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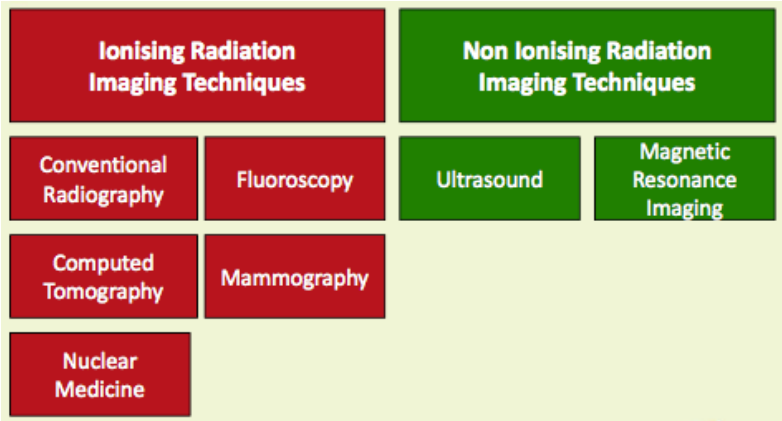
1. THE MEDICAL IMAGING DEPARTMENT

Medical imaging is the process of imaging the body in a medical setting to diagnose injury or disease. It is split up into two categories: **diagnostic** or **therapeutic**.

Medical imaging modalities can either be **ionising** or **non-ionising**. Ionising radiation is energy produced from an imaging technique that also interacts with tissue. It is radiation that has enough energy to cause an atom to become charged or ionised (loses an electron).



- Conventional Radiography
  - The first medical imaging modality
  - Wilhelm Roentgen discovered x-rays on 8 Nov 1895
  - Image produced is called a radiograph
  - It uses x-rays as an energy source
  - X-rays are attenuated when they interact with tissue: can be scattered or absorbed
  - Radiolucent: appears darker, less attenuation
  - Radiopaque: appears whiter, more attenuation
- Fluoroscopy
  - Uses x-rays as energy source
  - Contrast media helps improve visualisation
  - Provides real-time imaging
- Mammography
  - Radiography of the breast
  - Uses lower x-ray energy
- Computed Tomography (CT)
  - First available in 1970s
  - X-rays pass through patient using rotating x-ray tube
  - Tomographic image produced: “slice” of patient
  - High radiation dose
- Nuclear Medicine
  - Uses gamma x-rays
  - Functional imaging
  - Radioisotope is given either orally, injected or inhaled as a radio-pharmaceutical
  - Radioisotope distributes itself according to physiological function
- Magnetic Resonance Imaging (MRI)
  - Uses protons in atoms to produce images
  - Uses powerful magnetic fields and radio-waves

    - Non-ionising
    - Tomographic image produced
- Ultrasound
    - Uses high frequency sound waves
    - Sound generated from transducer, reflected sound wave returns to transducer
    - Pulse echo principle

2. THE HISTORY OF ULTRASOUND

Diagnostic ultrasound uses high frequency sound waves to view and assess structures and organs within the body.

- 500 BC - Pythagoras observed a relationship between sound, pitch and frequency. He invented an early sonometer: a device used for demonstrating the relationship between sound frequency produced by a plucked string and the tension, length and mass of the string
- 400 BC - Archytas studied pitch related to movement of vibrating air
- 350 BC - Boethius compared sound waves to ripples of water
- 1500 - Leonardo Da Vinci discovered that sound travels in waves and the angle of incidence is equal to the angle of reflection
- 1638- Galileo Galilei began study of modern acoustics through the study of vibrations
- 1668 - Isaac newton studied the speed of sound through air
- 1842 - Christian Johann Doppler proposed the 'Doppler' effect
- 1880 - Paul-Jacques Curie and Pierre Curie discover piezoelectricity
- 1914-1918 - Paul Langevin and Constantin Chilowsky discovered a way to use the property of echoing sound waves to detect underwater objects (SONAR = Sound Navigation and Ranging)
- 1940s - Karl Dussik is a psychiatrist and neurologist who detected intracranial lesions and discovered one-dimensional A-mode display
    - George Ludwig, John Wild and William Fry
- 1950s - Douglass Howry and Joseph Holmes produce a 2-D compound scanner and then the bistable display (2-D image displayed in black and white)
    - In 1959, the ultrasonic institute began in Sydney Australia, thanks to George Kossoff, Dr William Garrett and David Robinson
    - Doppler Ultrasound research began in late 1950s by Donald Baker
- 1965 - Walter Krause and Richard Soldner developed the first real-time scanner in Germany. It was manufactured as 'Vidoson' by Siemens and used rotating transducers
- 1969 - Grey scaling was developed at the ultrasonic institute by Kossoff and his team
- 1975 - "Octoson" was developed by the Ultrasonic Institute in Sydney. It is a rapid multi-transducer water-bath scanner that produced high-resolution compound scans at a rate of 1 scan per second
- 1980s - Transducer design improved with research
- 1900s - Harmonic imaging improved visualisation of different types of tissue
- 2000s - Introduction of 3D/4D ultrasound, contrast enhanced ultrasound, molecular imaging, fusion imaging and elastography

