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Independent Study and Mentorship - 3A

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Technology and Radiology

Assessment 2

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Assessment:

Over the past few years, technological advances have led to the development of new radiological techniques that have made diagnostic radiology more accurate and more efficient. Some of these new ideas include "filmless" radiology, the use of digital signals to capture and save images, the use of teleradiology to transmit images, faster image acquisition in CT scans, and shorter scan times and the ability to acquire functional information (accurate brain scans) in MRI procedures.

With new storage phosphor systems, which convert x-ray energy directly to digital images with no additional steps, filmless radiology is becoming more popular. Digital image acquisition allows for shorter image capture time and less radiation exposure for the patient. This is due to the ability to manipulate the signal after an image is captured, leading to fewer repeat exposures. Manipulation of a signal after an image is acquired also assists in strengthening the contrast of the image. Digital imaging and filmless radiology seem like more convenient ways to capture images that are more accurate and clear than typical x rays, which are developed on film. These methods assist the radiologist by making image interpretation simpler and assist the patient by limiting the amount of radiation they are exposed to. Filmless and digital imaging are helping radiology to make the shift to a completely electronic process, which helps with communication, getting accurate results, and overall ease of the diagnosis process.

Teleradiology is the new and improved process of image transmission that is gaining popularity among radiologists. While teleradiology is difficult to accomplish due to the large sizes of image files, the use of a compression algorithm to transmit the files does not interfere with the clarity of the image. The use of teleradiology allows for quicker transmission of images, which is probably very useful in emergency situations. Teleradiology sounds like a very beneficial improvement to the field of radiology that provides plenty of benefits, including fast communication times and lowered expenses.

Computed tomography (CT) has been improved by the introduction of slip ring technology and “virtual” endoscopy. Slip ring technology includes the use of circular data acquisition, which allows for faster scans and fewer issues caused by movement during a scan. Virtual endoscopy allows for imaging in patients who are not physically able to have an invasive endoscopy. These two techniques seem quite helpful for patients undergoing CT scans. Noninvasive endoscopy techniques allow for a wider range of patients to be diagnosed using this process and slip ring technology allows for clearer images of patients who are restless while imaging is occuring. Magnetic resonance imaging has also been improved to have shorter scan times and clearer images.

New probes used in ultrasonography have helped to acquire clearer and more accurate ultrasound images. These probes are smaller and have higher frequency, allowing them to be used in small arteries and more parts of the body than before. The use of smaller, more versatile probes lowers the cost of ultrasonography procedures and allows for clearer images, once again, benefiting the patient and the radiologist.

Overall, new imaging techniques have benefited all parties involved in the radiologic diagnosis process. Digital image acquisition, teleradiology, faster scan times, and clearer images have made the radiology process more efficient and more accurate, leading to the field growing in popularity and being recognized as reliable for diagnoses. The use of these new technologies greatly improves the career outlook for radiology. As advancements in technology continue to occur, radiology continues to be more practical, and more useful, making it a great future career to aspire to.

Abstract:

This study surveys the advances made in radiology as a diagnostic tool over recent years. Going through technological innovations from X-ray technology through computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography, the article indicates what radiology can and eventually will be able to do.

Full Text:

Radiology has participated in the recent trend towards computerised management in the health service and has responded to the demand for cost efficient and rapid communication between departments of radiology and their users. Digital image acquisition has become the standard for modern equipment used in angiography, ultrasonography, computed tomography, magnetic resonance imaging, and radionuclide radiology, but most radiological images are still recorded, interpreted, and stored on x ray film. With the increasing availability of more efficient and affordable storage phosphor systems, the simple radiograph looks set to become digital and the "filmless" radiology department will be a reality. In this review I discuss this topic and other aspects of radiology in which technological advances have had an impact on clinical practice.

Method

Although tremendous progress has been made in interventional radiology in recent years, I have confined this review to advances in diagnostic imaging that have resulted from recent technical innovations. Some applications have evolved only recently from research techniques and may not yet have undergone stringent clinical evaluation. This review comprises a personal selection of recent reports from mainstream radiology journals and the results of Medline searches which examine the highlighted topics in more depth.

