MRI, Ultrasound and Nuclear Medicine Imaging

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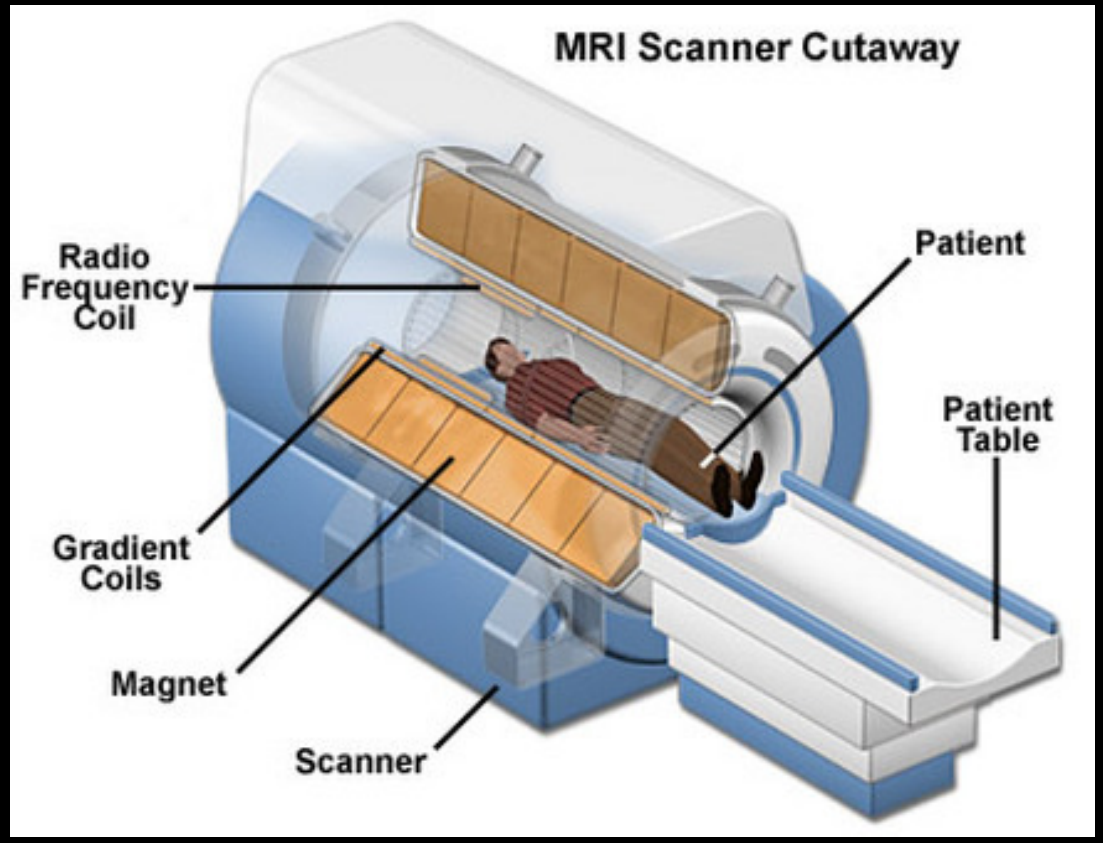
Learning Objectives

- To understand the basic theory of:
  - Magnetic Resonance Imaging (MRI)
  - Ultrasound Imaging / Ultrasonography (US)
  - Nuclear Medicine Imaging (NMI)
    - Scintigraphy
    - Positron Emission Tomography (PET)
    - Single-Photon Emission Computed Tomography (SPECT)
- To know applications / indications for each of the above advanced imaging modalities

I. Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI)

- Magnetic field
  - = **“Magnetic”**
- Radiofrequency waves
  - = **“Resonance”**
- **NO** ionising radiation
- **Soft tissue imaging**
- **Bore**



MRI Scan

- Long scanning time
- X Claustrophobia
- Noisy
- Heat in the area being examined
- X Ferromagnetic metals

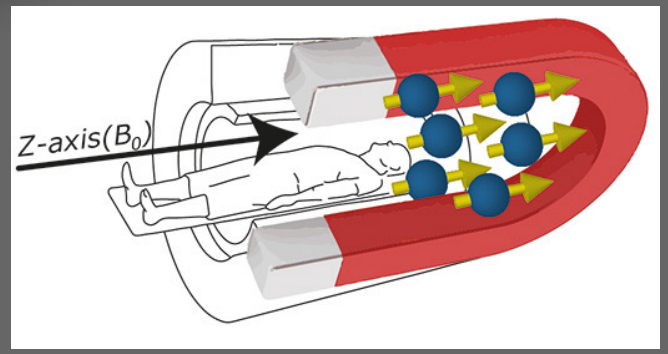
Pre-MRI Check

- Pacemaker / Defibrillator (ICD)
- Neurostimulator
- Cochlear Implant
- Stapedectomy (middle ear prosthesis)
- Aneurysm Clip
- Morphine / Insulin Pump
- Glucose Monitor
- Programmable VP Shunt
- Shrapnel
- Retained Metal fragment in eye (eg. from welding / grinding)

MRI – simplified theory

Step 1. *Magnetisation*

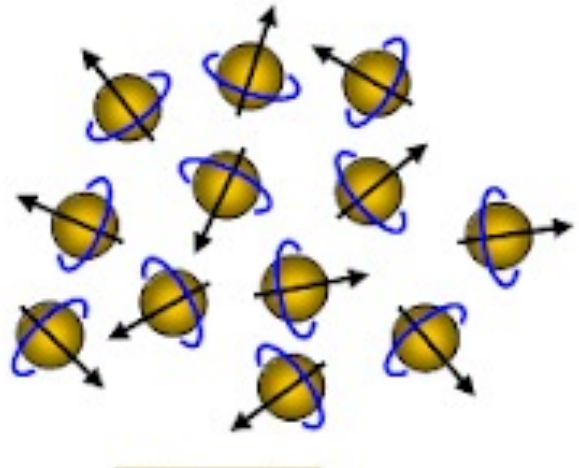
- STRONG external magnetic field of 1.5T or higher (MRI machine)
  - *1 T can lift a car!*
- **Hydrogen** atoms (in water “H2O” and fat)
  - **Single proton** (& 1 electron & zero neutron)
  - Naturally **spinning** and **wobbling** particles with +ve charge
  - *Charge with motion creates a magnetic field*



