UNTIL THE 1990s, the only diagnostic imaging techniques in most hospitals were X-rays and ultrasound scans. Now there are many other techniques, including magnetic resonance imaging (MRI), computed tomography (CT), positron emission tomography (PET), Doppler ultrasound and radionuclide imaging (RNI). This article examines a range of imaging techniques, their uses, safety considerations and preparation for patients undergoing imaging. The four basic techniques of medical imaging are:

- **X-ray**, which includes CT, contrast X-ray using a contrast medium like barium and X-ray angiography.
- **Ultrasound**, which includes Doppler ultrasound.
- **MRI**, which includes magnetic resonance angiography (MRA) and functional MRI (fMRI).
- **RNI**, which includes PET (Table 1).

X-ray, MRI and ultrasound are better at showing anatomical structure, while Doppler ultrasound, MRI and PET show the physiological function of organs and tissues. The choice of which scan to perform depends on a number of factors: how quickly the result needs to be produced, the level of detail required, whether structure or function is more important and risks to the individual patient and staff (Gould 2003).

**X-ray**

X-rays use high-energy electromagnetic radiation. As they pass through the body they are either absorbed (attenuated) or scattered, depending on the thickness and characteristic of the tissue and organs. X-rays pass easily through fluids and soft tissue, which appear dark, but are blocked by dense tissue such as bone, which is shown as white. X-ray images can be produced quickly and relatively cheaply. They are widely accessible and are useful for quick diagnosis, particularly in patients with trauma. The disadvantages of X-rays are that they differentiate poorly between different types of soft tissue, there are restrictions relating to pregnancy and ionising radiation doses have to be strictly monitored for safety (Box 1).

Contrast X-rays, like barium enemas or angiograms, are better at differentiating soft tissue and they use a contrast medium to make visible hollow or fluid-filled structures, such as the digestive tract, blood vessels or urinary system. A suitable medium is injected or swallowed and, as X-rays cannot pass through it, the area will appear white on the X-ray.

X-rays are the most common form of imaging, especially for trauma and initial diagnosis. They also assist in assessment of fitness for anaesthesia and positioning of internal devices, such as nasogastric tubes or central catheters. X-rays are used to spot lesions in the lungs and bones and to check that plaster casts are holding fractured limbs correctly. They also have widespread use in dental surgeries and in breast screening.

Digital images are beginning to replace photographic X-ray plates. They can be
manipulated to enhance images, and can be displayed on a monitor and sent instantly to another department or hospital. This allows consultants in one centre to give specialist advice to someone in another centre and enables surgeons to discuss images with radiologists at different sites. Digital X-rays expand the usefulness of the images and simplify storage and retrieval (Parvin 1997).

**Computed tomography** CT, sometimes known as computer assisted tomography (CAT), involves rotating the X-ray source around the patient to produce a very fine spiral of images or slices through the body. This allows two and three-dimensional images to be constructed which show fine detail of soft tissue structures in the body, including the head where normal X-rays are difficult because of the bony skull.

Head scans can identify tumours and problems with the cranial blood supply, especially in stroke. Abdominal CT scans are used in the diagnosis of cancer, osteoporosis, injury and disease of the bones, particularly the spine, damage to internal organs following trauma and planning and evaluating radiotherapy treatment (Rydeberg et al 2000).

**Special clinical radiological applications (X-ray angiography)** Angiography is used to visualise blood-filled structures such as the veins, arteries and heart chambers. A contrast medium is introduced via a peripheral vein usually in the groin. Angiography can show narrowing of blood vessels caused by atheroma or fatty plaques, ballooning of arteries which precede aneurysms and blood clots which can lead to thrombosis. It can also detect areas of angiogenesis or growth of new blood vessels. Tumours can be identified and the shape and pattern of growth can indicate the type and aggressiveness of the tumour. Damage to organs can also be determined (Parvin 1997).