Digital radiology departments and teleradiology

x Ray film is exposed by light photons emitted by intensifying screens sensitive to radiation transmitted through the patient. Storage phosphor technology uses photostimulable phosphor screens to directly convert x ray energy into digital signals. The increased dynamic range and image contrast of digital radiography compared with conventional x ray film-screen combinations and the facility to manipulate signal intensity after image capture reduce the number of repeat exposures, thereby increasing radiographic efficiency and reducing the radiation dose received by patients. As long as all equipment conforms to the Digital Image Communication in Medicine-3 standard, digital images can be made available immediately on a local network--for example, on the radiologist's workstation for reporting or for transmission to a ward based computer for review. Many radiology departments aspire to these picture archiving and communication systems because they enjoy greater efficiencies of image production, radiological report generation, and data storage, retrieval, and transmission, but the initial capital costs are high. Thus, replacing old management systems is often done gradually, and in the United Kingdom, the evaluation of complete picture archiving and communication systems has been limited to pilot sites.

In teleradiology digital images are transmitted over a distance by a communications network. For many typical digital radiological studies--for example, computed tomography of the thorax--the electronic file is very large, and only with the availability of compression algorithms and higher bandwidths for transmission has full implementation of teleradiology become feasible. Studies indicate that the process of image compression, transmission, decompression, and display on relatively low resolution monitors does not reduce the ability of radiologists to interpret the images. The potential benefits of this technology include financial savings on x ray film and storage costs, rapid transmission of images between departments or to specialist centres for an expert opinion, and "on call" interpretation of some emergency examinations from a computer terminal in the radiologist's home. Paperless radiology departments may be the next step; commercially available voice activated reporting systems work well in clinical practice and reduce appreciably the time taken to generate a printed report.

Computed tomography

The introduction of slip ring technology into the design of computed tomography scanners revitalised a mature technique in which progress had stalled in the 1980s. Current computed tomography scanners can acquire data in a continuous helical or spiral fashion, shortening acquisition time and reducing artefacts caused by patient movement." Faster scanning increases the likelihood of a diagnostically useful scan in patients who have difficulty cooperating with the investigation and increases patient throughput. A choice of image processing techniques is available to display volumetric data obtained during a "breathhold" in ways appropriate to the clinical question. For example, "virtual" endoscopy using reconstructed computed tomographic data to simulate intraluminal views of hollow organs may be useful in patients who are unsuitable for invasive endoscopy.

The use of contrast enhanced spiral computed tomography to show pulmonary emboli is gaining clinical acceptance, as it offers a relatively non-invasive technique with better specificity than radionuclide lung scans. Pulmonary embolism can be confirmed or excluded in patients with an indeterminate radionuclide study without having to perform pulmonary angiography, although the sensitivity of computed tomography for peripheral emboli is inferior. In other parts of the vascular system, contrast enhancement can be timed to show hepatic arterial and portal venous anatomy or the nephrographic and corticomedullary phases of renal enhancement, thereby increasing diagnostic accuracy.

However, the price of faster and more versatile computed tomography may be a higher dose of radiation. This is not intrinsic to spiral scan technology, but results from the ability to obtain an increased number and complexity of scans. Faster still is "ultrafast" computed tomography, which uses an electron beam to steer x rays around the patient and may have a role in screening for coronary artery disease by detecting calcification from which the presence of atherosclerosis can be inferred.

Magnetic resonance imaging

Until recently, progress in body magnetic resonance imaging was also restricted by the long times needed to collect sufficient signal to form an image, and the inevitable physiological motion degraded the image quality. Improved performance of the hardware and new software for image acquisition and reconstruction have dramatically shortened scan times, increasing the robustness and cost effectiveness of this investigation. Image acquisition during a breathhold overcomes problems of respiratory motion and has generated new enthusiasm for magnetic resonance imaging of the thorax and abdomen. The digital signals can be acquired, processed, and displayed in several ways. For example, cardiac-gated magnetic resonance imaging uses signals from the same point in successive electrocardiographic cycles to effectively freeze cardiac pulsation and provide excellent anatomical information in congenital and acquired heart disease. Conversely, a cine loop of myocardial pulsation and blood flow can be created from breathhold magnetic resonance imaging performed during several heartbeats. Perfusion imaging using breathhold contrast enhanced magnetic resonance imaging may show ischaemic myocardium that is active metabolically and thus potentially salvageable by revascularisation. Treating this "hibernating myocardium" could improve left ventricular function and thus survival in patients with ischaemic myocardial disease. Magnetic resonance imaging also has the potential to show coronary artery stenoses non-invasively, although further development is required before the technique is sufficiently robust for clinical use.

