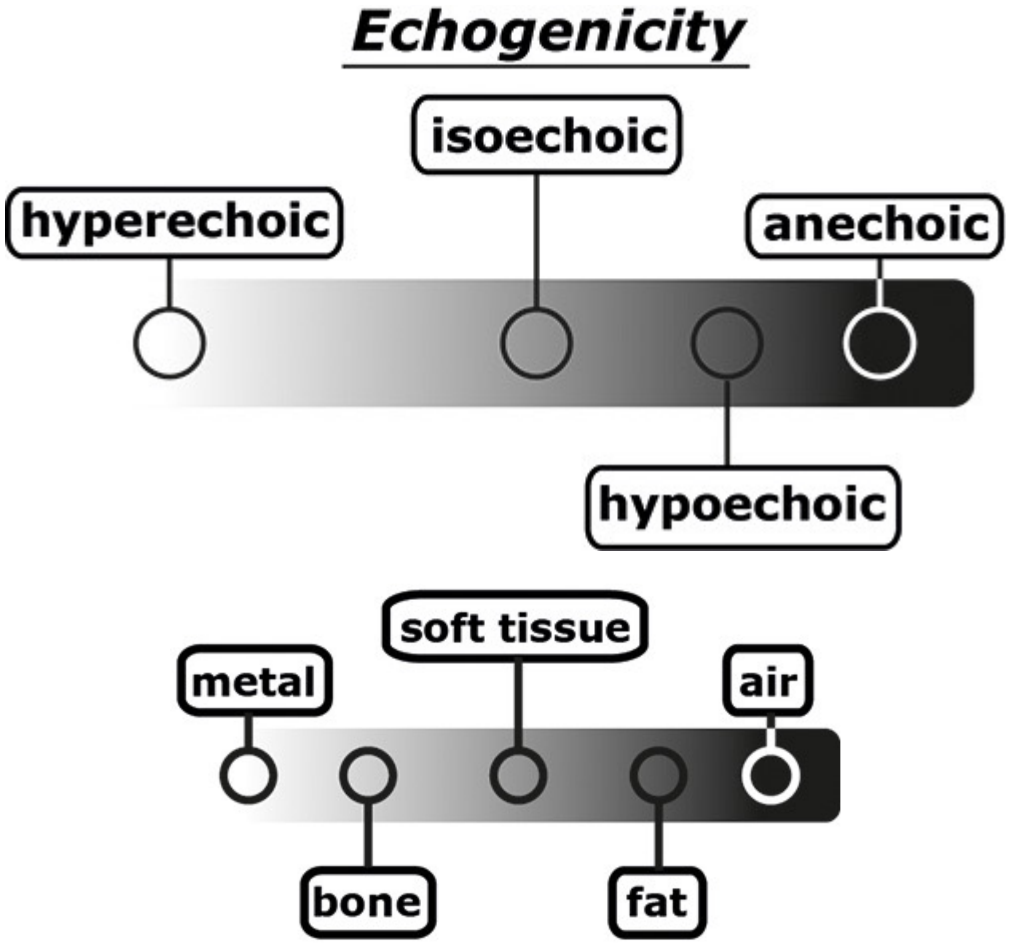
Ultrasound

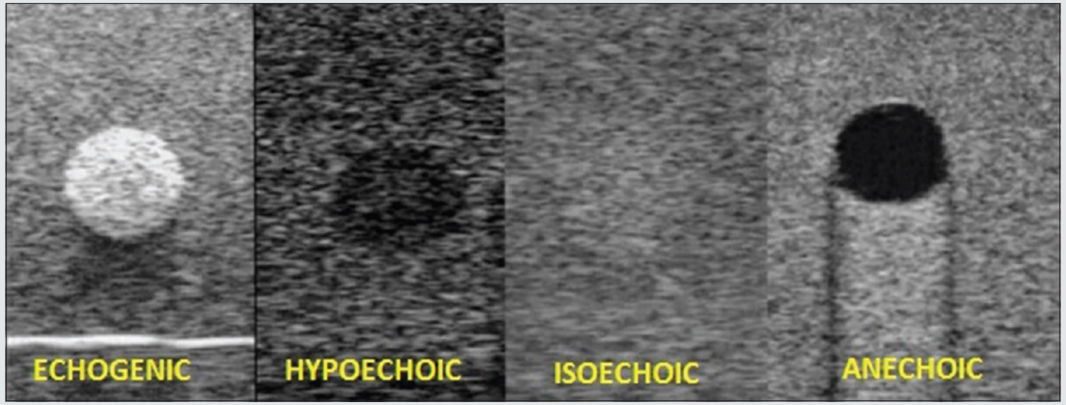
- Ultrasonic beam **No radiation**
- Tissues have different acoustic impedance
- Some of the sonic waves will reflect (echo) back to the transducer
- Tissues have characteristic echo pattern

- **Real-time imaging**
- **Soft tissue**
  - **Cystic vs solid**
- **Colour Doppler ultrasound – blood flow**
- Relatively low cost



Understanding US Signals “Echogenecity”