Angiography is mostly used to assess the condition of coronary arteries before drug treatment, balloon angioplasty or coronary artery bypass graft. However, it has increasing use in studies of arterial supply to the brain and in making treatment decisions for patients with cerebrovascular accident (CVA) (or stroke). Standard X-rays are of little use in assessing CVAs because of the blanking effect of the skull. If the CVA is caused by a clot in the brain, it can be treated quickly with anticoagulants to prevent further damage. If it is caused by a bleed, anticoagulants should not be given (Wardlaw et al 2003).

### TABLE 1: Medical imaging techniques

<table>
<thead>
<tr>
<th>Imaging technique</th>
<th>Diagnostic use</th>
<th>Risks/limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>X-ray imaging</strong></td>
<td>Trauma, initial diagnosis, lung lesions, assessment for anaesthesia, internal device positioning, dentistry, breast screening</td>
<td>Ionising radiation, pregnancy, limited annual exposure</td>
</tr>
<tr>
<td><strong>Contrast X-rays</strong></td>
<td>Digestive tract, blood vessels, urinary system</td>
<td>As above</td>
</tr>
<tr>
<td><strong>Computed tomography (CT)</strong></td>
<td>Soft tissue, head scans, tumours, cranial blood supply, stroke, osteoporosis, bone disease, evaluating radiotherapy treatment</td>
<td>As above and claustrophobia</td>
</tr>
<tr>
<td><strong>Special clinical radiological applications (X-ray angiography)</strong></td>
<td>Blood vessels, coronary arteries, tumour staging, arterial supply to the brain, cerebral vascular accidents</td>
<td>Ionising radiation, pregnancy, limited annual exposure</td>
</tr>
<tr>
<td><strong>Ultrasound imaging</strong></td>
<td>Obstetrics, soft tissue, abdominal organs, trauma, cancer diagnosis</td>
<td>No known risk</td>
</tr>
<tr>
<td><strong>Doppler ultrasound</strong></td>
<td>Organs and tissue function; blood flow in the heart, kidneys, liver, smaller vessels; tissue function</td>
<td>As above</td>
</tr>
<tr>
<td><strong>Magnetic resonance imaging (MRI)</strong></td>
<td>Structure and function, soft tissue injury and disease, detection of tumours, kidney and liver function. Differentiates between similar types of tissues</td>
<td>Noisy and claustrophobic, must exclude any metal in the body due to strong magnetic field. Induction of electrical currents can stimulate nervous tissue and muscle</td>
</tr>
<tr>
<td><strong>Magnetic resonance angiography (MRA)</strong></td>
<td>Cardiac function and surgery</td>
<td>As above</td>
</tr>
<tr>
<td><strong>Functional MRI (fMRI)</strong></td>
<td>Function of the brain, blood flow</td>
<td>As above</td>
</tr>
<tr>
<td><strong>Radionuclide imaging (RNI)</strong></td>
<td>Soft tissue, tumours, lung function. Radio-pharmaceuticals can be used for cancer treatment</td>
<td>Low-level radioactive emission 24 hours after imaging, limited annual exposure. Pregnancy, state of organs, disease, age, sex and size of patient need to be considered</td>
</tr>
<tr>
<td><strong>Positron emission tomography (PET)</strong></td>
<td>Research, brain, cerebrospinal fluid, tumours, organs, metabolic activity</td>
<td>As above</td>
</tr>
</tbody>
</table>
Ultrasound

Ultrasound imaging uses acoustic waves to form an image by echo-reflection, which is like echolocation used by bats to navigate. A pulse of ultrasound around 1-12 megahertz is sent from a transducer rolled on the skin surface. The time taken for the pulse to return to the surface builds up a picture of the tissues underneath. Gel is applied to the skin to form an airtight contact between the transducer and skin surface. Interpretation of the image requires a highly skilled operator, but new techniques are being developed to improve the quality of the images. Ultrasound is non-invasive. No risks have been identified and it is relatively cost-efficient. Recent developments are improving the displays and increasing the usefulness of this technique.

Abdominal ultrasound is used to examine soft tissue which does not show up well on X-rays. It reveals damage and disease in abdominal organs, such as the spleen, liver and bladder, and is suited to trauma and cancer diagnosis. Ultrasound within bony structures, for example the skull, is difficult because so much of the sound energy is reflected at the bone surface.