Ultrasonography

Advances in probe design, which enable endoluminal ultrasonography to be peformed--for example, in assessing the integrity of the anal sphincter--are familiar to many clinicians. Ultrasound probes of small diameter and very high frequency can now be inserted into the coronary arteries so that plaques can be seen and the degree of stenosis assessed. These devices are mainly being developed by cardiologists for managing coronary atherosclerosis. Ultrasound has also benefited from digital signal manipulation and post-processing. Volumetric ultrasound can be displayed as three dimensional or surface rendered images and has potential applications in obstetrics and gynaecology. Measurement of broadband ultrasound attenuation provides a quantitative measure of fracture risk, equivalent to radiation bone densitometry techniques. Conventional ultrasound uses the same frequency bandwidth for both the transmitted and received signal. Use of higher harmonic frequencies generated by propagation of the ultrasound beam through the patient improves the quality of the image in clinical applications.

Imaging of function

Most radiological techniques depend on morphological change for detecting disease, while radionuclide imaging primarily shows abnormal function. Positron emission tomography, for example, using the radionuclide labelled glucose analogue 18-fluoro-deoxyglucose, shows differences in glucose metabolism between benign and malignant tumours, identifying tumour metabolic activity with high sensitivity. Radionuclides can be targeted at specific tumours; for example, [sup.99m]technetium-sestamibi detects breast cancers of more than 1 cm diameter with a sensitivity that exceeds 95%.

Developments in magnetic resonance imaging mean that this technique is beginning to challenge the supremacy of radionuclide imaging for functional imaging, particularly in the brain, where structural detail aids spatial localisation. Functional magnetic resonance imaging uses specific pulse sequences and sophisticated image processing techniques to map brain activation in response to various motor and sensory stimuli onto anatomical images. The physiological mechanism exploited is the increase in cerebral blood flow that accompanies neuronal activation. This overcompensates for the rise in the demand for oxygen and causes a relative increase in the oxyhaemoglobin concentration in cerebral blood. Increased oxyhaemoglobin is detectable as a transient local signal change on magnetic resonance imaging--for example, in the occipital cortex during visual stimulation. Sequential studies of brain topography and function in normal volunteers and children become feasible because of the non-invasive nature of magnetic resonance imaging. Applications in clinical practice include preoperative localisation of the motor strip and language areas for neurosurgical planning, and monitoring the effects of psychotropic drugs on cognition.

Current high performance magnetic resonance scanners can also show the diffusion of water protons over a distance of a few microns during the application of specific pulse sequences. In evolving stroke, the local diffusion of water molecules is restricted by cytotoxic oedema of ischaemic cells. Signal changes detectable by diffusion weighted magnetic resonance imaging provide early evidence of acute cerebral ischaemia before structural changes become apparent. Patients who are diagnosed during this potentially reversible stage may benefit from thrombolyric drug treatment, and their response can be monitored by diffusion weighted magnetic resonance imaging

Conclusions

This review illustrates some of the ways in which diagnostic imaging has exploited advances in technology and computation to provide greater insight into physiological structure and function for medical applications. In the United Kingdom, our ability to take advantage of areas of technical progress is often tempered by limited resources. Before adopting new radiological techniques, we also need to examine the evidence for benefit, taking into account the impact on clinical outcomes, health economics, and radiation protection issues.

Competing interests: None declared.

Summary points

All types of diagnostic images can now be acquired as digital signals

Digital imaging and developments in computer technology and telecommunications mean that the "filmless" radiology department is technically feasible

Faster image acquisition in computed tomography has extended its diagnostic applications, but has implications for the population radiation dose from medical imaging

Magnetic resonance imaging continues to develop rapidly, propelled by the benefits of shorter scan times and the potential to provide functional information

New or updated radiology equipment and techniques are expensive and may not be cost effective in every radiology department