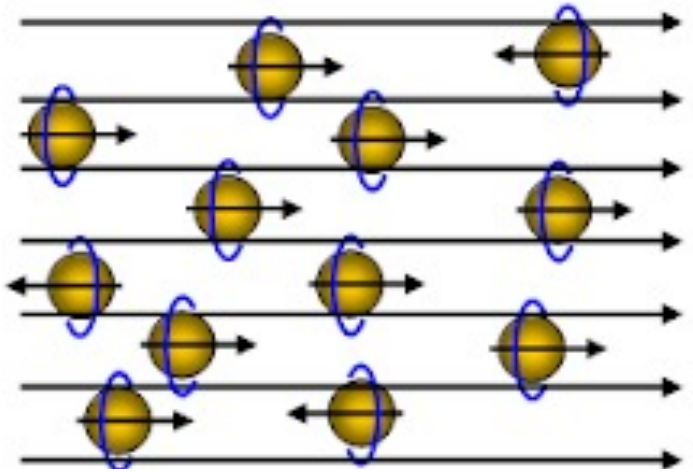
MRI – simplified theory

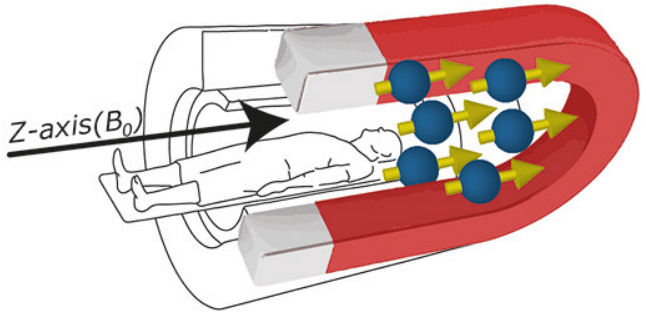
Magnetisation & z-axis

No external magnetic field



Under external magnetic field (MRI scanner)



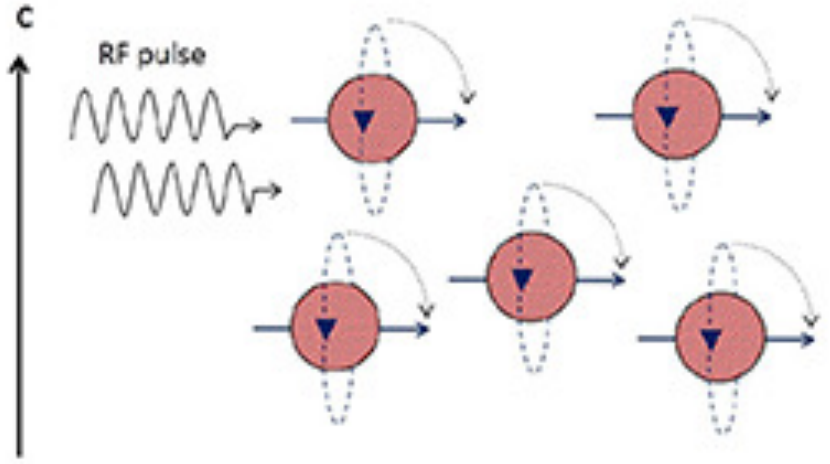


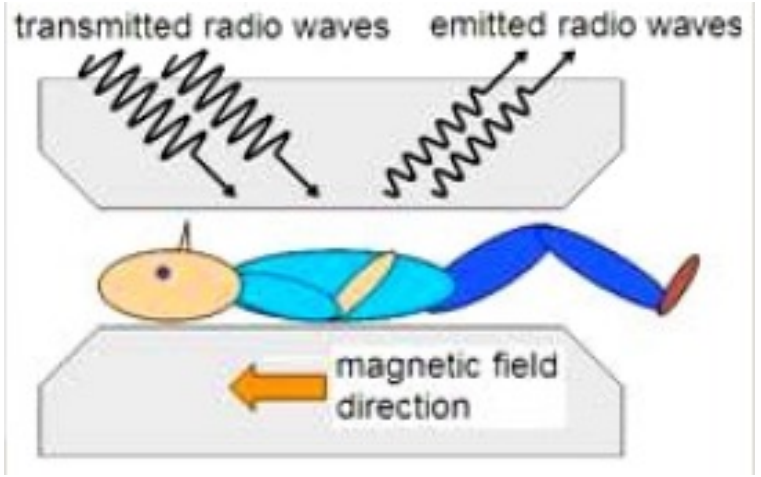
MRI – simplified theory

Step 2. *Resonance; precession, excitation & relaxation*

- Hydrogen spin & wobble motion= precession
- Larmor's equation ➔ ω = γB
  - ω is the **frequency** in MHz,
  - γ is the gyromagnetic ratio in MHz/Tesla,
  - B is the strength of the magnetic field in Tesla
- *H protons precess at the rate of **63.87MHz** at 1.5T*
- Matching radiofrequency (RF) waves create RESONANCE
- **Resonance results in 'Excitation'**
- **'Relaxation' releases MR Signals captured by receiver coil**
  - Different body tissues 'relax' at different rates

