Diagnostic imaging and scans

A short history of medical imaging

The first X-rays

The first medical images were X-rays, discovered by Wilhelm Röntgen in 1895 and quickly followed by research by other scientists in laboratories in Europe and America. The radiographs (initially on glass plates) enabled a view of the skeletal system and allowed an assessment of bony trauma not previously possible. Metal bullets and rings could also be seen. By the late 1940s, the long-term risks of radiation were starting to be understood, although lead aprons used as a shield were used as early as the 1930s.[1]

The development of ultrasound

The concept of ultrasound (US) dates back to the late 1700s when Lazzaro Spallanzani hypothesised that bats used sound waves to navigate. In 1826 the speed of sound in water was calculated by Jean-Daniel Colladon, and in 1842 the Doppler effect was described by Christian Doppler. Piezoelectric crystals (discovered by the Curie brothers) vibrate with an alternating current. This all led to the development of US transducers. US was initially used for therapeutic purposes, and was not used for imaging until the 1940s. In 1958, it was first used to study the unborn fetus and uterus.

Development of CT and MRI

Computerised tomography (CT) was developed in 1967 by Sir Godfrey Hounsfield and was first used on a patient in 1971. It is widely used - in 2019/20, there were 5.9 million CT scans done in the NHS and as of 2020 there were around 300 million CT scans done worldwide every year.[2] [3] Unlike X-rays, soft tissue is contrasted with anatomical details, and images are presented in two-dimensional cross-sections. This helps achieve significantly greater diagnostic accuracy and allows a far wider variety of internal organs to be examined. The scope of CT scanning continues to be developed, particularly in the management of stroke and cardiac medicine.

The development of magnetic resonance imaging (MRI) involved scientists, clinicians and technicians from across different fields. Scientists Felix Bloch and Edward Purcell separately but concurrently introduced the concept of nuclear magnetic resonance (NMR), for which they were awarded the Nobel Prize for Physics in 1952. The first NMR images were published in 1973 by Paul Lauterbur. MRI scanning is now used in almost every medical speciality and because of its clarity and detail, is considered the gold standard of imaging. In 2019/20, there were 3.8 million MRI scans done in the NHS.

Ultrasound scanning - non-obstetric

US does not involve the use of ionising radiation. It can therefore be used safely in pregnancy; for children; and when repeated examinations are required.

It creates a picture from the reflection of high-frequency sound waves by interfaces between tissues. Particular advantages for mass use are the relatively low cost and high portability of US equipment.

It is used for a variety of diagnostic and therapeutic purposes and technological advances mean that the quality of the imaging has greatly improved.

- **Abdominal ultrasound** - including liver and gallbladder (cirrhosis, malignancy, gallstones); pancreas (pancreatic cancer, pancreatitis); assessing for appendicitis; assessing blunt abdominal trauma; aortic aneurysm.
- **Urological ultrasound** - including kidneys (glomerulonephritis, renal stones); bladder; prostate; testes (torsion, epididymo-orchitis, undescended testicle).
- **Gynaecological ultrasound** (also transvaginal ultrasound) - including distinguishing between ovarian and adnexal mass; differentiating between ovarian cancer and benign ovarian tumours; monitoring follicle production during infertility treatment; identifying ectopic pregnancy (via transvaginal US); identifying precise location of an IUCD; hydatidiform mole. US is also routinely used in obstetrics, to monitor growth and to screen for fetal abnormalities.
- **Thyroid ultrasound** - distinguishing thyroid lumps; thyroid cancer.

- **Breast ultrasound** - breast cancer (along with mammography); benign breast lumps.
- **Musculoskeletal** - used to diagnose conditions such as Achilles tendonitis; tendinopathies, injuries, bursae, effusions of the shoulder, elbow, wrist, knee, hip and foot; screening for developmental dysplasia of hips; muscle tears.
- **Lumps** - distinguishing the nature of lumps almost anywhere on the body (lipomas, cysts, lymph nodes).
- **Vascular** - diagnosing deep vein thrombosis; varicose veins
- **Lungs** - diagnosing pneumothorax.

Please see the separate Ultrasound Scanning - Non-obstetric article for more detail.

Computerised tomography scans

There are two types of CT scans:

- Conventional CT scan where the scan is taken slice by slice.
- Spiral CT scan - a continuous scan taken in a spiral fashion.

Advantages include: better detail than ultrasonography; quick compared to MRI scanning; most systems can be scanned.

Disadvantages include:

- Requires breath holding (may be challenging for some patients, particularly those with lung conditions such as COPD).
- Artefact is common (eg, metal clips).
- High doses of radiation by comparison to those involved in X-rays of the equivalent system or body part.
- Risk of childhood cancer and leukaemia if a fetus is exposed during the mother's pregnancy.

Contrast can be used in CT scans to improve imaging, but the use of contrast adds additional risks including anaphylaxis and worsening renal impairment (particularly with iodine-based scans) as well as more minor side effects.

Please see the separate Computerised Tomography (CT) Scans article for more detail.

Magnetic resonance imaging

MRI scanning is used alongside CT scanning and ultrasound, and has largely superseded it for some indications. However, the contra-indications for the two techniques are different and this may determine the type of imaging used.

Indications for MRI scan include:

- Central nervous system - stroke, demyelinating disorders, tumours.
- Musculoskeletal - ligament tears.
- Circulatory system - veins and arteries.
- Cardiac - cardiac structure, ischaemia.

Advantages include:

- Harmless to patient (no radiation is used).
- Highly detailed images as good as CT scanning.
- Contrast agent (if used) less allergenic than iodine-based agents used in CT scans.

Disadvantages include:

- Limited availability.
- Noisy, lengthy procedure (30 minutes or more), in which the patient may be required to lie still. This may be particularly difficult for patients with claustrophobia or anxiety (open MRI scanners exist but are not routinely available).

- MRI is contra-indicated if the patient has a metallic implant (including cardiac pacemaker, aneurysm clips, some cardiac stents) or foreign body (metal fragments in an eye).

Cardiology investigations

US, CT and MRI scanning are all used in investigation of cardiological symptoms. The principles including risks and side-effects, are similar to those seen in use of these tools in other clinical areas. In addition, radionucleotide-based scanning techniques are widely utilised.

For more detailed understanding of the role of these investigations in cardiology, please see our separate articles on Echocardiography, and Exercise Tolerance Testing.

Authored by:	Peer Reviewed by: Dr Colin Tidy, MRCGP	
Originally Published: 20/11/2023	Next review date: 07/08/2023	Document ID: doc_30801