Applications

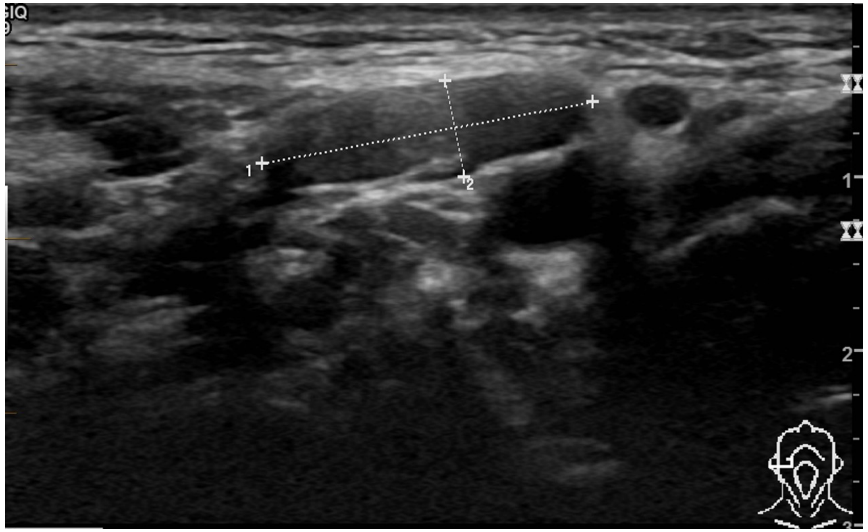
Soft tissue lumps and swellings

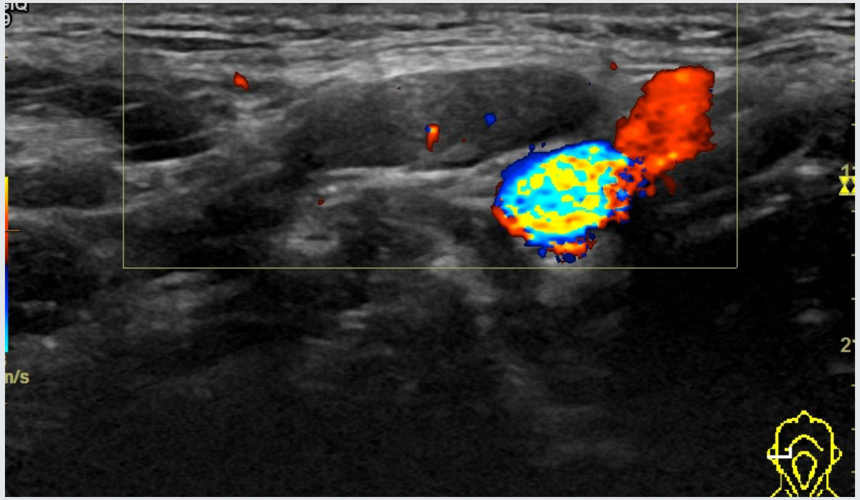
Soft tissue pain/discomfort

Salivary glands

Lymph nodes

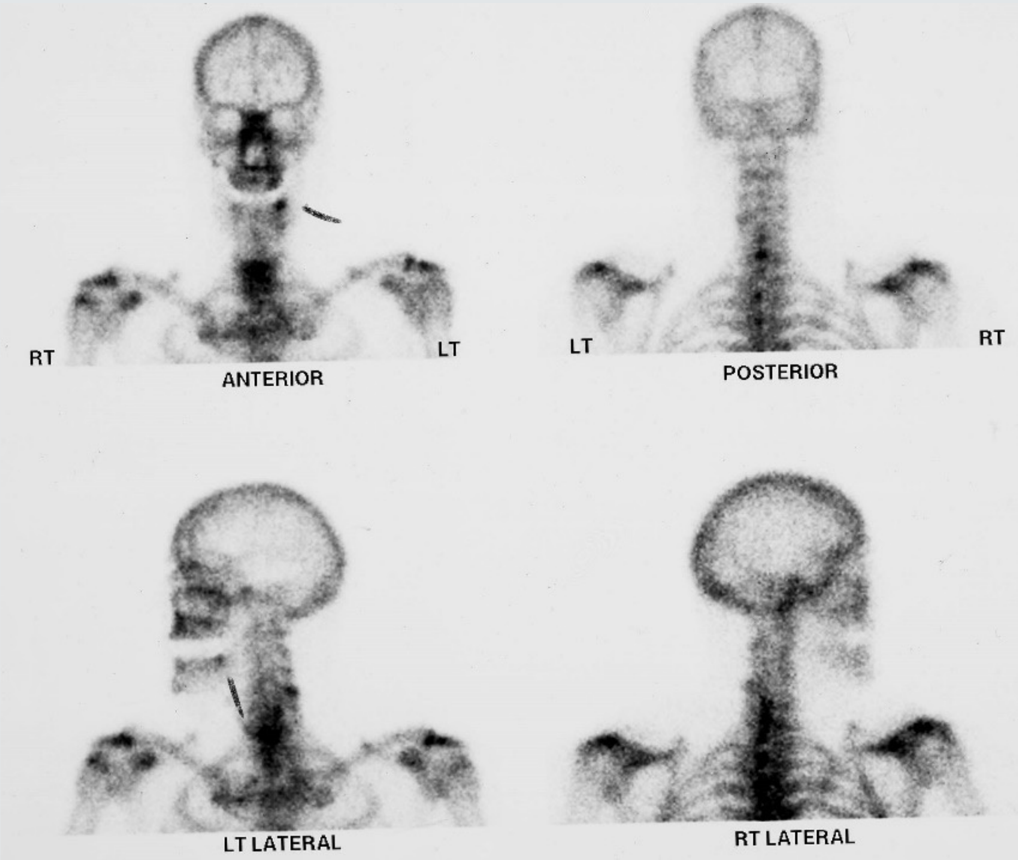
Guided FNA and core biopsies





Nuclear Medicine

- Functional imaging → detects abnormal metabolic processes
  - Rather than anatomical/morphological changes