The faster the tissue relaxes, the more the MR signals released in a given time

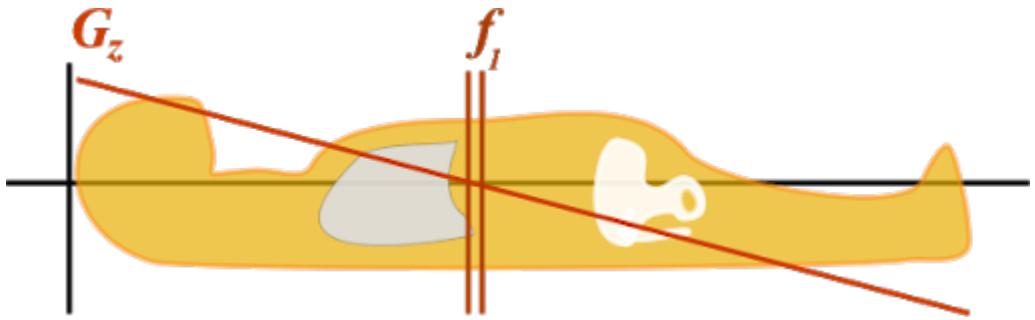


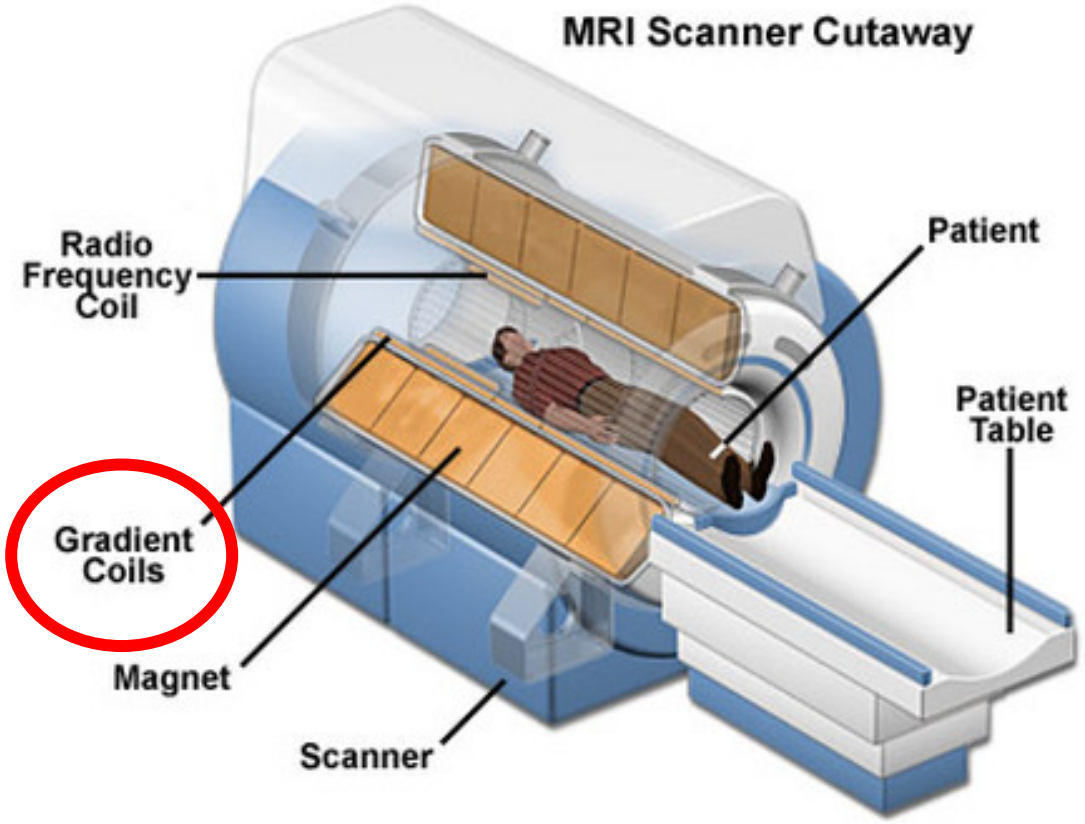


MRI – simplified theory

Secondary magnetic field IE ***Gradient***

- Distorting / tilting the main magnetic field to acquire slices from different sections of the body
  - Different resonance frequencies along the gradient
  - Localisation of different anatomical structures





(a)

(b)

(c)

(d)

MRI – simplified theory

Step 3.

- **MR Signal** received by receiver coil is converted into a digital form and transmitted to computer
- The computer processes the data and an image is created

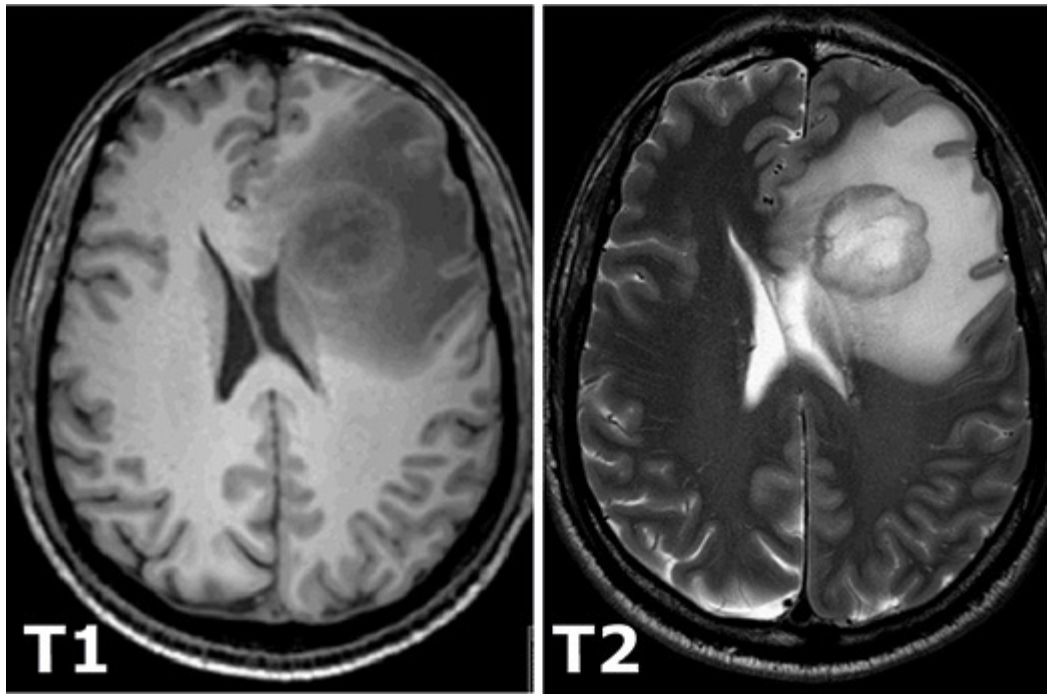
Understanding MRI Signals

T1 weighted sequence

(black)	low SI	intermediate SI	high SI
air, calcium, cortical bone, rapidly flowing blood	*fluid, ligaments/ muscles/tendons, abdominal organs, cartilage*	*high-protein tissue (abscess, complex cysts, synovial fluid)*	*fat, blood, gadolinium (= contrast), melanin, protein*

