Digital Radiography Image Quality: Image Processing and Display

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This article on digital radiography image processing and display is the second of two articles written as part of an intersociety effort to establish image quality standards for digital and computed radiography. The topic of the other paper is digital radiography image acquisition. The articles were developed collaboratively by the ACR, the American Association of Physicists in Medicine, and the Society for Imaging Informatics in Medicine. Increasingly, medical imaging and patient information are being managed using digital data during acquisition, transmission, storage, display, interpretation, and consultation. The management of data during each of these operations may have an impact on the quality of patient care. These articles describe what is known to improve image quality for digital and computed radiography and to make recommendations on optimal acquisition, processing, and display. The practice of digital radiography is a rapidly evolving technology that will require timely revision of any guidelines and standards.

Key Words: Digital radiography, image quality, image display, soft-copy display, image processing, workstation

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INTRODUCTION AND OVERVIEW

Image quality is affected by a number of factors, beginning with the acquisition process and device and including the manner in which images are displayed. In digital systems, the functions of acquisition and display are clearly separable, so that the evaluation and optimization of image quality can take place at both ends of this imaging continuum. The analysis of image quality also depends on the particular type of imaging task [1-3]. Digital radiography is used in a wide variety of imaging tasks (eg, chest, musculoskeletal, genitourinary), but there are basic image-quality parameters that can be defined that are applicable to all of these tasks.

This paper on image processing and the display of digital radiography images, together with its companion paper on image acquisition, was developed with reference to information available in the peer-reviewed medical literature. The companion paper on image acquisition contains in its introduction a common definition of digital radiography that serves as a reference point for both articles. Briefly, in this guideline, the term *digital radiography* refers to all types of digital radiographic systems, including those historically termed *computed radiography* and those historically termed *digital radiography*. This guideline is applicable to the practice of cassette and cassetteless digital radiography.

It defines equipment guidelines, specifications of data manipulation and management, and quality control and quality improvement procedures for the use of digital radiography that should result in high-quality radiologic care. In all cases for which an ACR practice guideline or technical standard exists for the modality being used or the specific examination being performed, that guideline or standard will continue to apply when digital image data management systems are used. A glossary of commonly used terminology and a reference list are included.

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EQUIPMENT SPECIFICATIONS AND EXISTING STANDARDS

Specifications for equipment used in digital image data management will vary depending on the application and the individual facility's needs, but in all cases they should provide image quality and availability appropriate to the clinical needs, whether those needs be official interpretation or secondary review. Compliance with the current Digital Imaging and Communications in Medicine (DICOM) standard of the ACR and the National Electrical Manufacturers Association (especially part 14, on gray-scale displays) [4] is strongly recommended for all new equipment acquisitions, and consideration of periodic upgrades incorporating the expanding features of that standard should be part of ongoing quality control programs. Compliance with the Radiological Society of North America and the Healthcare Information and Management Society's Integrating the Healthcare Enterprise initiative [5], as embodied in the available technical frameworks, also is strongly recommended for all new equipment acquisitions.

Relevant standards for the soft-copy display of images have been summarized in the literature [6] and include Society of Motion Picture and Television Engineers (SMPTE) Recommended Practice 133-1991 [7,8], the National Electrical Manufacturers Association–DICOM standard (PS 3) [4], Deutsches Institut für Normung V 6868-57 [9], International Organization for Standardization 9241 and 13406 series [10,11], the Video Electronics Standards Association Flat Panel Display Measurements standard [12,13], American Association of Physicists in Medicine (AAPM) Task Group 18 Recommendations and Standards [14], and Integrating the Healthcare Enterprise Consistent Presentation of Images [15]. Each provides guidance and tools for the acceptance and quality testing of medical display devices and should be consulted if further detailed information is desired.

IMAGE DISPLAY TECHNOLOGY

Display device guidelines are currently divided according to two basic categories of digital image data set size when used for rendering an official interpretation: small matrix size (eg, computed tomography, magnetic resonance imaging, ultrasound, nuclear medicine, digital fluorography, and digital angiography) and large matrix size (eg, digital radiography, computed tomography, digitized radiographic films, and digital mammography). This guideline covers only the use of nonmammography large-matrix images. Specific guidelines for digital mammography can be found in the ACR's Practice Guideline for Determinants of Image Quality in Digital Mammography (proposed for 2007 [6,16]). The present guidelines also apply to primary displays or those used for diagnostic interpretation. Secondary displays (eg, those used by clinicians or technologists) for radiographic images do not need to adhere to these guidelines as long as the images are not used for primary interpretation purposes. A number of authors have reviewed the factors that contribute to image quality in soft-copy reading of radiographic images [17-19]. The minimum quality specifications are summarized here.

Matrix Size and Display Size

Soft-copy displays should render images with sufficient pixel density to allow viewing of the whole image with sufficient spatial detail at a normal viewing distance of approximately 30 to 60 cm (with eyeglasses specifically selected for this distance when required). Matrix size should be as close to the for-processing image data as possible, or attainable with magnification. A 5-megapixel (MP) (2,048 × 2,560 pixels) monitor (usually in portrait mode with a diagonal dimension of 54 cm [21 in]) exceeds the matrix size stipulated by the ACR's standard of a resolution of at least 2.5 lp/mm at the detector plane when acquiring a 35 × 43 cm image (equivalent to 14 × 17 in), and thus is sufficient for viewing all types of computed radiographic and digital radiographic images in a single view. Note that the US Food and Drug Administration recommends that only monitors that have been approved for digital mammography be used for interpreting digital mammography images [6,16].

A 1-MP (1,024 × 1,280 pixels), 2-MP (1,200 × 1,600 pixels), or 3-MP (1,536 × 2,048 pixels) monitor will not permit full simultaneous viewing of 35 × 43 cm images at a detector plane resolution of 2.5 lp/mm. For those images, zooming and roaming display functions are required to achieve a correspondence between the detector element matrix and the display pixel matrix so that the resolution of the display monitor does not limit the resolution of the partially displayed image. This is true for any size image for which the detector element matrix size exceeds the display pixel matrix size.

Luminance and Contrast

The luminance of a display can affect image quality significantly, so the appropriate range of luminance should be maintained. The ratio of maximum luminance to minimum luminance of a display device for images (other than for mammography) should be at least 100. The maximum luminance of gray-scale monitors used for viewing digital conventional radiographs should be at least 200 cd/m^2. Smaller ranges could lead to inadequate levels of contrast in displayed images, and larger values could lead to poor visualization of details at the extremes of the luminance range because of the limited range of the contrast sensitivity of the human eye. The contribu-