  - May not be discernible in the early stages of some diseases.
- Radionuclide imaging:
  - Radionuclides which emit gamma rays (e.g. Technetium 99m) - combined with a pharmaceutical to form a radiotracer which is distributed to various parts of the body based on their chemical properties.
  - A gamma camera captures the emitted photons
- <u>Single photon emission computed tomography (SPECT):</u>
  - Acquires tomographic slices - gamma camera rotates around the patient detected emitted gamma rays. – similar to multislice CT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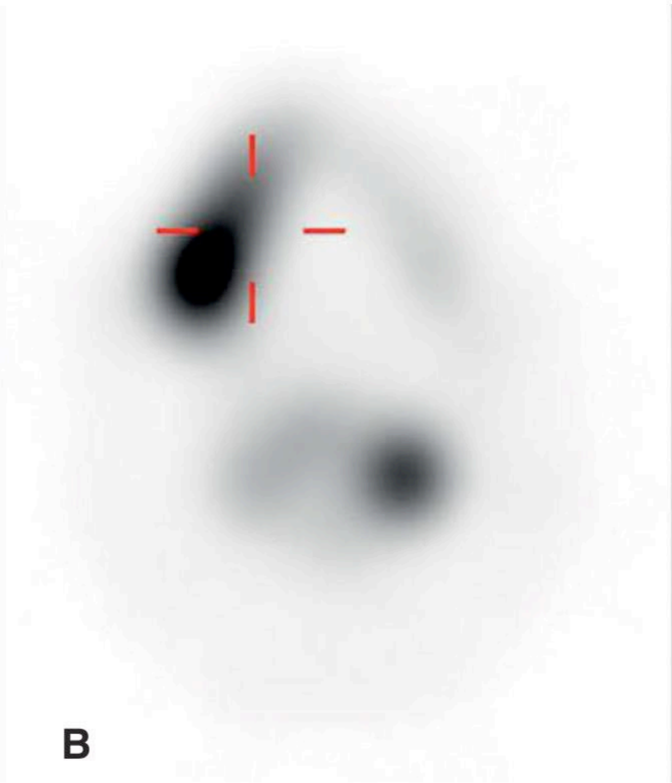
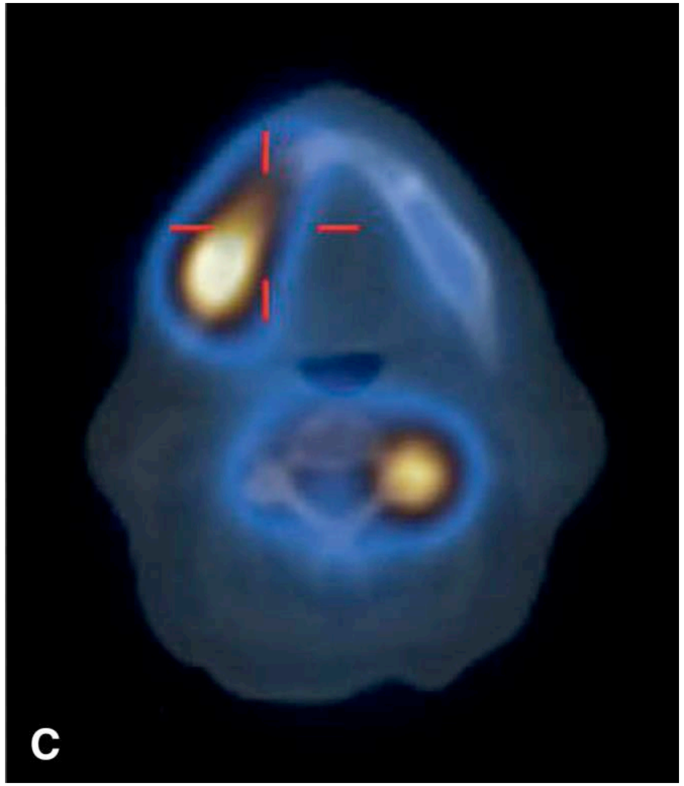
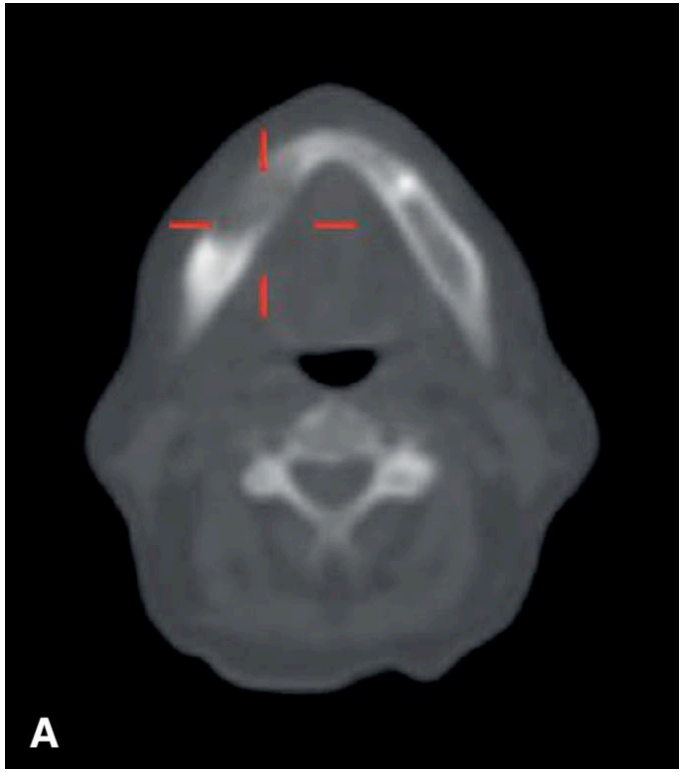
SPECT