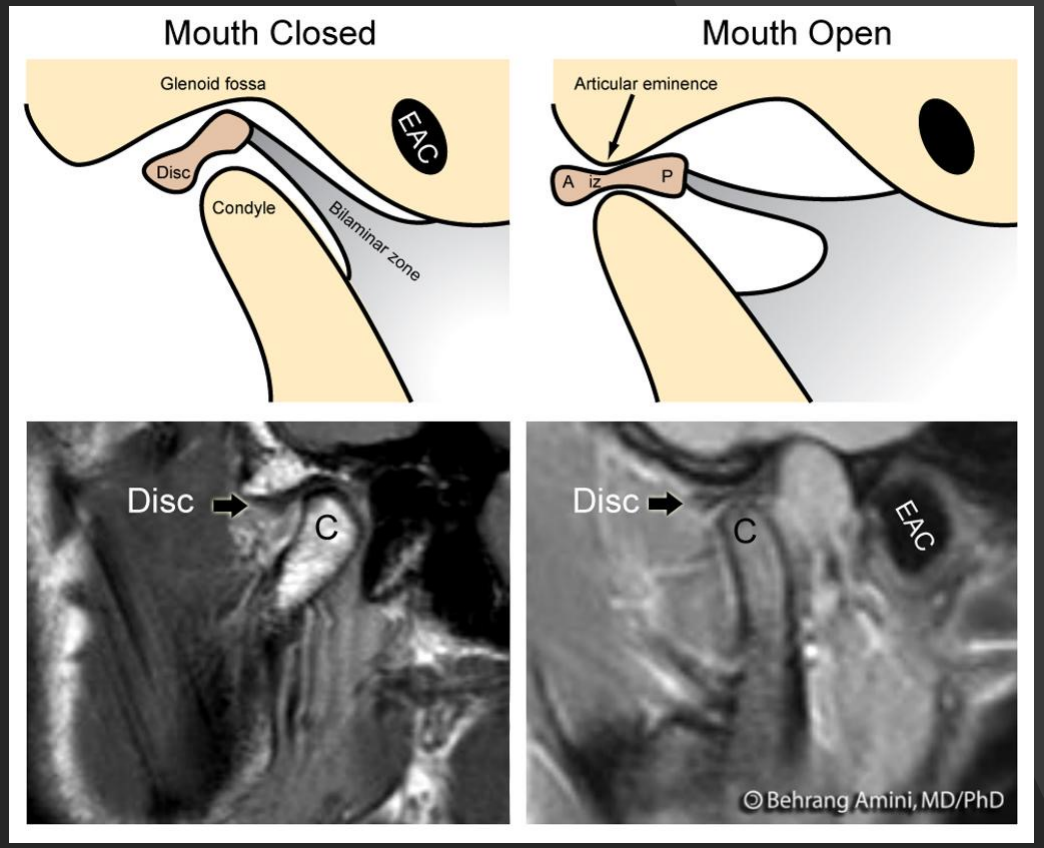
T2 weighted image

(black)	low SI	intermediate SI	high SI
air, calcium, cortical bone, rapidly flowing blood	*ligaments, tendons, liver, pancreas, adrenals, cartilage*	*fat, liver, pancreas, adrenals, muscles, cartilage*	*fluid, CSF, bladder, bile/ gallbladder, kidneys*



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**



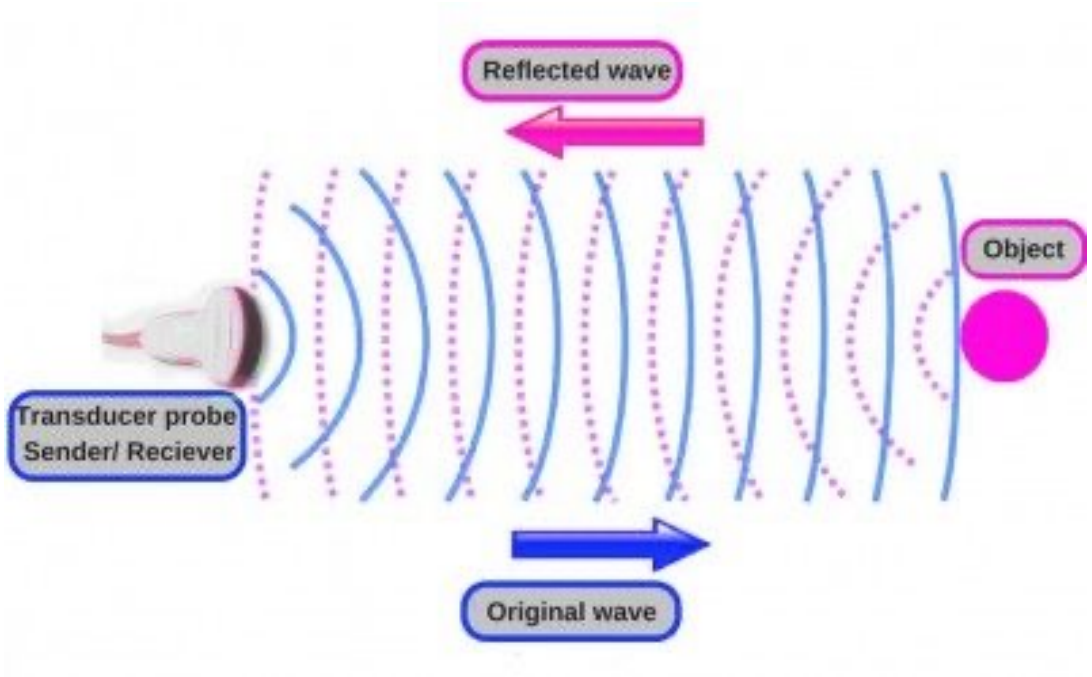
II. Ultrasound / Ultrasonography (US)

Ultrasound Imaging

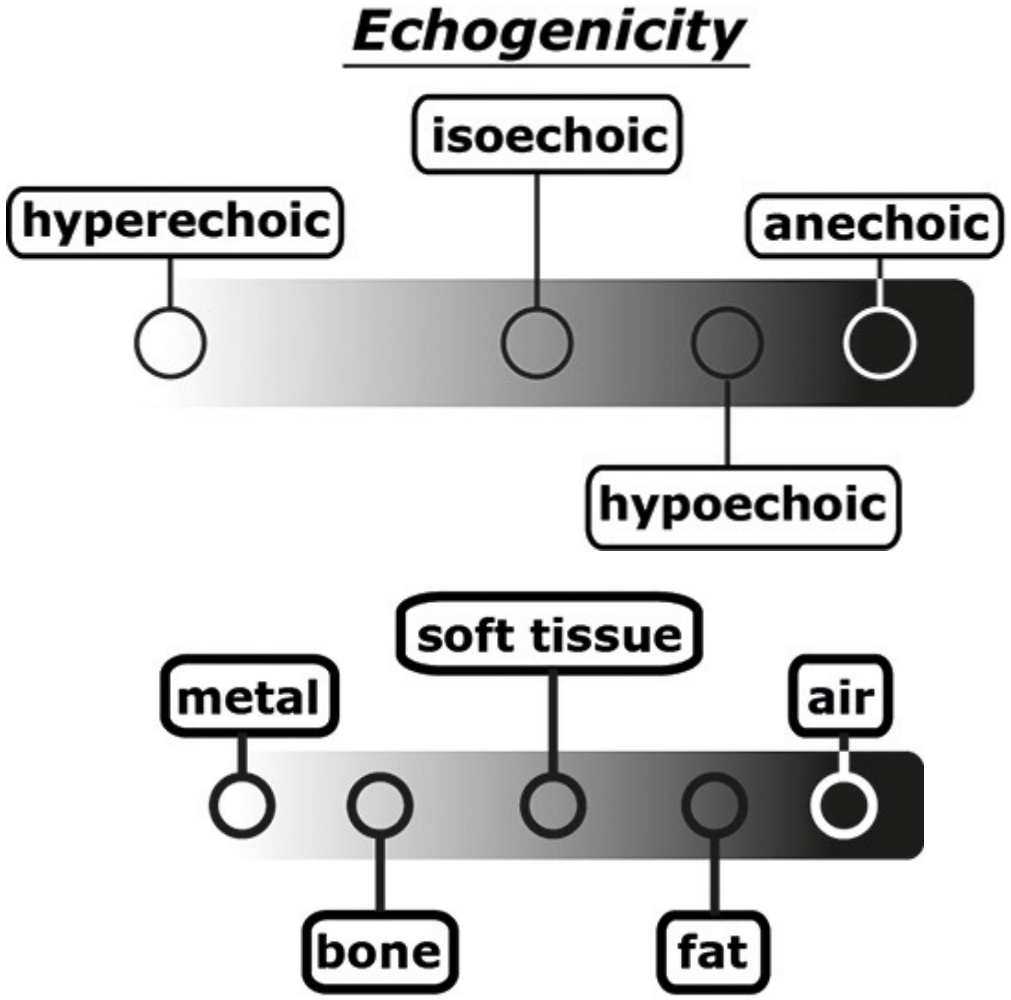
- Non-ionising
  - Sound waves
- Soft tissue imaging
- Compact
- Inexpensive
- Real-time imaging
- Technique sensitive