Ultrasound can be enhanced by the use of contrast agents. Contrast agents are suspensions of tiny gas bubbles, a few microns in diameter, which are given by intravenous injection. Exposure to ultrasonic frequencies causes the micro-bubbles to resonate, which increases the strength of the reflected signal giving clearer images. Very intense high energy pulses can cause the bubbles to burst, boosting the signal further. The bubble-bursting mechanism is also being investigated as a method for targeted drug delivery, for example, to break up fatty plaques in blood vessels (Burns 1995).

**Doppler ultrasound** Doppler ultrasound provides information about the function of organs and tissue. It uses the movement of sound to produce images. It identifies whether structures (usually blood) are moving towards or away from the probe, and determines its relative velocity. It can image any movement in the body and colour can be used to show the changes. Doppler information is of particular use when modelling blood flow in the heart, kidneys, liver and, increasingly as techniques improve, in the smaller vessels. Doppler ultrasound is useful for assessing the functional ability of tissue, for example, whether blood vessels are narrowed by disease or how the bladder copes with micturition. The transducer can be applied to the skin surface or introduced into body cavities, which reduces the depth through which the sound waves must travel and removes the difficulties of angling the transducer, for example, to avoid the ribs during cardiac monitoring. There is no known risk associated with this technique.

**Ultrasound scanning in obstetrics** Ultrasound scanning is used widely for examining pregnant mothers and their unborn children. Most pregnant women are screened by ultrasound between the 16th and 20th week of pregnancy. Ultrasound scanning is used to follow the stage of development of the fetus(es), the position of the placenta and any problems identified can be followed throughout the pregnancy without harm to the fetus (Box 2).

**Magnetic resonance imaging**

MRI is a technique that provides information about structure and function and is especially useful for assessing soft tissue injury and disease. This technique examines the behaviour of molecules, usually hydrogen atoms, when placed in a strong magnetic field and subjected to pulses of radio frequency energy. This produces two types of image: one showing anatomy and the other function. The operator can choose the most appropriate settings to provide the desired images for the clinician.

MRI is non-invasive and does not use ionising radiation, although patients often find the procedure claustrophobic and noisy. As imaging speeds increase with new technology and scans...
become quicker, this will become less of a problem. MRIs produce high-quality images that can be used to produce scans at any angle and to construct three-dimensional images. It can differentiate between tissues of similar nature, for example, bones and joints, and nerves and blood vessels.

MRI is of great value in trauma and sports injury, tumour detection and investigation of kidney and liver function. MRI is also useful in imaging the brain and spine. It shows damage to the nerves in multiple sclerosis and following stroke. Changes in blood flow can be detected to reveal the function of different areas in the brain using fMRI (McDonnell et al 1994).

MRI can be used to allow surgeons to operate via thin wire catheters, which is less invasive than other approaches. Ultrasound and X-ray fluoroscopy have long been used for this, but the accuracy of ultrasound is dependent on the skills of the scan operator, and X-ray exposes patients and staff to ionising radiation. Attention is beginning to focus on the potential of MRI-guided procedures, particularly in neurosurgery and cardiac operations where accuracy and minimising risks from X-ray exposure are of prime importance.

The main risk from MRI relates to ferromagnetic objects, such as pacemakers and surgical clips, which are greatly affected by the strong magnetic field. Departmental procedures should protect patients, visitors and all staff, including cleaners and escorts. Care must be taken to ensure that patients with implanted ferromagnetic devices are identified and that they do not undergo MRI. Other hazards are noise and the induction of electrical currents within a patient, which can stimulate nervous tissue and peripheral and cardiac muscle, for example, twitching in the fingers.

MRA examines blood flow using contrast media and is used to assess cardiac function, for example, in patients with cardiac myopathy and myocardial infarction. MRA can also be used in surgery, for example, arterial grafts.

