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## WHAT'S NEW IN...

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### Radiology

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#### ABSTRACT

**The speciality of Radiology is little over 100 years old yet the expansion and diversity within the speciality is accelerating. This paper reviews the recent technological developments by modality, their impact on medical imaging and touches on some research techniques which may find their way into mainstream imaging.**

#### Introduction

In 1895 Wilhelm Conrad von Roentgen successfully imaged his wife's hand with X-rays, marking the dawn of radiology. From the time of this first exposure, which lasted 1 minute, there have been a myriad of technological advances to reach our current radiographic capability. Initial advances, by Crooke for instance, developed vacuum technology and the first fluoroscope was used in Italy only 3 months after the discovery of X-rays. Roentgen's work and equipment was easily replicated and led to an explosion in scientific interest in radiology. There were over 1000 scientific publications on X-rays in the first year alone. In the 1970s and 80s technological advances in cross-sectional imaging progressed and by the 1990s the current imaging modalities had all been developed and were established in clinical use. The advances in the last 20 years have virtually all been technology based with the exception of contrast media (1). With the exponential development of computers the processing of the imaging data is faster and, in this digital era, the means of acquiring and storing the data has led to the development of integrated hospital (and even international) computer systems. Patient Archiving and Communications Systems (PACS) are now being installed in hospitals throughout the country and it is now possible to view and report images taken on the other side of the world almost as they are produced. Coupled with digital voice recognition technology an authorised report can now be issued within minutes.

#### Plain Radiography

In recent years with digital advances there are now several plain film radiographic techniques. With this comes some new terminology. Conventional radiography is practised in the majority of hospital

facilities in the UK. This long practised method exposes a film-screen combination to the X-ray beam. The film is then processed to develop, fix and wash the film with the end product being a hard copy analogue image on a sheet of film. Computed Radiography (CR) relies upon photostimulable phosphor plate technology (2). This is currently the most common way of obtaining plain radiographic images in digital form. In this technique electrons in the plate are promoted to metastable traps of a higher energy level when X-rays fall on the plate. This forms a latent image that can then be read out by a scanning laser beam. This releases photons of visible light as the electrons return to their basal energy level and it is these photons of light which form the digital signal.

Direct Digital Radiography (DR) on the other hand does away with plate processing and has spatial resolution on a par with conventional film but comes at a cost expense which can currently only be recouped if there is a high department throughput. This method relies on an X-ray detector producing either light or electrical signal that can be detected by an amorphous silicone photodiode/transistor array. Lower-dosage X-rays can often be used to achieve the same high quality image as film. One advantage of this method of acquisition is that this technique produces a direct digital signal, rather than a latent image on cassette, and that allows for an immediate image without the need for any processing. Until recently this technology was confined to the radiology department but now with lighter more robust plates has a mobile platform. The resolution now achievable with DR means that mammography, a high-resolution examination, is possible digitally. Although CR is the main technique of digital acquisition in use, ultimately DR will become the routine technique both within the department and as a mobile imaging modality as the technology continues to advance with excellent resolution and as the relative costs fall.

#### Ultrasound

Ultrasound (US) was developed during the 1960s and entered widespread clinical use in the mid 1970s. As with all imaging modalities ultrasound is in constant evolution. Ultrasound is the cross-sectional

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tool in general use that offers the best spatial resolution. Applications such as tissue harmonics and compression within the systems enhance the image improving the diagnostic power of the technique. Tools such as colour and power Doppler have been in use for a number of years and are well established in imaging practice. The sensitivity of the probes is now such that blood flow for instance, within the synovium, can be assessed and quantified in patients with arthropathy and management tailored accordingly before the gross plain film changes become apparent.

3D and latterly 4D (or real time 3D) ultrasound is now available (Figure 1). This technology is predominantly employed in foetal assessment and is particularly useful in the assessment of the face and digits. Having an image of such detail is not only useful for the clinicians, but is a useful tool to aid discussion with parents when an anomaly is found. Foetal well being may also be easier to assess with the 4D system although there is no published evidence on the sensitivity of imaging in this field.



Fig 1. The monitor view of a 4D Ultrasound scan of the face and hand of a 25week foetus showing the reconstructed image and planes of orientation. Image courtesy of Siemens UK.