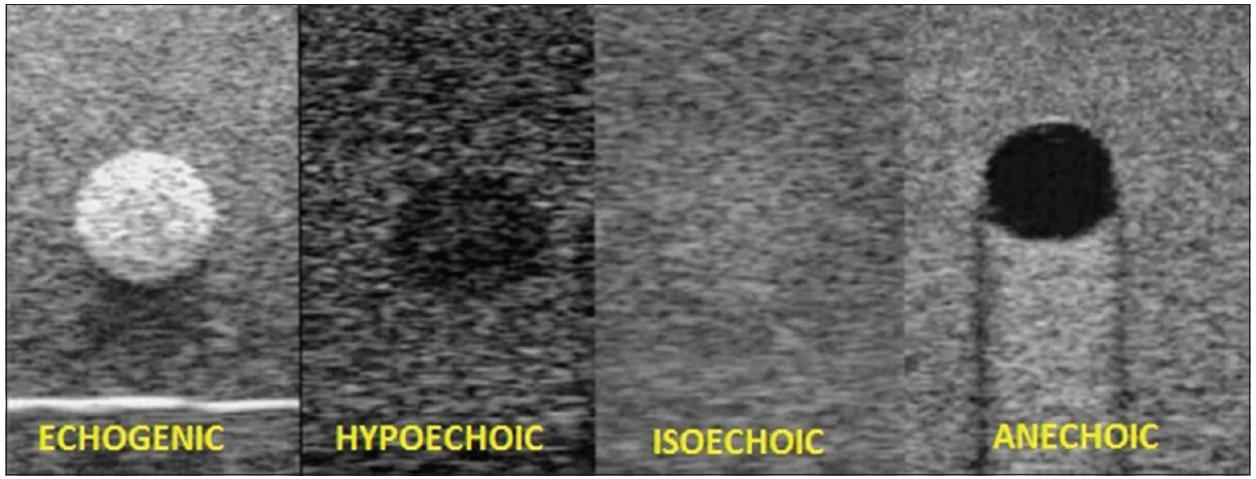
US Explained (V Simply)

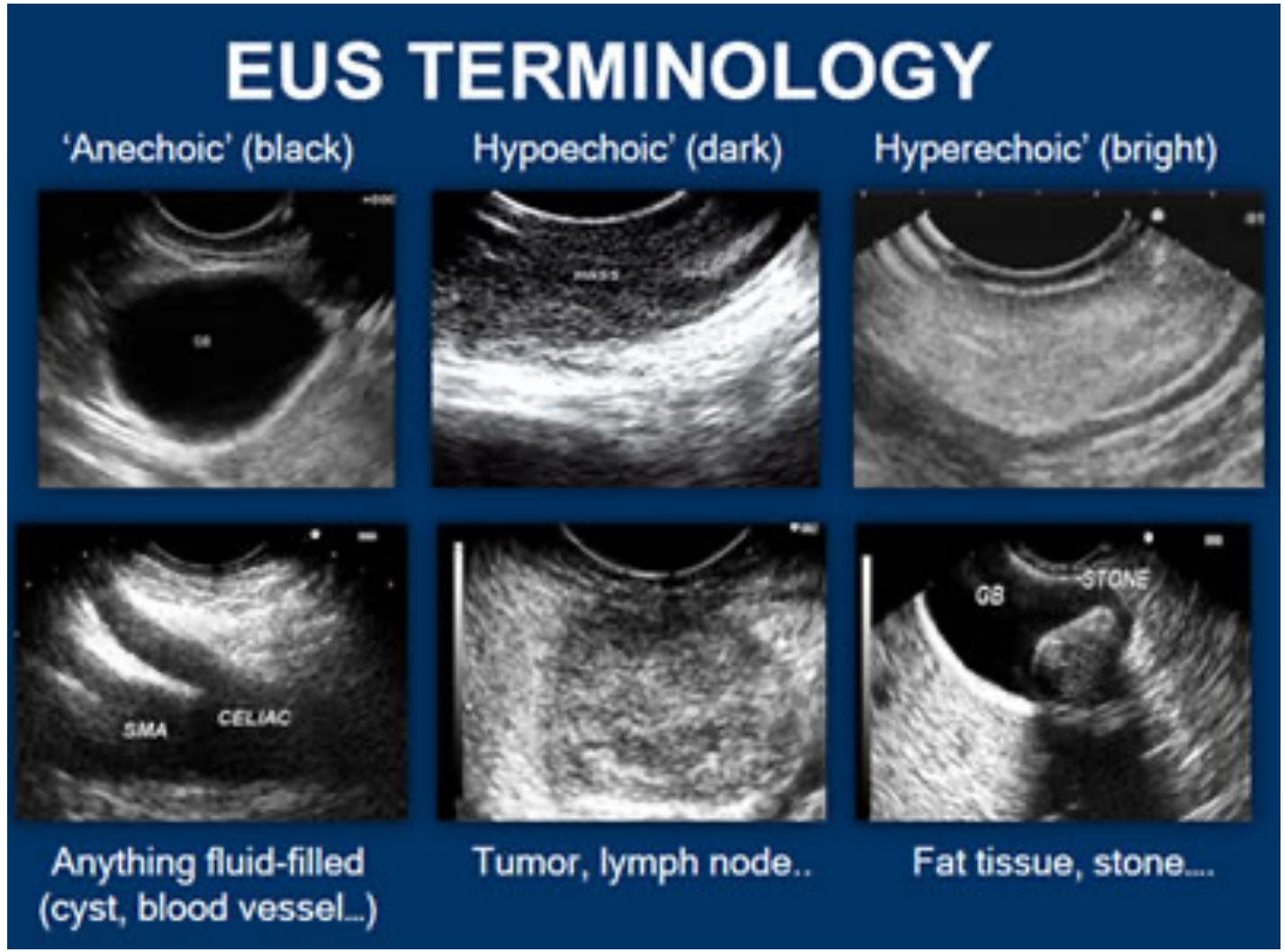
- Ultrasound (US) = sound wave with high frequency
  - Diagnostic frequency = 2MHz to 30MHz
  - Human hearing is 16Hz – 20kHz
- Piezoelectric transducer
  1. Send US waves into the body
  2. Receive reflected waves “echoes” from the body
  3. Convert echoes into electric signal
  4. Signal sent to computer for image display
- US transmission is improved with ultrasound gel “jelly”