3. ULTRASOUND EDUCATION

The origins of formal ultrasound training:

- In 1969, the Australasian Society for Ultrasound in Medicine (ASUM) began from Ultrasonic Institute (UI) staff and clinical collaborators

- ASUM introduced – 1976 – the Diploma of Diagnostic Ultrasound (DDU) established for doctors and in 1979 – the Diploma of Medical Ultrasonography (DMU) established for para-medical persons (obstetric/vascular/cardiac/general, still available today)

Postgraduate ultrasound education:

- 1980 – RMIT established Graduate Diploma in Ultrasonography (no longer offered here)
- 1984 – pressure from within QLD to develop ultrasound course – QUT attempts to accredit course – not accomplished until:
- 1989 – QUT establishes Masters of Applied Science (Medical Ultrasound) with opt out Graduate Diploma
- 1992 – Australian Sonographers Association (ASA) established in Melbourne
- 1994 – Australasian Sonographers Accreditation Registry (ASAR) established by ASUM, AIR, ASA and the universities involved in sonographer education at the time
- 1995 – first private practical ultrasound training institute, the Australian Institute of Ultrasound (AIU) setup on Gold Coast
- Today – the following universities offer accredited postgraduate qualifications in Australia: CQUniversity, Queensland University of Technology, University of South Australia, Monash University, Curtin University of Technology, Charles Sturt University, Western Sydney University. And other organisations to offer accredited programs: ASUM (general, cardiac, vascular, obstetric) and AIHE (general)

In Australia, the practice of sonography requires:

- Successful completion of an accredited program
- **Registration with Australian Sonographer Accreditation Registry (ASAR)**
- Recommended membership with one of the following professions bodies: Australasian Sonographers Association (ASA) OR Australasian Society for Ultrasound in Medicine (ASUM)
- ASAR provides accreditation of programs and sonographers. Overseas qualifications assessed by AIR

National Registration and Regulation

- Registration – a health practitioners name is on a register that the general public can access
- Regulation – practitioners abide by national laws regarding their practice
- In Australia – AHPRA (Australian Health Practitioner Regulation Agency) assists in regulation of medical imaging practitioners **except sonographers**
- The AHPRA is governed by the Health Practitioner Regulation National Law. The primary aim is to *protect the health and safety of the general public*
- MRPBA (Medical Radiation Practice Board of Australia) are part of AHPRA – primarily radiographers and nuclear medicine technologists

Sonographer Regulation

- Sonographers are not part of the MRPBA or AHPRA
- Sonography is a self-regulating profession in terms of entry level requirements, education and continuing professional development
- **ASAR accredits sonographers and educational institutions**
- To maintain accreditation sonographers must undertake CPD
- There is no mandatory reporting of sonographers

4. THE AUSTRALIAN HEALTHCARE SYSTEM

The Australian health system is world-class in both its effectiveness and efficiency: Australia consistently ranks in the best performing group of countries for healthy life expectancy and health expenditure per person (World Health Organisation 2003)