SPECT / CT

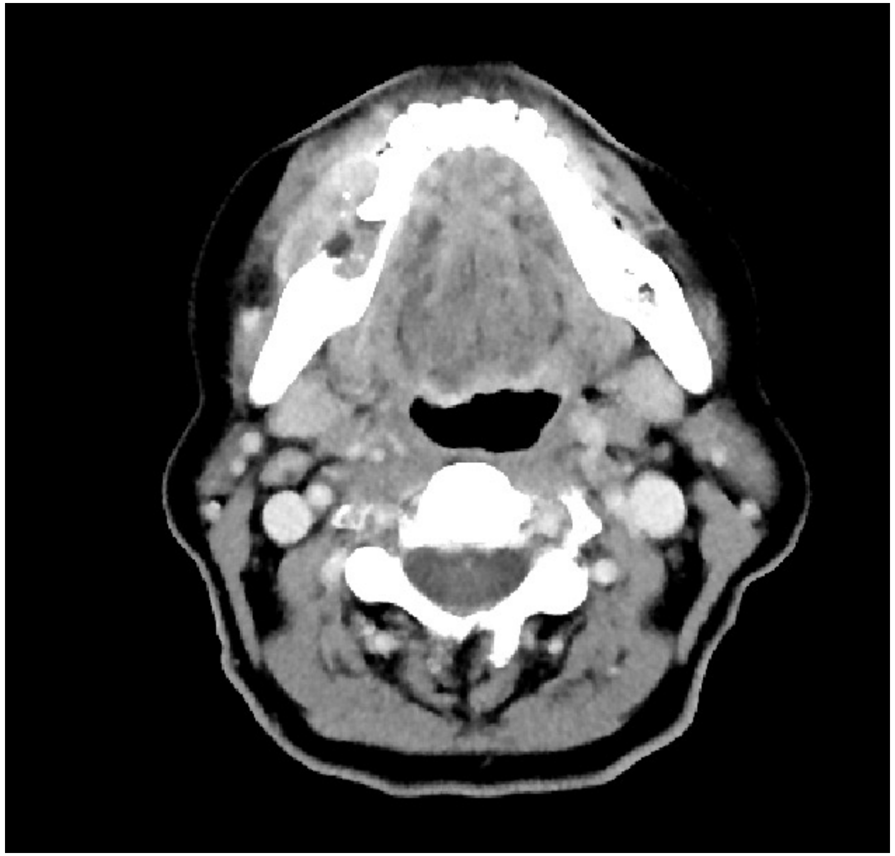
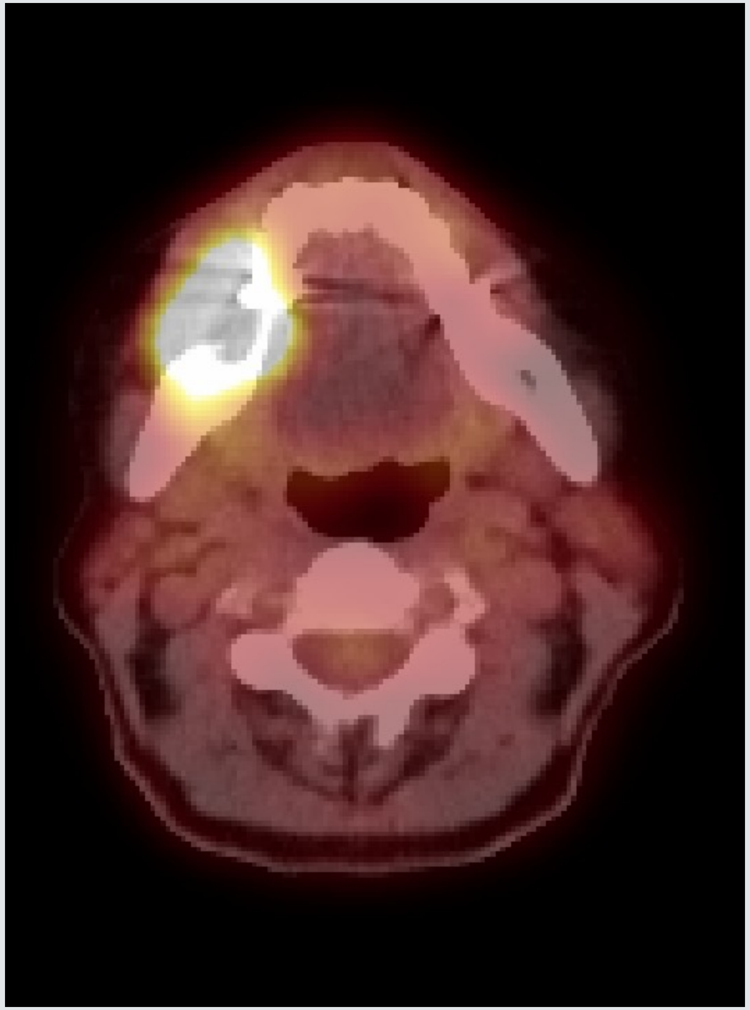


