Digital Radiography

The Evolution Towards Portable Digital Radiography

a report by
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Radiography is an established technology that is every bit as medically important today as it was when it was first conceived more than 100 years ago. It remains the first and most dominant diagnostic imaging and screening modality in hospitals. However, with the advent of new technologies such as multidetector computed tomography (CT), positron emission tomography and magnetic resonance imaging (MRI) – coupled with the increasingly advanced digital networking of hospitals – the field of radiography needs to advance in order to retain its position. Since the 1970s, digital radiography (DR) has been possible (initially as computed radiography and latterly as direct radiography) and this has led the way in innovating new imaging capabilities.

Putting the impact of DR in perspective becomes easier when we consider the challenges in optimising the quality of the images and the overall process of diagnosis. With conventional, non-digital imaging there is an issue concerning the time taken to acquire an image. It is also not possible to review the image during examination to determine whether it is adequate. Long intervals between multiple image acquisitions delay diagnosis, and there is an inherent inefficiency associated with having to take the image plates to the central department. These issues make the whole process extremely time-consuming. In addition, it is difficult and often not desirable or possible to reposition critically ill, unstable or fragile patients for standard image views.

In this report, the general principles of DR will be outlined briefly, its contribution in the radiography field so far discussed and new technology that will simplify the road to accurate, timely diagnosis will be focused on.

General Principles of Digital Radiography

In conventional radiography, the X-ray-sensitive film serves as both detector and storage medium. In DR, digital detectors only generate the images, which are then stored in a digital storage medium. The whole procedure of digital imaging comprises four separate steps: generation, processing, archiving and presentation of the image. X-rays are emitted by X-ray tubes and absorbed by the digital detector. The absorbed energy is converted to produce the digital image. Once the image is generated, post-processing software transforms the raw data into an image suitable for diagnosis, which is then sent to a digitised storage archive. A digital file containing patient demographic information is linked to each image. In contrast to X-ray images developed on film, digital images can be manipulated for viewing. Operators can zoom in/out, enhance image contrast, invert greyscale and measure distance and angle of the focal plane. In addition, image distribution over local area networks is possible with DR. Digital images and associated reports can be linked to a digital patient record for enhanced access to diagnostic data and treatment planning (discussed later in the report).1

There are two types of DR: computed and direct. Computed radiography systems use storage phosphor image plates and require a separate image read-out process. In contrast, direct radiography systems convert X-rays into electrical charges, and the images can be viewed instantly on the screen. Direct radiography systems can be further divided into direct and indirect conversion groups, depending on whether the X-rays are first converted into light before creating the electrical charges.1

Computed Radiography

Rather than using conventional X-ray film to capture an image, computed radiography uses an imaging plate. The plate contains photosensitive storage phosphors that retain the latent image. When the imaging plate is scanned with a laser beam in the digitiser, image information is released as visible light, which is captured and converted into a digital stream to compute the digital image.

A crucial advantage in the use of flexible storage phosphor plates and computed radiography systems is that any exposure source that can be used with conventional X-ray films can also be used with computed radiography. More importantly, the flexible storage phosphor imaging plates can be substituted directly for film. They can be used in the same film holders and cassettes, as well as with other applications requiring a flexible medium (bending them around the specimen). Therefore, computed radiography allows for the use of existing sources and cassettes in the hospitals, making the transition from traditional film radiography to computed radiography a fairly uncomplicated and inexpensive alternative.

Direct Radiography

In direct conversion radiography, X-ray photons hit a photoconductor, freeing electrons and thus generating an electrical charge.2 Amorphous selenium, lead iodide, lead oxide, thallium bromide and gadolinium compounds are typical photoconductor materials, with selenium the most common. All of these elements have a high intrinsic spatial resolution.3 As a result, the pixel size, matrix and spatial resolution of direct conversion detectors are not limited by the detector material.

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Indirect conversion systems consist of layers of a scintillator, amorphous silicon photodiode circuitry and a thin-film transistor array. These flat-panel detectors have strong optical properties and quantum efficiency. In addition, they can be quite small in size, allowing them to be integrated with existing equipment, such as bucky tables. Those detectors that use cesium iodide tend to be more delicate and are therefore less portable. Newer gadolinium oxide sulphide detectors are much more robust.