- Australia's population as at 11th March 2017 was estimated to be over 24 million people (24 386 711) – increasing by 1 person every 1 min and 24 seconds
- The Australian population has a generally good health status, with an average life expectancy at birth of 8.14 years (79.2 for men and 83.7 for women), one of the highest in the world
- There are some groups with poor health status, notably Aboriginal and Torres Strait Islander people; otherwise the pattern of disease is like that of other developed countries
- Australia's robust private health sector is complemented by a universal public health system called Medicare
- We have three tiers of government:
  - Federal Government – Canberra based
  - State Government – capital city based
  - Local Government – centrally based in their own city or shire

Federal Government Responsibilities

- Medicare – national scheme providing free or subsidised access to medical facilities
- Pharmaceutical Benefits Scheme (PBS) – subsidises universal access to thousands of prescription medicines
- Rebates for private health insurance premiums
- Veterans health care
- Research funding
- Collecting taxes to pay for these schemes

State Government Responsibilities

- Public hospitals, their management and administration
- Breast screen and immunisation, delivery thereof
- Funding and management of community health schemes, public dental clinics, ambulance services, patient transport subsidy scheme etc.

Local Government Responsibilities

- Community-based health and homecare services e.g. local women's health clinics including pap smear clinics, farmer's health clinics, vaccination clinics, homecare for the homebound
- Environmental health e.g. sanitation services

Issues with the 3-tier government system

- Bickering and disputes over funding, along with cost-shifting occur regularly, especially between federal and state governments of different political persuasions e.g. Liberal Federal government vs State Labour government
- Duplication of services/waste

Healthcare system tiers

- Primary care: first level of contact with the health system e.g. GP – no referral is needed. Dentists, indigenous health workers, pharmacists, physiotherapists and chiropractors fall under this category
- Secondary care: referral from primary caregiver e.g. referral from GP to see a specialist. Sonographers, echocardiographers, radiographers, radiologists, cardiologists, obstetricians, urologists and paediatricians fall under this category

- Tertiary care: typically, hospital – public or private

Medicare
- Universal healthcare system introduced in 1984
- Medicare is the federal government health insurance system managed by the "department of health and aging"
- The principal aim of Medicare is to make healthcare affordable and accessible for all Australians through free of subsided health care
- The Medicare Benefits Schedule (MBS) lists all services that are covered under Medicare insurance scheme
- The Pharmaceutical Benefits Scheme (PBS) provides subsidised funding for necessary pharmaceuticals
- Reciprocal healthcare agreements enable Australians to receive free essential medical treatment whilst overseas in certain countries
- 3 main objectives: fund medical services, fund pharmaceutical benefits and fund public hospital care

Medicare Levy
- Started in 1984
- Provides approximately 1/3 of Medicare funding (remainder comes from general taxes)
- 2% of taxable income paid by individuals earning above a certain threshold

Medicare Surcharge
- An additional surcharge in addition to the Medicare Levy that high earning individuals pay that do not have an appropriate level of private health cover

Pharmaceutical Benefits Scheme
- Started in 1948
- The PBS is a scheme that subsidises the cost of medicine for a range of medical conditions
- The PBS schedule lists all the medicines available to patients at a government subsidised price
- All individuals that hold a current Medicare card are eligible for PBS
- Co-payment of $38.30 for most PBS medicines
- Patient safety net of $1,475.70 per family per annum

Private Health Insurance
- Strongly encouraged by the Australian government
- Government offers a rebate for Medicare card holders who take out private health insurance
- Benefits: provides shorter waiting times, more physician/hospital choice, funds part ancillary services like dentistry, physiotherapy

Medicare and Diagnostic Imaging
- Rebates are provided for certain diagnostic imaging services, but only to: practices accredited under the Diagnostic Imaging Accreditation Scheme (DIAS)
- DIAS developed to ensure safety and quality standards for diagnostic imaging practices
- MRI units must be registered for patients to receive rebates
- Ultrasound in MBS:
  - General: Group 1 Subgroup 1 Item number 55005-55855
  - Echocardiography: Group 1 Subgroup 2 Item number 55113 –

NHMRC
- National Health and Medical Research Council
- Established in 1926

- Supports health and medical related research
- Provides health advice to health professionals and governments, as well as the general community
- Provides advice on ethical behaviour

5. MEDICAL TERMINOLOGY

The main sources of medical terminology are drawn from many languages. **Greek** terms are used mainly in **clinical** terminology and **Latin** terms are used mainly in **anatomical** terminology.