Intravenous microbubble agents have been developed in recent years to augment the ultrasound signal. The microbubbles are small enough (2-7 $\mu$ m) to pass through the pulmonary capillary bed without disruption and resonate when exposed to ultrasound frequencies between 2-10MHz making them extremely reflective (3). Microbubbles are now used in the assessment of liver disease and tumour characterisation. Recent studies show the increased sensitivity of US with contrast that matches CT and MRI (4). Assessment of hepatic venous blood flow is useful in detecting the presence of cirrhosis and malignancy due to the arterialisation of the blood supply (5). Monoclonal antibodies or other ligands on the bubble surface, as well as different bubble shells, are being developed to help direct bubbles to specific sites of disease and can theoretically carry a payload of directed drug into the heart of the lesion (6). Pulsed ultrasound can disrupt the microbubble releasing the

therapeutic agent in the predetermined location, thereby minimising the systemic effects. Other investigators have developed functional ultrasound techniques using microbubbles (7). This too remains a research tool. Perhaps one of the greatest changes in the use of US has been its adoption by non-radiologists in situations such as abdominal trauma. Focussed Abdominal Sonography for Trauma (FAST) scanning is now an integral part of the trauma surgeons diagnostic armamentarium. It utilises lightweight portable ultrasound machines to examine four specific areas of the thorax (pericardium, subhepatic, perisplenic and pelvis); it is used solely to diagnose the presence of fluid in these areas and is taken as presumptive evidence of intraperitoneal haemorrhage or visceral perforation.

### Computed Tomography (CT)

In 1972 Sir Godfrey Hounsfield produced the first Computed Axial Tomography scanner. There have been great technological leaps with several generations of scanner developed over the last 30 years. The current state of the art scanner is the multislice CT. In 1998 the 4 detector slice scanners were unveiled and now there are 64 slice scanners on the market. Such devices allow for greater volume coverage but with reduced examination time and improved resolution. The image clarity and sharpness for such procedures as cardiac CT is unprecedented. With improved dose efficiency the radiation dose is minimised although a CT study of the abdomen and pelvis, for instance, is still regarded as a high dose procedure. This dose implication will continue to be a focus of debate in the use of CT as a screening tool particularly in the abdomen and pelvis.

Software developments have advanced hand in hand with the hardware and now reporting is work-station based rather than from hard-copy film, not simply due to the vast number of images each examination now produces, but for the tools available for interrogation. The volume information allows accurate multiplanar reconstruction (Figure 2) and applications such as virtual colonoscopy (Figure 3) or virtual bronchoscopy can now be performed with ever improving diagnostic sensitivity and specificity, although virtual colonoscopy will still miss half of all polyps between 6-9mm in size (8). 3D surface shaded display and volume rendering produce images of outstanding detail. Whether these latter tools are useful in diagnosis is debatable but the referring clinicians generally find such images useful in procedure planning (9). Advances in detector technology under investigation include flat panel detector technology. Rather than increasing the number of detector rows alone the aim is to

increase the volume coverage in non spiral dynamic studies. The detector is large enough to cover a single organ in a solitary axial acquisition. This would possibly allow functional CT or volume perfusion CT in the future if the dose restriction demands can be met.

### Magnetic Resonance Imaging (MRI)

Surprisingly the first clinical applications of MRI date back to 1967 before CT was developed. The technique did not receive approval for clinical use until the early 1980s but, as with other modalities, this technique has benefited massively from computer processing advances. With software advances and improved coil



Fig 2. Coronal reconstruction of a contrast enhanced CT of the abdomen showing the detail of the superior mesenteric artery and vein and both the hepatic arterial and portal venous supply of the liver. Image courtesy of Siemens UK.