Both computed radiography and direct conversion systems require only a short burst of radiation. The difference is that a direct system will display the image on a screen in front of the radiographer almost instantly upon exposure. Post-processing can be performed on both direct and computed radiography images.

In addition to providing enhanced image quality, digital detectors have the potential to substantially lower the radiation dose to which patients need to be exposed without compromising image resolution. One way that harmful exposure is minimised is by reducing the number of failed exposures and the need for additional images. DR faces no limits as to range of use. Any part of the body can be imaged digitally, and this advantage stems from all the diverse types of post-processing software available today. Software used to assess bone images is different from that used for the analysis of X-rays of the chest or abdomen. Every part of the body has specialised software tailored to outline its specific details and bring unique pictures into the foreground.

Specialised post-processing was not feasible with traditional film radiography. The only processing parameters available with conventional imaging were alterations of the developing or fixation liquid used. Adjusting the temperature in the chemicals could modify the intensity of the images. Altering the radiation dose could affect the picture. Higher doses could give darker pictures, whereas lower doses could give lighter pictures. Similarly, increasing the temperature of the liquids produced high-intensity pictures. However, these modifications were limited. Digital images are independent of radiation levels.

**Direct Radiography Databases – Beyond Storage**

Deciding the radiation dose is the first step of diagnosis in radiology. Information on dose parameters cannot be extracted solely from a radiograph. With DR it is possible to obtain information on the appropriate dose using the Radiography Information System (RIS), a computerised database used in radiology departments to store, manipulate and distribute patient radiological data and images. Before taking a picture, the area of interest can be pre-defined using RIS. Information regarding the patient and the organ examined is fed into the RIS, which in turn is able to determine the specific dose levels required in each situation. The generator system of the radiation emitter is connected to RIS to give the appropriate dose. Determining the optimal radiation dose level in advance was not possible with the early digital systems. However, with the new DR systems, dose levels for different areas examined are already pre-determined. These prevent abnormally high radiation doses from being used, for instance when the area exposed is small, such as a finger. New systems have an alarm that will warn the radiographer in cases of overexposure.

Images taken using DR are fed into the picture archiving communications system (PACS). PACS is an image management system that was integrated into daily clinical practice in 1992, incorporating images from MRI, CT, ultrasonic, computed and digital radiography, digital subtraction angiography, nuclear medicine and endoscopy, to be distributed selectively to designated workstations for review and diagnosis. With radiation therapy, many parameters are stored and modified in a PACS database, including patient information necessary for treatment planning, data on image registration to identify regions to be treated; markers to align images; image fusion to delineate pathological structures from various imaging modalities; shape, size and location of the target organs; and dose computation, in order to ensure specific delivery of uniform doses to the target.

Portability – to allow bedside readings – is a key element of digital systems. Portable detectors are extremely useful for examining patients restricted to their hospital beds and generally for people who are not able to go to the imaging department. They also offer flexibility regarding the position that the patient must adopt in order to secure the appropriate image.

**Potential Issues with Direct Radiography**

Some of the advanced technological aspects of both computed and direct radiography present their own risks. Although individual radiation doses can be monitored by RIS, the ease of use of DR systems means that a radiographer may choose to take more images than would be possible with a traditional system. Repeated exposures can burden patients with high radiation levels. It is good practice for every radiologist to comply with the ALARA (as low as reasonably achievable) principle of basic radiation protection. Any amount of radiation exposure can increase the risks of cancer or sarcomas (stochastic effects). In addition, the negative effects of radiation exposure increase with cumulative lifetime dose. The aim of the ALARA principle is to minimise risk while keeping in mind that some exposure is acceptable to aid medical radiography. Radiation doses should be controlled tightly to keep a balance between optimal radiation levels for the images and the safety of patients and staff.

The phenomenon of ‘dose creep’ occurs when radiation dose delivered by a digital system gradually, yet inadvertently, rises over time. This is not possible with film detectors, as the image will get darker. DR systems, however, can compensate. Once the images are acquired, whatever the intensity of the radiation delivered, post-processing can reconstruct them into high-quality pictures. With the first DR systems, the only way for the radiographer to determine the level of radiation used after taking the image was to obtain the parameters from the PACS system. As discussed, the newer systems are connected to an RIS, which can monitor the amount of radiation used and trigger an alarm if it is too high.