Greek origins of Medical Terminology

- Greeks were founders of rational medicine in about 5th century BC
- Hippocratic School, and later Galen formulated the theories which dominated medicine up until beginning 18th century
- Hippocratics first to describe disease based on observation
- Diagnosis and surgery terms are mainly Greek in origin

Latin Origins of Medical Terminology

- Latin was the original universal language of the western world, and was the language of science up to the beginning of the 18th century. All medical texts were therefore written in Latin
- Andreas Vesalius – De humani corporis fabrica
- Anatomical terms are predominantly Latin in origin

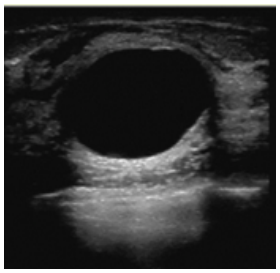
Components of Medical Words

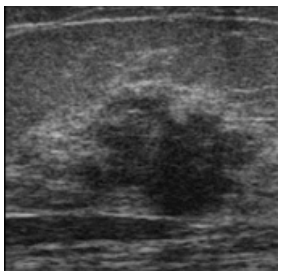
- Most medical words have three components: prefix, root and suffix
- Root = often equals an element of anatomy
- A suffix or prefix are added to modify the root word and add additional meaning
- E.g. pericarditis: peri – around, card – heart, itis – inflammation

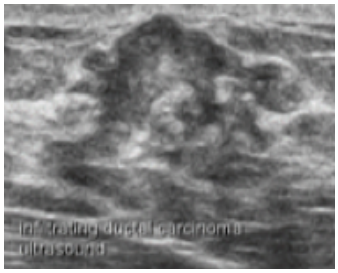
Ultrasound Terminology

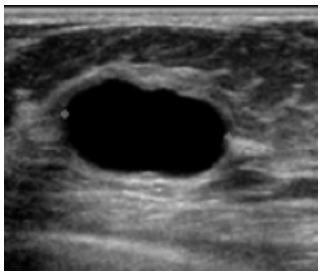
- Echogenic – to produce echoes. Structures which are more echogenic appear 'brighter'
- Hyperechoic (comparative term) – area with increased echoes (appears 'brighter' on image)
- Hypoechoic (comparative term) – area with decreased echoes (appears 'darker' on image)
- Isoechoic (comparative term) – area with a similar level of echo return on image (similar echogenicity)
- Anechoic/sonolucent – area with no internal echoes (appears black on image)
- Homogenous – area which contains echoes of a uniform composition
- Heterogeneous – area which contains echoes of varying composition
- Echotexture – description of the echo pattern within a structure e.g. Homogeneous, echogenic
- Acoustic window – an area of the body which is free from gas or bone, which ultrasound can easily pass through. The anatomical structures deep to this 'window' can be more optimally evaluated. We use the urinary bladder as an acoustic window to image the uterus. We use the liver as an acoustic window to image the kidney
- Attenuation – ultrasound loses energy as it travels through tissue. Five main processes of attenuation: absorption, reflection, scattering, refraction and divergence
- Artefacts – structure in an ultrasound image which does not correspond to an actual structure within the body. Structures which are seen in an image but are not actually present, or structures which are present and should be seen in an image but are not. They are an apparent echo for which the distance, direction or amplitude of the echo do not correspond to a real target

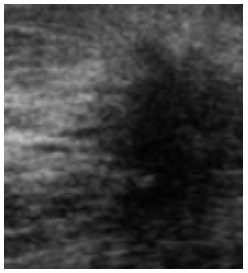
- Posterior enhancement – an artefact due to an over-amplification of echoes deep to an area of low attenuation, such as a fluid-filled area
- Posterior shadowing – an artefact caused by an area of low amplitude of echoes deep to a highly attenuating structure, such as bone
- A description of the outer edge/surface of an anatomical structure may be described as: encapsulated, well defined/poorly defined, lobulated/smooth/speculated, thick walled/thin walled