Understanding US Signals “Echogenecity”







https://www.educationaldimensions.com/eLearn/aspirationandbiopsy/eusterm.php

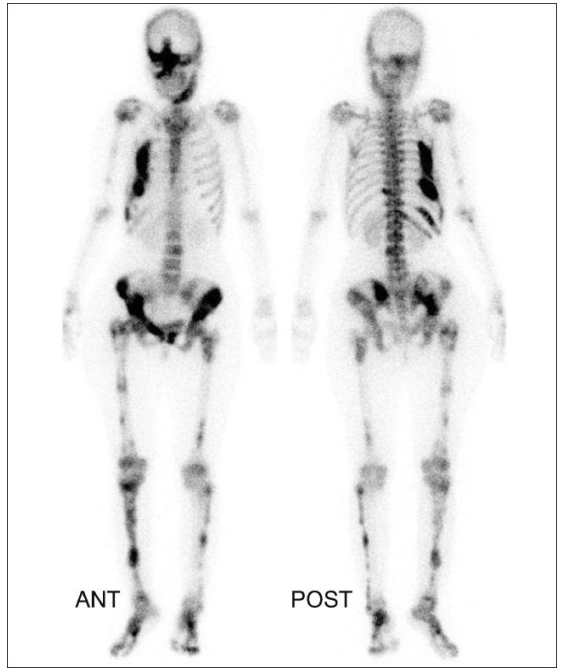
US Applications in DMFR

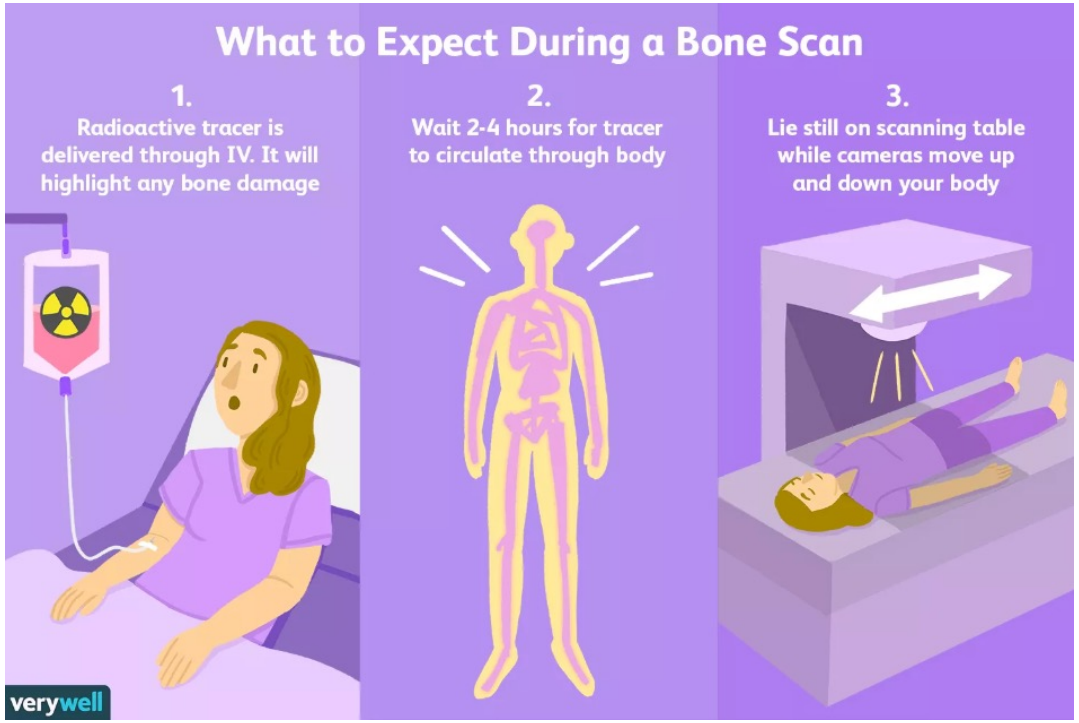
- Salivary gland disease
- Soft tissue swelling of the head and neck
  - Tumours, Cysts, Infection, etc.
- Vascular diseases and anomalies of the head and neck
  - Carotid artery stenosis (blockage or narrowing)
  - Hematoma (collection of blood in tissues from damaged vessels)
  - Abnormalities in the blood vessels, lymph node, etc.
- Ultrasound-guided procedures
  - Biopsy (Fine needle aspirational / FNA)
  - Corticosteroid injection (TM joint)
- TMJ Imaging
  - Real-time imaging (disc-condyle relationship on mouth opening)

III. Nuclear Medicine Imaging (NMI)

What is Nuclear Medicine Imaging?

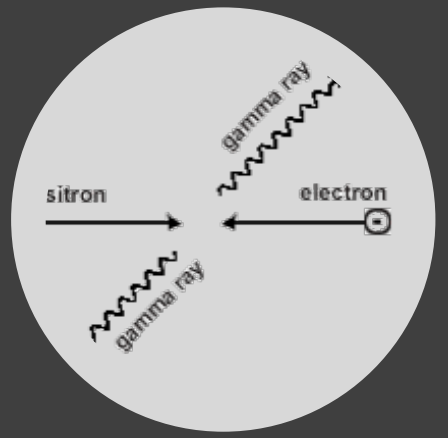
- Radiology “done inside out”
- Radiopharmaceuticals
  - 99mTc MDP
    - Technetium99m + Methyl diphosphate
    - Half life of 6 hrs
- “Hot spots”
- Three types:
  - Scintigraphy (2D imaging eg. Bone scan)
  - Single photon emission computed tomography (SPECT)
  - Positron emission tomography (PET)