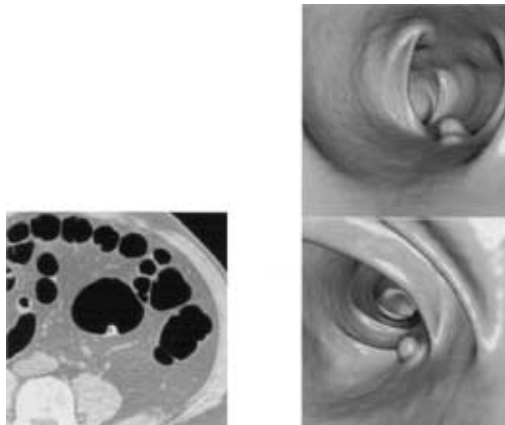


Fig 3. Axial CT image (0.75mm slice) showing a polyp in the descending colon and the virtual colonoscopy images looking at the same lesion from both directions. Images courtesy of Siemens UK.

technology which improves the signal-to-noise ratio and optimises the field of view the resolution of the images has improved. New pulse sequences have been developed and adapted for different clinical problems and there are now open scanners that can be used for MR-guided intervention or claustrophobic patients. With faster

sequences and image acquisition there is less motion artefact and is more comfortable for the patients.

High field (greater than 1.5Tesla) and functional MRI remain on the whole in the realm of research and have not found wide scale use in clinical radiology, however, functional MRI has the potential to match or exceed the capabilities of NM in the future.

Diffusion weighted imaging is an MR technique that has had a major impact in the imaging and early management of stroke patients. The technique detects the very slow flow of protons attached to water and, therefore, if there is a restriction of diffusion of water by a pathological process this can be detected. Vasogenic oedema does not alter the diffusion of water, however, if there is cytotoxic oedema within the brain, most commonly as a result of ischaemia or infarction, the distribution of the involved area can be mapped (10). Diffusion abnormalities can be detected virtually as soon as the patient can be scanned from the time of onset of the symptoms. Armed with an early diagnosis the clinicians can institute the appropriate treatment in an attempt to minimise the damage.

The resolution of imaging with MR has also improved to the extent that virtual endoscopy is possible in vessels such as the internal carotid artery and areas of stenosis can be detected and assessed (11).

### Nuclear Medicine

The most recent advances in Nuclear Medicine imaging have been the emergence of Positron Emission Tomography (PET) and subsequently CT/PET and CT/Single Photon Emission Computed Tomography (SPECT). PET has come to the fore in the popular press recently with the Government's investment in PET to aid cancer staging. PET relies in the detection of the two annihilation photons (gamma rays) in a pair of opposed detectors when a positron and electron come together. Physiological molecules can be labelled with the positron emitters of carbon, oxygen, nitrogen and fluorine.  $^{18}\text{F}$ -deoxyglucose is an agent which transports and phosphorylates like glucose and can, therefore, be used to assess areas of high metabolic activity as demonstrated within tumour or metastasis.

By performing a CT scan at the same time, CT/PET and superimposing the two studies it is possible to map tissue with uptake and more confidently stage the disease (Figure 4). The technique can also be used to guide biopsy to reduce the risk of false negative biopsy, for example distinguishing a reactive node from an infiltrated node (12-14). PET has some major restrictions including the need for a

local cyclotron as the half life of these agents is very short and with this there is a cost penalty. It has been proven very useful and recent publications highlight the ability to differentiate post-surgical change from tumour recurrence after abdominoperineal and anterior resection, to staging and re-staging Non-Hodgkin Lymphoma and Hodgkin Disease and to depict residual ovarian cancer after first-line treatment as examples.

### Interventional Radiology

Nitinol stents have recently been developed and released into the clinical domain over the last 5 or 6 years. These intermetallic alloy lattice stents have the remarkable memory of shape. At body temperature the metal returns to the shape at the time of manufacture. Stent deployment in atherosclerotic vessels and biliary obstructions is the mainstay of most

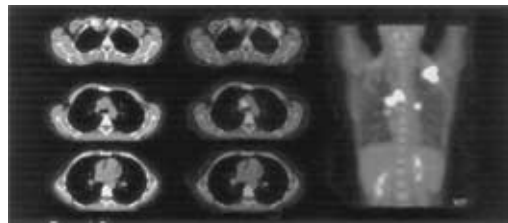


Fig 4. PET/CT images of a 37 year old female with metastatic breast carcinoma with increased uptake and activity following 400MBq FDG. Disease is demonstrated in the mediastinum, both hila and on the anterior left chest wall. Image courtesy of Siemens UK.

interventional radiologists and this technology eases their deployment dispensing with balloon and stainless steel stents. The stents can also be coated with pharmaceutical agents that help prevent restenosis, however, their long term benefits are not yet proven. Stenting and angioplasty of the extracranial internal carotid artery has been developed but remains suitable only for those not deemed fit for endarterectomy. This procedure is not without risk. Any catheter manipulation in this region runs the risk of dislodging material. If there is vessel rupture, unlike other vessels, the ICA is not usually amenable to surgical correction. Another consideration is in the event of restenosis surgery may not be possible (15)

Catheter placement for interventional techniques is crucial, particularly if coiling is to be performed. The aim is to safely get the catheter tip into the smallest possible vessel and thereby minimising any collateral damage. Special catheters have been developed with a magnetic tip that can be steered in a magnetic field around the patient to achieve position. This can reduce the screening time and in the case of an emergency, such as an intracranial haemorrhage, could have an impact on outcome.

