Developments in digital radiography: an equipment update

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Abstract  Digital X-ray imaging technology has advanced rapidly over the past few years. This review, particularly aimed at those involved in using and purchasing such technology, is an attempt to unravel some of the complexities of this potentially confusing subject. The main groups of X-ray imaging devices that are considered are digitisers of conventional radiographs, image-intensifier-based fluorography systems, photostimulable phosphor computed radiography, amorphous selenium-based technology for thorax imaging and flat-panel systems. As well as describing these different systems, we look at ways of objectively assessing their image quality. Concepts that are used and explained include spatial resolution, grey-scale bit resolution, signal-to-noise ratio and detective quantum efficiency. An understanding of these basic parameters is vital in making a scientific assessment of a system’s performance. Image processing and techniques are also briefly discussed, particularly with reference to their potential effects on image quality. This review aims to provide a basic understanding of digital X-ray imaging technology and enables the reader to make an independent and educated assessment of the relative merits of each system.

Keywords  Digital radiography · Radiographic image enhancement · Radiological technology · Thoracic radiography · Fluoroscopy

Introduction

Traditionally, the X-ray image has been recorded in analogue form using conventional screen film combinations. The term digital radiography refers to X-ray imaging techniques which at some stage utilise a digital data format in acquiring, processing, displaying or managing a medical X-ray image. In recent years there have been major advances in digital technology applied to X-ray imaging, with much promise for future development. This technology is developing rapidly and is potentially confusing given the diversity of approaches being adopted by different manufacturers.

The main advantage of digital radiography is the separation of image acquisition, processing and display, allowing optimisation of each of these stages. Computer processing can improve image quality by changing the overall contrast and brightness of an image, as well as allowing image manipulation such as edge enhancement and smoothing. These manipulations are mostly beneficial, although there is a potential for image degradation if incorrectly implemented.

This review is specifically aimed at practising radiologists and radiology managers, to provide a basic understanding of these processes and their impact on image quality. This is required when both purchasing and using digital X-ray imaging equipment. This review is an attempt to unravel some of the complexities of modern digital imaging.

Digital image acquisition can take place using numerous methods, from digitisation of conventional radiographs through to direct digital image acquisition.
This review concentrates on currently available acquisition systems as well as examining new and emerging technology. Image processing and display techniques are also briefly discussed.

**Assessing image quality**

Before reviewing the technologies used in digital X-ray image acquisition, it is useful to introduce the key terminology used to objectively describe image quality. Concepts discussed herein include matrix spatial resolution, grey-scale bit resolution, signal-to-noise ratio and detective quantum efficiency. An understanding of these basic parameters is crucial in making a scientific assessment of a digital X-ray imaging system’s performance.

A digital image is constructed from discrete picture elements (or pixels) laid out as a regular two-dimensional matrix array. The number of pixels describing a digital image is the matrix size. In general, the greater the number of pixels for a given field of view, the greater the maximum achievable spatial resolution of the image. The typical pixel sizes and field coverage of a range of modern digital radiography systems are listed in Table 1. However, assessing the spatial resolution of an imaging system purely in terms of “pixel size” or “matrix size” is simplistic and can be misleading. For instance, in a photostimulable phosphor-based computed radiography system (PPCR), spatial resolution is also affected by optical scatter processes within the image plate during image readout. In this case doubling the sampling resolution, i.e. increasing the number of pixels by a factor of four, would not improve the spatial resolution of the displayed images to the same degree.

Another factor that affects image clarity in digital X-ray imaging system is grey-scale bit resolution. It is the distribution of different grey-scale values on a display that actually represents the visible image. The number of shades of grey is expressed in binary digits (or bits) of information per pixel. We consequently talk in terms of bit depth or grey-scale resolution of the image, where each pixel is allocated a discrete (digital) grey-scale intensity value. The greater the number of grey-scale levels, the better the contrast resolution of the digital image. One-bit grey-scale resolution would represent a binary image providing only a choice of “black” or “white” at each pixel. In an 8-bit system each pixel can have 28 (i.e. 256) grey-scale values. A 10-bit imaging system, such as a digital fluorography unit, would typically use 210 or 1024 levels of grey. Modern PPCR systems acquire data with 12 bits per pixel, i.e. 212 or 4096 levels of grey. The latest designs of solid-state digital X-ray image detector typically utilise 14-bit (or 16,000) levels of grey, although this may increase with future products. These characteristics are compared in Table 1. Rather than simply consider the number and size of the pixels produced by an imaging system, it is better to describe the spatial resolution properties with the aid of the modulation transfer function (MTF). The MTF describes the ability of an imaging system to reproduce (sinusoidal) image signals over a range of spatial frequencies. At a given spatial frequency, the value of the MTF will lie between zero and one. An MTF of zero represents no signal modulation being reproduced, and an MTF of one representing perfect transfer of the signal. Typically, a system’s ability to represent a signal decreases as the spatial frequency of the signal increases. The MTF can be applied to both analogue (e.g. film based) and digital X-ray imaging systems. Typical MTFs produced by a range of digital radiographic image detector systems are presented in Fig. 1. Using MTF as a measure of image quality is limited because it only considers the reproduction of signal information, and takes no account of the other major influence on image quality “noise in the image”.

| Table 1 Comparison of the basic performance characteristics of modern X-ray image acquisition systems |
|---------------------------------------------------|------------------|------------------|-------------------|----------------|
| Screen-film radiography (400 speed)                | Up to 35 × 43 cm | 20               | 100:1             | –2 min         |
| Computed radiography (PPCR)                        | Up to 35 × 43 cm | 20               | 12 bits–4000:1    | –3 min         |
| Digital fluorography                                | 35/25/15 cm      | 40               | 10 bits–1000:1    | < 0.2 s        |
| Selenium digital thorax radiography                | 43 × 49 cm       | 50               | 14 bits–16,000:1  | –20 s          |
| Flat-panel detector (CsI:Tlayer+1FT readout)       | 43 × 43 cm       | 70               | 14 bits–16,000:1  | < 10 s         |

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