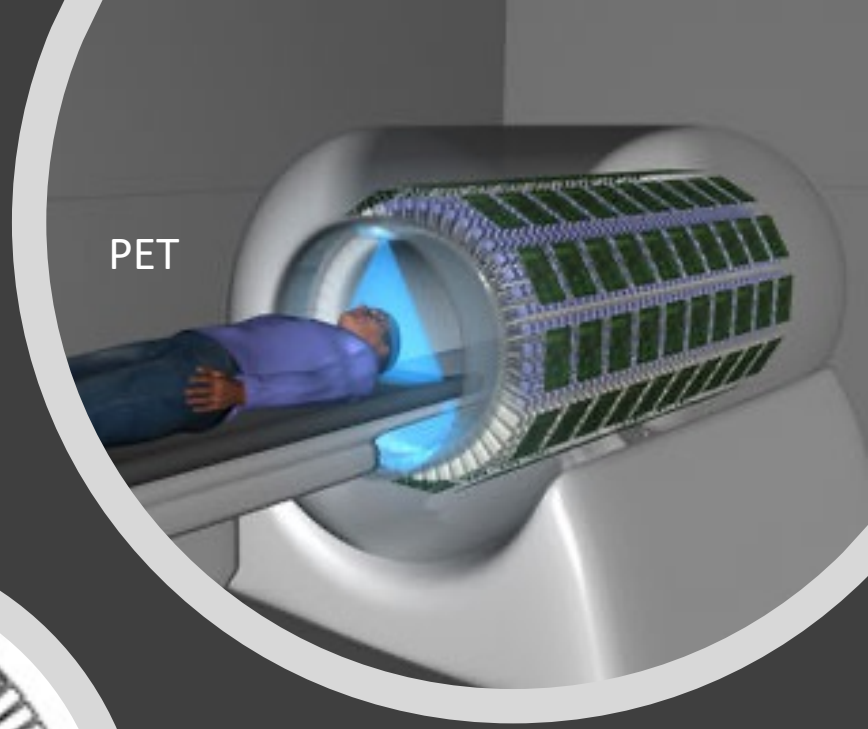


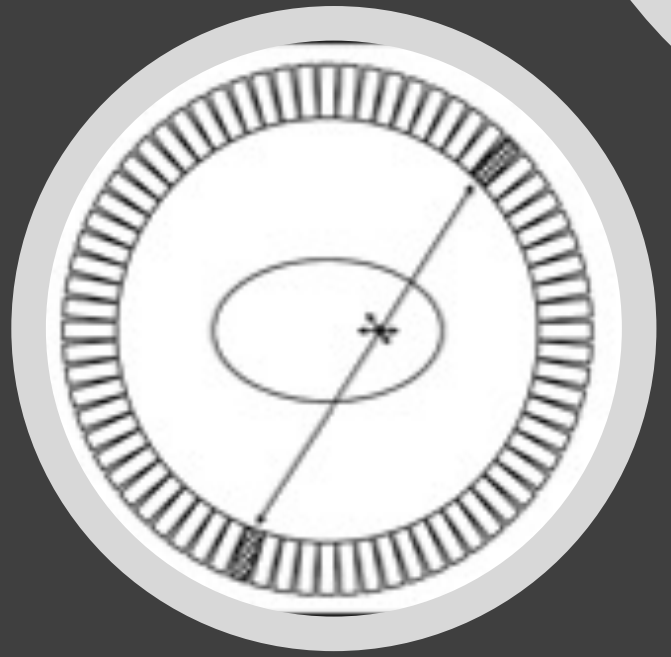


SPECT and PET - 3D Nuclear Medicine Imaging

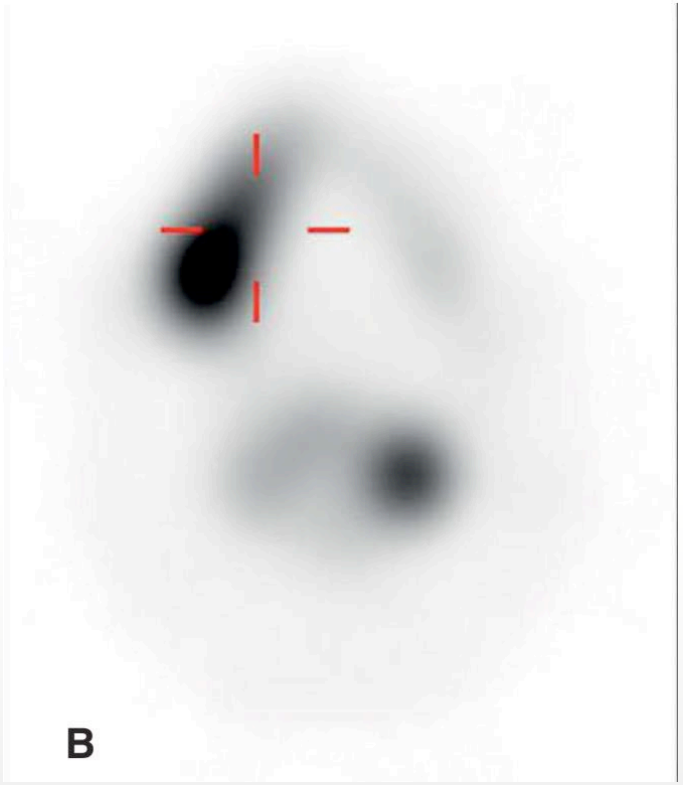
- SPECT (single photon emission computed tomography)
  - 3D → localisation & estimation of the size & extend of the disease
  - Single gamma rays
  - Two receptors
- PET (positron emission tomography)
  - Like SPECT, but more dimensionally accurate
  - Paired gamma rays
  - Multiple receptors