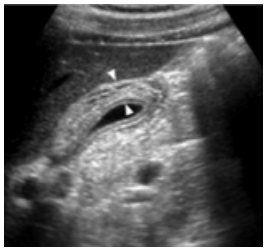

Well defined


Poorly defined

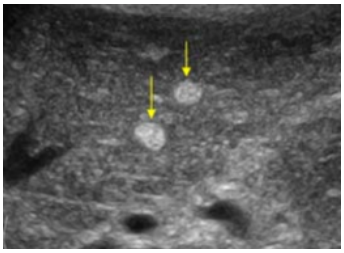

Lobulated

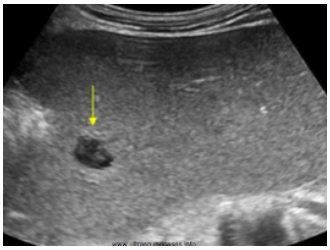

Smooth

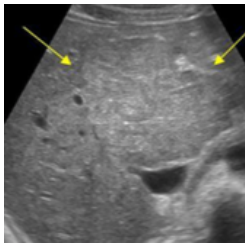

Spiculated


Thick-walled

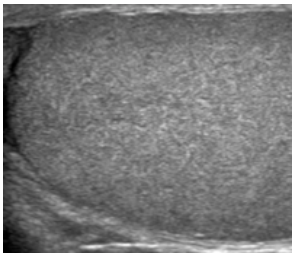
Thin-walled

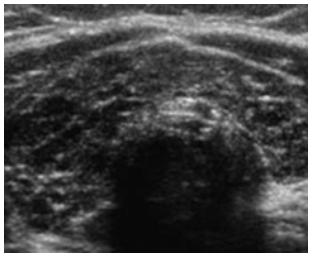

Hyperechoic


Hypoechoic

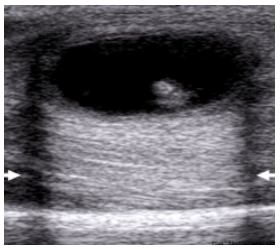

Isoechoic

Anechoic

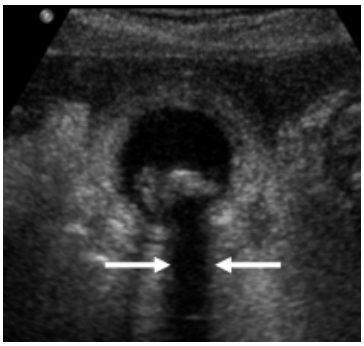

Homogenous


Heterogeneous

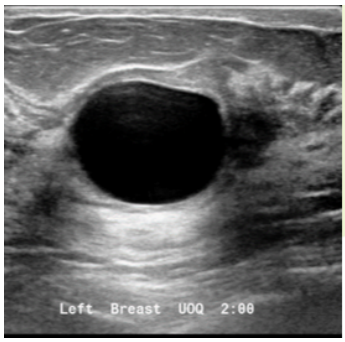
Acoustic Window


Posterior enhancemen

- Posterior Shadowing



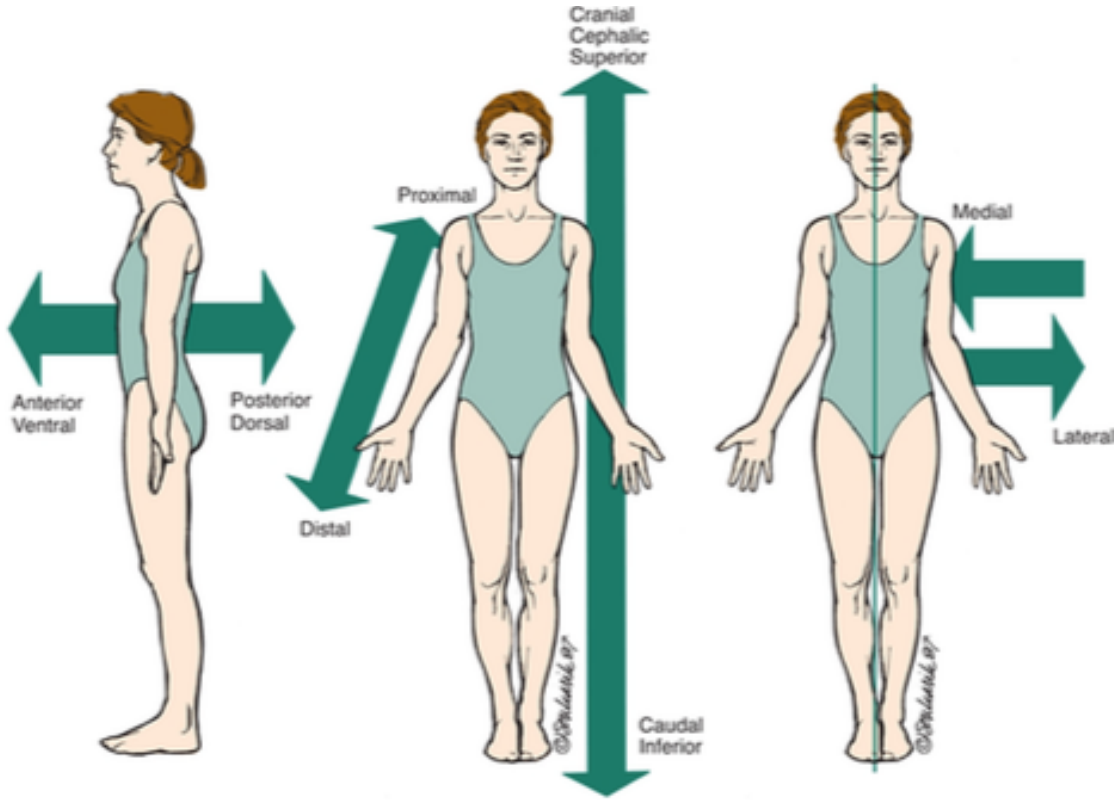
- Cystic – used to describe a fluid-filled structure. Does not contain internal echoes and exhibits posterior enhancement



- Loculated – fluid collections which are separated into compartments by septations

- Septations – divisions within a structure. Variable appearances e.g. thick, thin, vascular