Scatter-reduction grids are used in radiography to absorb the X-rays that do not contribute to the image. Thick anatomy can generate...
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considerable scatter and compromise the sharpness of an image. Although the conditions under which a scatter-reduction grid should be employed are not universally accepted, it has been suggested that a grid should be used whenever the body part is 10cm or greater in thickness and when the tube potential is greater than or between 60 and 70kVp. There is always a fine balance between image quality and acceptable radiation levels. However, very thick grids filter a lot of X-rays and therefore necessitate higher radiation doses. In most conventional systems the grids are fixed to the detector. With digital detectors an unfortunate choice of grid line rate or orientation can result in artefacts such as interference patterns. Artefacts and misalignment of grids with the central ray of the X-ray tube contribute to repeated examinations and additional patient doses. One study found that grids with low atomic number interspace and cover material had a higher signal-to-noise improvement factor.

In day-to-day clinical practice, grids are not removed from conventional systems, as they are expensive and delicate items and removing them is a complex task. Instead, the grid is left on the detector and higher doses of radiation are given, which is not beneficial for the patients. Some newer detectors do not have a grid, which allows them to be both smaller and more portable and to require a lower radiation dose.

Personal Experience
At our hospital we have exclusively been using digital equipment and systems for approximately three years. The first DR system we used was the Swissray DDR system. Now we have several different types, including a phosphor-based system from AGFA, an analogical digital system especially for chest imaging and four Canon devices (60G, 40G, both fixed and portable). There is quite a bit of difference between the systems. The reason we have four Canons is that we have found them to be the most user-friendly and most reliable of all the systems. When the other devices need replacing, we will replace them with Canons.

All digital systems from Canon are efficient and user-friendly. They cover a broad range of imaging applications and are used extensively in our hospital. Canon’s range of compact, lightweight and large-area flat-panel detectors have several configurations allows for high-definition images of various target organs. Portable detectors from Canon come in two sizes: one small, 23x28cm, which weighs about 2.7kg, and a larger device of 35x43cm, weighing approximately 4.8kg. The smaller detector is an excellent tool for challenging applications such as neonatal care or for detailed imaging of small bone structures such as fingers, elbows, knees, feet and ankles. The detectors come in several solutions for the end-user, such as Mobile DaRt Evolution, a high-tech motor-driven system that incorporates a 50G flat-panel detector and greatly enhances the speed of diagnostic workflow. Thanks to the motor, the detector is easy to manoeuvre in even the most crowded areas in the hospital, where rapid movement and fast examinations are crucial, and can be positioned securely to capture high-precision images. In areas such as trauma and intensive care units, bedside imaging has been simplified further with the EasymovingDR mobile unit. Another valuable tool is DRagon, a compact, semi-portable system that makes the examination of immobile patients in challenging situations much easier.

The most recent system, Canon CXDI-60G, is a constellation of DR advantages featuring a large flat-panel silicon detector and 2.6 million pixels. It allows for rapid image preview (three seconds after X-ray exposure) and automatic sizing up of images (23x28cm). As with all Canon systems, detector portability is a strong feature of CXDI-60G. The detector has a detachable cable for easy service. In addition, no grid is attached to the detector and we do not need to use a bucky, the area where the detector is placed with the grid and an automatic dose regulator. This is the power of the portable Canon detector: it can be removed from the bucky and positioned on the table without the grid. Although we have the option of three different grids with CXDI-60G, it is also possible to image small parts, such as fingers, hands, elbows, knees or ankles, without a grid, which contributes even further to flexible diagnosis.

Imaging becomes straightforward and we do not need to use higher doses to overcome grid-related obstacles.

Summary and Conclusions
Digital X-ray technology options have expanded dramatically over the past decades. Current state-of-the-art digital X-ray systems offer excellent dynamic range, permitting dose reduction without compromising image quality. DR also allows for immediate image processing and direct transfer of the pictures to archiving communication databases. Sophisticated treatment planning is implemented with new digital archiving and communication databases. Versatile portable detectors have been a major breakthrough in everyday clinical practice, improving the examination procedure for both patients and clinicians. Hospitals today depend greatly on digital systems, and I hope the future will see radiology departments with portable digital detectors using even lower radiation doses.

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