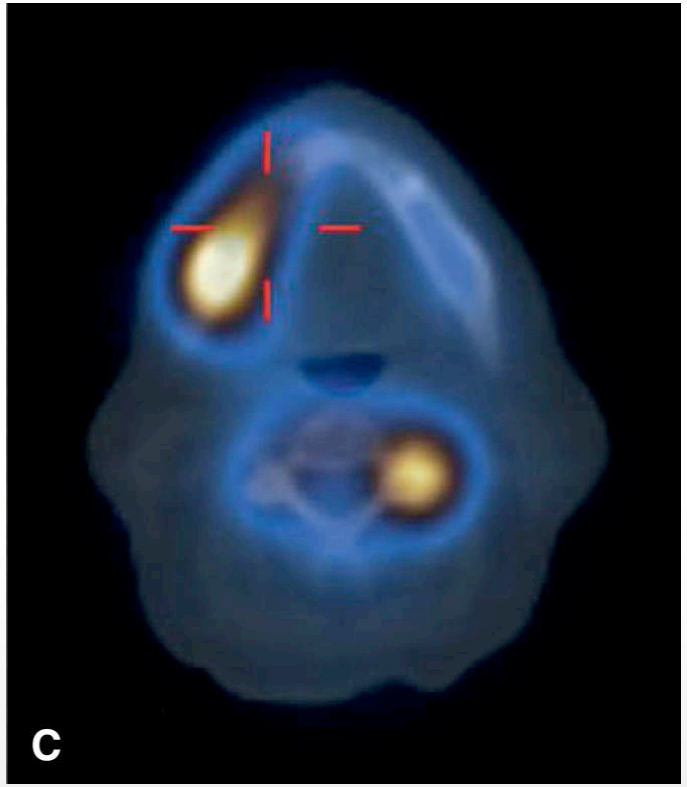




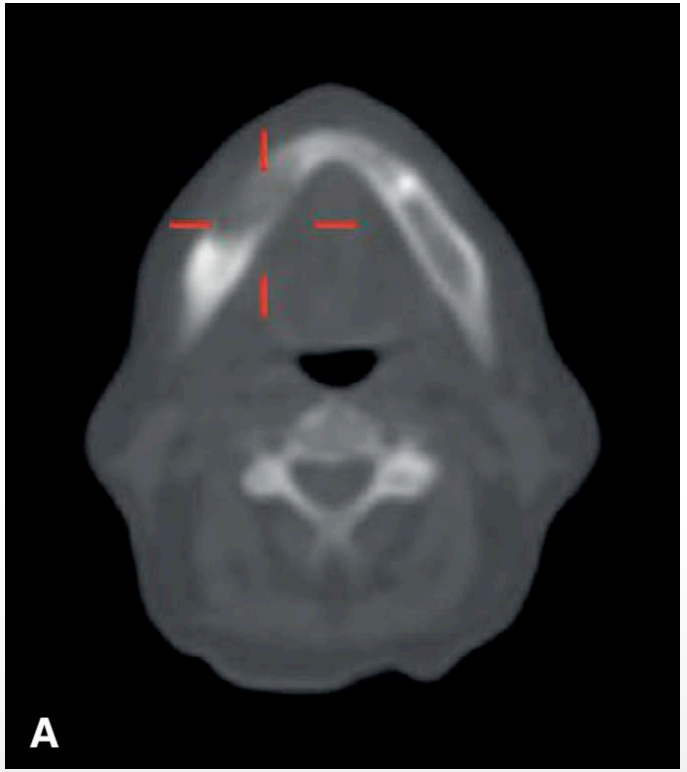
SPECT

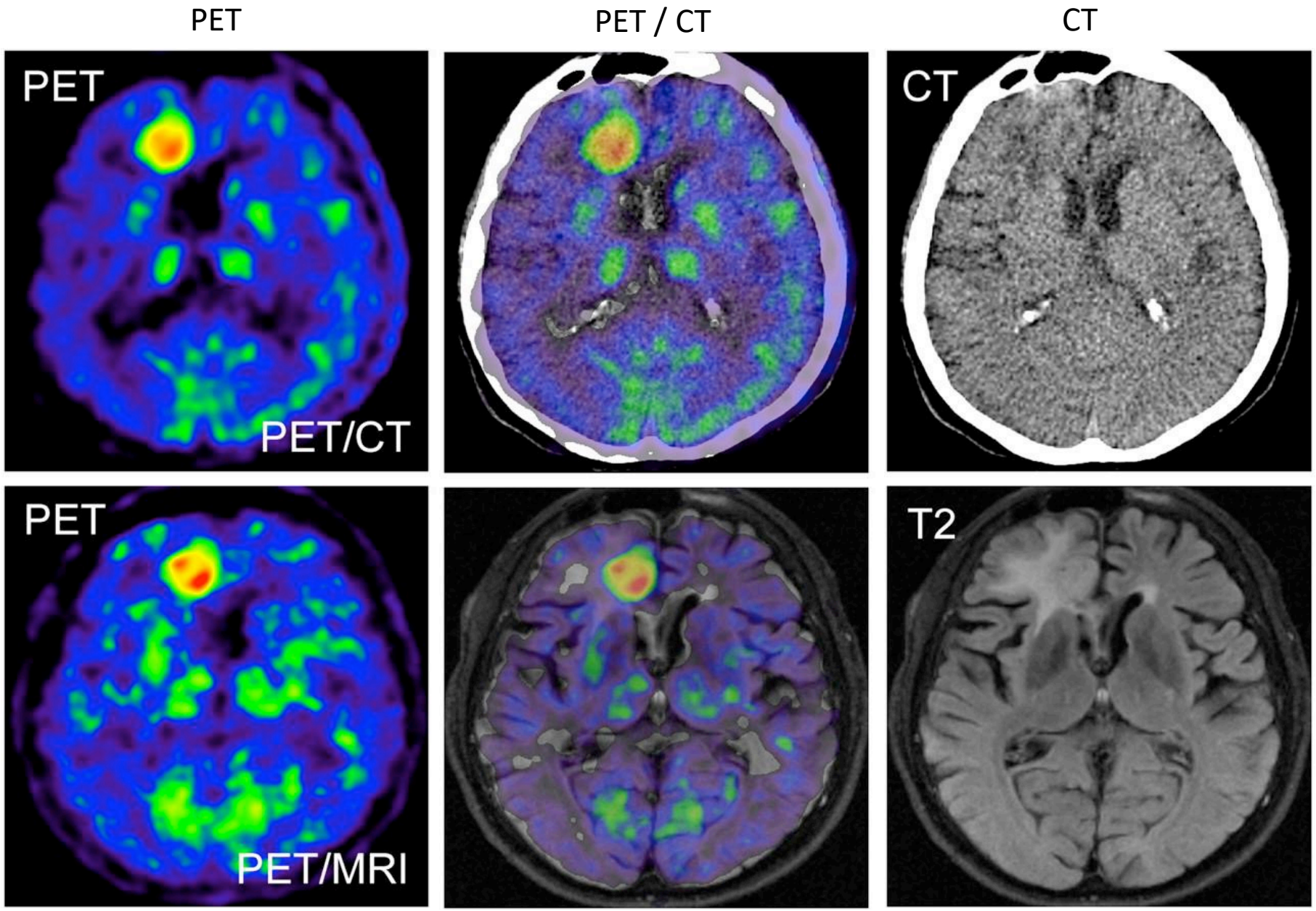


SPECT / CT



CT




PET
PET / CT
CT
PET
PET/CT
CT
PET
PET/MRI
T2

Nuclear Medicine Imaging in DMFR

- Progressive or spontaneous growth of the jaws
  - Eg. condylar hyperactivity, neoplastic growth
- Osteonecrosis of the Jaws
  - Eg. Medication-related osteonecrosis of the jaws (MRONJ), Osteoradionecrosis of the jaws (ORNJ)
- Osteomyelitis
  - Eg. infectious (secondary) osteomyelitis, primary osteomyelitis
- Bone fractures
- Bone disorders inc. primary bone tumours
- Head and neck cancer → *PET*
  - Eg. oral squamous cell carcinoma (OSCC), lymphoma

Further Reading

- Whaites E, Drage N. Essentials of Dental Radiography and Radiology.5thedn. Edinburgh: Churchill Livingstone, 2013.
- Lam E, Mallya S. White and Pharoah’s Oral radiology: Principles and Interpretation. 8th edn. St. Louis: Elsevier, 2018.