6. ULTRASOUND SCAN PLANES



Transducer Orientation

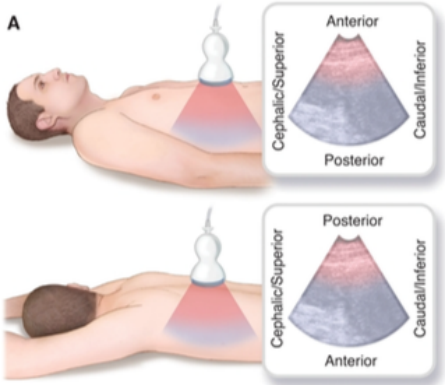
- Think about: path of insonating sound and echo and notch indicator and transducer
- Scanning plane: transducer orientation to anatomic plane of organ

Ultrasound Scan Planes

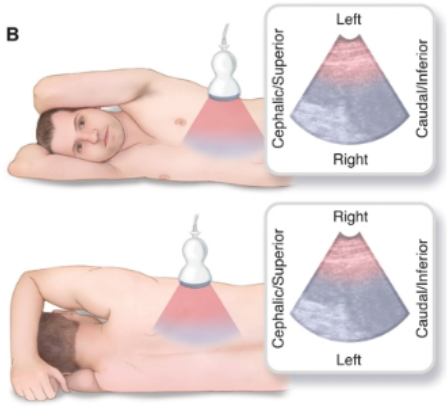
- Longitudinal 'long' – the longest length of the structure being examined (sagittal or coronal)

- Transverse/Axial plane of structure being examined (90 degrees to Long)

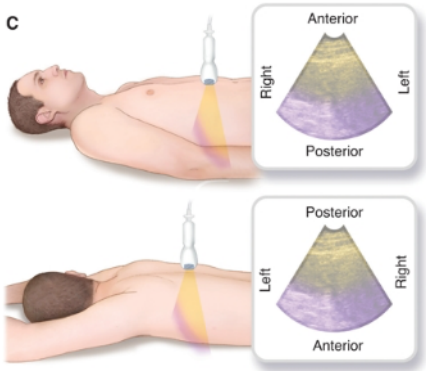
Longitudinal: Sagittal planes – transducer notch always towards patient head in sagittal planes



Longitudinal: Coronal planes – transducer notch always towards patients head in coronal planes



Transverse planes anterior and posterior surfaces – transducer notch always towards you in transverse planes



Transverse planes right or left surfaces – transducer notch always towards you in transverse planes