Radionuclide imaging

RNI displays soft tissue, such as tumours, and can be used to assess lung function. It uses a radioactive source called a radio-pharmaceutical to produce beta and/or gamma particles which can be detected by the scanner. Gamma emissions are preferable because they cause less damage to surrounding tissue. The most common radio-pharmaceuticals are labelled with Technetium-99, which is easily handled within the department. Larger doses of radio-pharmaceuticals can be used in radiotherapy, particularly in cancer treatment.

In RNI a radioactive compound is injected or inhaled to target a particular tissue or organ. The radiation emitted shows the structure or function of the targeted area. Factors affecting the type or strength of radio-pharmaceutical are the state of the organs responsible for metabolism and excretion (liver, kidneys, lungs and skin), the disease state of the body, and the age, sex and size of the patient.

The radio-pharmaceutical needs time to accumulate in the tissue being imaged for a clear scan. The time needed for the agent to accumulate needs to be balanced with restricting exposure to the worker administering the radio-pharmaceutical and ensuring that the patient is not unduly constrained in his or her activities following exposure. The radio-pharmaceutical is excreted naturally, mainly in urine, over the next 24 hours. If the RNI recipient is an inpatient there are restrictions directly related to incontinence following the injection. Outpatients need to be aware of any risk to family and the public during the 24 hours following the scan while the radionuclide is in the body. Additional considerations are required for patients who are pregnant, breastfeeding and those with young children, and there are limits to annual exposure (Perkins 1996).

Ventilation-perfusion studies Ventilation-perfusion studies of pulmonary gaseous and blood exchange are used to diagnose pulmonary

| BOX 2 |
| Ultrasound screening in obstetrics |
| The aims of ultrasound in pregnant women are to: |
| ▶ Detect twins or other multiple pregnancies. |
| ▶ Check that the fetus is the right size for the stage of pregnancy. |
| ▶ Check that there are no problems with the fetus’s development, such as encephalopathy, spina bifida or cleft palate. |
| ▶ Measure the rate of blood flow through the fetus’s heart. |
| ▶ Detect congenital heart disease. |
| ▶ Display the position of the placenta so that incorrect positioning can be safely managed. |
| ▶ Enable staff to carry out other types of tests, such as amniocentesis, fetal blood sampling and chorionic villus sampling. |
| ▶ Enable surgeons to carry out procedures while the fetus is in the womb. Used in conjunction with fetal endoscopes or fetoscopes, for example, to correct a blocked urinary tract causing a swollen bladder. |
| ▶ Enable parents to view the unborn child. |

(NHS Direct Online Health Encyclopaedia 2004)
embolism, that is, when a clot blocks blood supply to the lungs causing severe breathing difficulty and disruption of the supply of oxygenated blood to the left ventricle of the heart. Pulmonary embolism affects perfusion but not ventilation, and is normally treated with an anticoagulant like heparin. Ventilation-perfusion studies are useful for diagnosis of lung diseases. For example, chronic obstructive pulmonary disease shows defects in perfusion and ventilation. It also shows deposition in the lungs after prolonged use of inhalers and nebulisers in the treatment of conditions such as asthma. Patients receive a radioactive substance by inhalation and/or injection which allows accurate imaging of the lungs.

**Positron emission tomography** PET is a recent RNI imaging procedure which is currently used more in research than clinical settings. It can be used to indicate whether a growth is benign or malignant. Beta rays are emitted by the radioactive source and these decay to other particles called positrons whose detection forms a more accurate image. The most widely used clinical PET tracer is bound to glucose which is taken up by the brain and other organs at different rates depending on whether the tissue is normal or diseased. Glucose and oxygen metabolism can be evaluated in organs, cerebrospinal fluid and tumours.

**Combined techniques**

Imaging techniques are increasingly being used in combination to merge structural information with the study of function. Combining fMRI with electroencephalogram (EEG) studies to examine brain activity produces high spatial resolution information from fMRI and excellent temporal resolution from EEG. CT and PET in combination are also useful, particularly in cancer imaging where metabolic activity, such as blood flow, can be detected using PET and matched with accurate spatial information from CT.