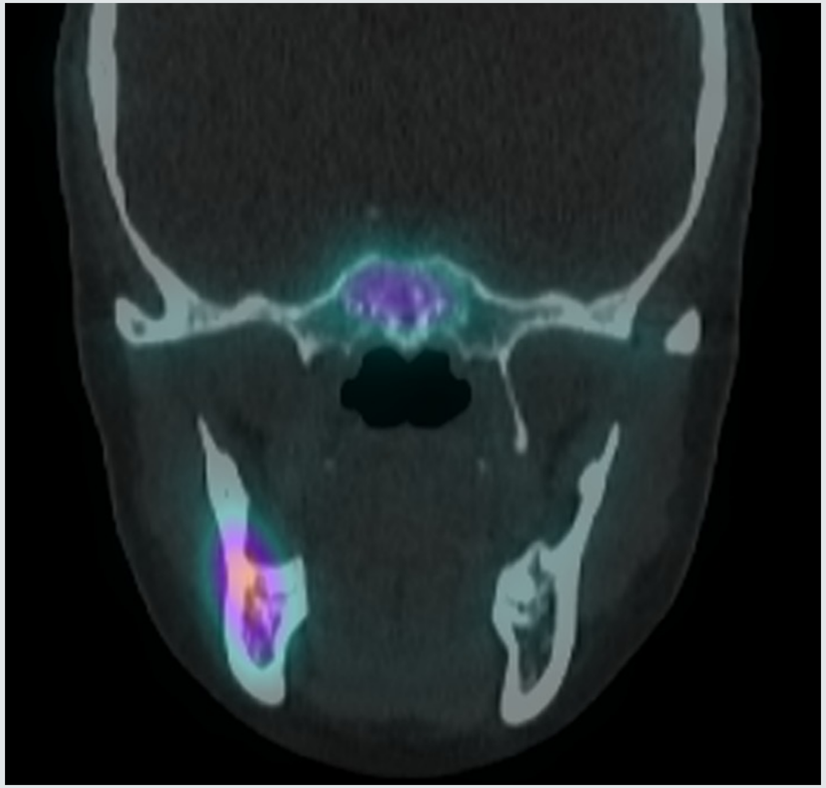
CT

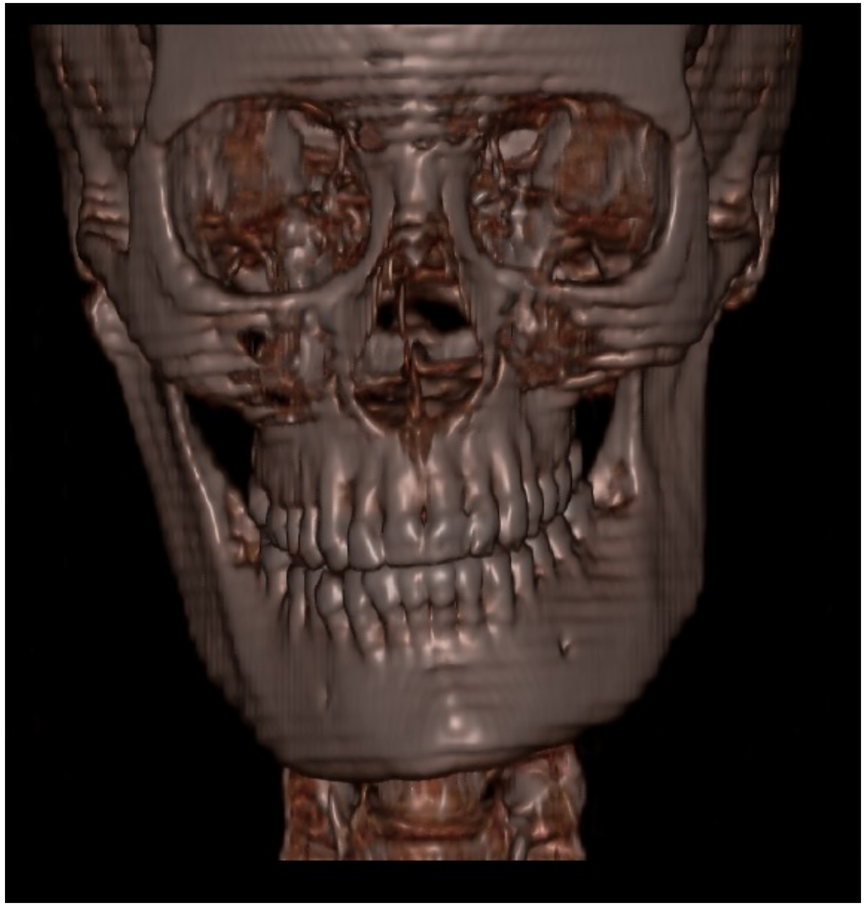


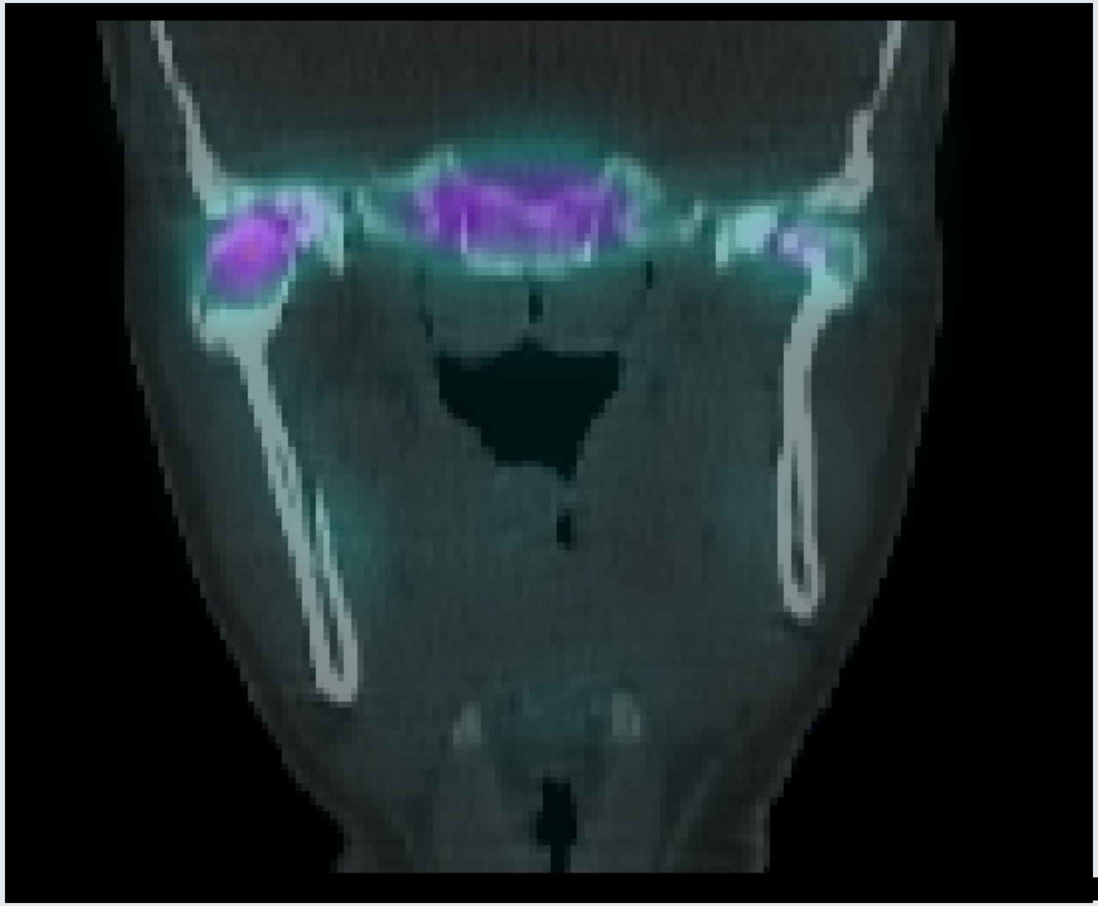
Nuclear Medicine: Positron emission tomography (PET):

- Positron emitting radionuclides - usually combined with pharmaceuticals such as glucose or amino acids, to assess metabolic processes in the body.
- After a set period of time, positron emission decay occurs, and two photons are produced which travel in opposite directions
- A PET camera has a ring of detectors which can map the photons that arrive at the same time - produce a functional image of organs and tissues.
- Hybrid imaging systems where the nuclear medicine images are co-registered with a CT or MRI images (ie PET/CT and PET/MRI) allowing for combined morphological and functional imaging.
  - Very high spatial resolution – detect very small lesions
  - Examples of use
    - Cancers
    - Identify viable heart muscle with previous myocardial infarcts
    - Brain – identify epileptic foci, diagnosis of dementia







Conclusion

- Assessment of hard tissue: Intraoral Radiographs, Extraoral Radiographs, CBCT, MSCT
- Assessment of soft tissues: MSCT, MRI, Ultrasound
- Functional Imaging Techniques: SPECT, PET