Radiofrequency tumour ablation is another interventional technique that has come to the fore. A high-frequency alternating current is

emitted through an electrode in the target lesion. The probe is positioned radiologically most often by CT prior to the procedure. The probe is insulated, except at the tip, and when the current is passed there is heating of the tissues adjacent to the tip resulting in coagulation of the tissues and cell death. This is now a well-recognised technique for the treatment of osteoid osteoma (16) and is as effective as surgery in the long term for the treatment of hepatocellular carcinoma (17). Hepatic metastases and renal primary tumours can also be managed by this technique (18,19).

### Picture archiving and communication systems (PACS)

With PACS there is the ability to view images with retrievable, previous films and clinical information together in a hospital wide environment. CR and DR provide digital images, however, conventionally acquired images have to be digitised which is time-consuming and can have implications with loss of detail if there is an area over-exposed on the original image. The advantages of PACS include no lost films, automatic retrieval with 24hour access, ease for film comparison, less storage space and provides a link to allow teleradiology. The images can also be manipulated and enhanced (20).

There are, however, cost considerations. Where reductions are made in clerical staffing there is the need for onsite engineering support. There is also considerable expense at the time of installation and the initial teething problems of a new system to be factored in.

### Teleradiology

Teleradiology is defined as “the electronic transmission of radiographic images from one geographical location to another for the purposes of interpretation and consultation” (21). The image production, archiving and transmission is facilitated by enormous technological developments in recent years which means that despite the large amount of information in, for instance an MRI study, the data can be transferred without loss.

The benefits of teleradiology are multiple. The system provides an interpretation and reporting system for remote facilities, a feature pertinent to military medicine. It allows clinical and radiological review with, for instance, a tertiary centre without patient transfer or discussion at a Multi-Disciplinary Team meeting. It can increase the efficiency of a small staffed department that covers several sites. Teleradiology also provides a means of out-sourcing imaging studies to private companies for reporting in an attempt to reduce waiting lists, as recently implemented by the Department of Health (21).

## DICOM

DICOM is an acronym for Digital Imaging and Communication in Medicine. The DICOM standard was introduced at the advent of digital medical imaging as a standard method for the transmission of medical images and their accompanying information. The standard was established by committee and involved the manufacturers from the outset. In essence it avoids the use, therefore, of proprietary formatting of information and eases communication between different facilities regardless of the manufacturer of their equipment. With the development of Electronic Health Records (EHRs) DICOM provides the necessary standard for communication. All PACS and most digital imaging equipment now produced is accompanied by a DICOM conformance statement which details the capability of that particular item in terms of the DICOM attributes it possesses.

The standard has not only enabled the transfer of images but has enabled the development and establishment of PACS as well as facilitating the interfacing with Radiology Information Systems (RIS) and/or Hospital Information Systems (HIS). Any medical specialist who utilises medical images will now use the DICOM standard to some extent.

## Computer Aided Detection (CAD)

An area of innovation currently being assessed is the use of computer aided detection, also known as second reader technology. CAD has been successfully employed in some units for the assessment of screening mammography and investigators are now assessing the ability of computers to highlight pulmonary nodules on CT and assess for polyps on virtual colonoscopy. Algorithms have even been developed that can distinguish the ileocaecal valve from a polyp (22). With the vast increase in the number of images obtained in CT and the relative shortfall of consultants it may be that such tools become necessary.

## Conclusions

This article is not attempting to be all encompassing but reflects the diversity of recent development within an ever expanding speciality. Each imaging modality is undergoing evolution reflecting the technological advances predominantly in computer processing, but the aim remains to provide a diagnosis with greater diagnostic confidence in a more timely fashion.

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