A series of images taken over months or years will show the growth of tumours or the effectiveness of therapy. As imaging techniques improve, quicker scanning time will allow real-time use in surgery so that surgeons can guide instruments remotely and view the effects as they proceed. Lower costs and higher speeds will aid the current growth in genetic and brain function research and open up new areas for research, for example, the detection of Alzheimer’s disease and the treatment of stroke.

**Safety**

Provided that procedures are strictly followed, imaging in hospitals is safe, particularly techniques that do not involve ionising radiation, such as ultrasound and MRI. X-rays and CT of pregnant women are generally avoided; pregnant radiological staff may need to take extra precautions, especially when using portable machines in the ward or theatre.

The level of exposure to ionising radiation during X-ray can be viewed in relation to other risks. Exposure to ionising radiation of one mSv per year is associated with a one in 20,000 risk of developing a fatal cancer, while the yearly risk from smoking ten cigarettes per day is one in 200, and the risk of being killed in a road accident one in 17,000 (Gaines 2000). Eighty per cent of exposure to radiation is from background sources such as the earth’s surface and atmosphere and less than 0.5 per cent is attributable to imaging. This suggests that the risks of radiation during diagnosis or treatment are minimal (Cope 1997).

All exposure to radiation has to be kept as low as is reasonably possible and all medical exposures must be justified. Planning each scan to get the best results is essential to avoid over-exposure to radiation and radioactive chemicals. Nurses need to be aware of a patient’s previous scanning history and help prepare patients to procure the best images. The increased quality of imaging leads to higher demand for scanning, and care must be taken that this does not lead to increased patient risk. Suitability for certain imaging techniques must take into account whether patients are pregnant or have implants such as pacemakers or surgical clips. Following RNI, patients may emit radiation. This should not be a hazard to their friends and families because the radiation stays within the body, although nursing mothers are advised not to breastfeed their babies for a while after imaging.

**Implications for nursing**

The increasing use of medical imaging has implications for nurses who need to:

- Be aware of the range and characteristics of imaging techniques.
- Communicate with radiology staff about patients.
- Prepare patients physically and mentally for their scans.
- Provide information to supplement that given by medical staff.
- Ensure the safety of patients, staff and relatives.
Awareness of imaging techniques

Nurses need to find out about the scans available at their place of work, what they are used for and how they are arranged by radiology staff. They should be aware of established protocols, particularly those related to safety and preparation, and should familiarise themselves with the range of literature available for patients, visitors and staff.

Communication with radiology staff

Nurses need to be aware of reasons why patients are undergoing medical imaging and should be involved in preparation for the scan. Liaising with radiology staff about scheduling will help to minimise patient apprehension and discomfort, particularly if scans require a full bladder, fasting or aperients. Criteria to be considered by radiologists include the following:

- Has the clinical examination been thorough?
- Have previous films and reports been tracked down and consulted?
- Have the procedures been explained and understood by the patient?
- Can the patient comply with these procedures?
- What quality of image would be acceptable rather than ideal?
- How small an area needs to be scanned?
- Would the use of contrast medium enhance the images: type, timing of administration, tissue take-up?

Informing and preparing patients

The nature of the examination should be clearly explained to the patient. Patient leaflets are available in hospitals about what the examination involves and whether preparation is required. The patient may need to fast or to hold his or her breath and keep still during a scan. Where there are injections, the procedures should be explained and the patient should be reassured that the scan is painless. Patients should be clear about what is expected of them before, during and after the procedure and have some indication of when they will be taken to the department and how long they are likely to be there. Nurses can be actively involved in this process of preparing the patient for examination.

Safety

Patients should also be told about any risks associated with the scan and the precautions taken to minimise those risks. Nurses should check that all steps have been taken to reduce risks by adhering to established protocols.

Conclusion

In modern health care, diagnosis and treatment are increasingly being determined by medical imaging. An understanding by nurses of the techniques involved and the implications for patients is essential. Nurses must also be aware of their responsibilities towards patients, staff and visitors by ensuring that safety protocols are adhered to.

References


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