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ACR–AAPM–SIIM TECHNICAL STANDARD FOR ELECTRONIC PRACTICE OF MEDICAL IMAGING

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, ___ N.W.2d ___ (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

This technical standard has been revised by the American College of Radiology (ACR), the American Association of Physicists in Medicine (AAPM), and the Society for Imaging Informatics in Medicine (SIIM).

For the purpose of this technical standard, the images referred to are those that diagnostic radiologists would normally interpret, including transmission projection and cross-sectional x-ray images, ionizing radiation emission images, and images from ultrasound and magnetic resonance modalities. Research, nonhuman, and visible light images (such as dermatologic, histopathologic, or endoscopic images) are out of scope, though many of the same principles are applicable.

Increasingly, medical imaging and patient information are being managed using digital data during acquisition, transmission, storage, display, interpretation, and consultation. The management of these data during each of these operations may have an impact on the quality of patient care.

This technical standard is applicable to any system of digital image data management, from a single-modality or single-use system to a complete picture archiving and communication system (PACS) to the electronic transmission of patient medical images from one location to another for the purposes of interpretation and/or consultation.

It defines goals, qualifications of personnel, equipment guidelines, specifications of data manipulation and management, and quality control and quality improvement procedures for the use of digital image data that should result in high-quality radiological care. A glossary of commonly used terminology (Appendix A) and a reference list are included.

In all cases for which an ACR practice parameter or technical standard exists for the modality being used or the specific examination being performed, that practice parameter or technical standard will continue to apply when digital image data management systems are used.

In general, digital mammography is outside the scope of this technical standard (see ACR–AAPM–SIIM Practice Parameter for Determinants of Image Quality in Digital Mammography [1]). However, given the constant evolution of display technology and quality control, this technical standard does make suggestions on those areas that are not fully addressed in other technical standards or practice parameters.

The goals of the electronic practice of medical imaging include, but are not limited to:

1. Initial acquisition or generation and recording of accurately labeled and identified image data
2. Transmission of data to an appropriate storage medium from which it can be retrieved for display for formal interpretation, review, and consultation
3. Retrieval of data from available prior imaging studies to be displayed for comparison with a current study
4. Transmission of data to remote sites for consultation, review, or formal interpretation
5. Appropriate compression of image data to facilitate transmission or storage, without loss of clinically significant information
6. Archiving of data to maintain accurate patient medical records in a form that:
    a. May be retrieved in a timely fashion
    b. Meets applicable facility, state, and federal regulations
    c. Maintains patient confidentiality
7. Promoting efficiency and quality improvement
8. Providing interpretations of images, selection of key images, and/or annotated images to referring providers
9. Supporting telemedicine by making medical image consultations available in medical facilities without on-site medical imaging support
10. Providing supervision of off-site imaging studies

11. Providing timely availability of medical images, image consultation, and image interpretation by:
12. Facilitating medical image interpretations in on-call situations
13. Providing subspecialty support as needed
14. Enhancing educational opportunities for practicing radiologists, as well as those radiologists currently in training programs
15. Minimizing the occurrence of poor image quality
16. Providing/assuring data security and preventing data theft ("breach"), in accordance with ACR–AAPM–SIIM Practice Parameter for Electronic Medical Information Privacy and Security [2]

Appropriate database management procedures applicable to all of the above should be in place.

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

Qualified personnel trained in the examination to be performed must perform the imaging examination at the transmitting site. In all cases this means a physician, and a licensed and/or registered radiologic technologist or radiation therapist. It is also strongly recommended that each site have a Qualified Medical Physicist and an Imaging Informatics Professional as consultants.

A. Physician

1. Physicians using the image data management system for official interpretation[2] should understand the basic technology of image acquisition, transmission, manipulation, retrieval, and display, including the strengths, weaknesses, and limitations in the use of the image viewing equipment. Where appropriate, the interpreting physician must be familiar with the principles of radiation protection, the hazards of radiation, and radiation monitoring requirements as they apply to both patients and personnel. The physician performing the official interpretation must be responsible for the quality of the images being reviewed and understand the elements of quality control of digital image management systems[3].
2. The physician must demonstrate qualifications as delineated in the appropriate ACR practice parameter or technical standard for the particular diagnostic modality being interpreted.
3. The physician should have a working knowledge of those portions of the digital image chain from acquisition to display that affect image quality and potential artifact production.

B. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields in medical physics. The American College of Radiology considers certification, continuing education, and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice one or more of the subfields in medical physics and to be a Qualified Medical Physicist. The ACR strongly recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, or by the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist should meet the ACR Practice Parameter for Continuing Medical Education (CME) (ACR Resolution 17, 1996 – revised in 2012, Resolution 42) and should include continuing education in radiation dosimetry, radiation protection, and equipment performance [3].

The appropriate subfields of medical physics for this technical standard are Therapeutic Medical Physics, Diagnostic Medical Physics, and Nuclear Medical Physics. (Previous medical physics certification categories

[2]The ACR Medical Legal Committee defines official interpretation as that written report (and any supplements or amendments thereto) that attach to the patient's permanent record. In health care facilities with a privilege delineation system, such a written report is prepared only by a qualified physician who has been granted specific delineated clinical privileges for that purpose by the facility's governing body upon the recommendation of the medical staff.

[3]The ACR Rules of Ethics state: "It is proper for a diagnostic radiologist to provide a consultative opinion on radiographs and other images regardless of their origin. A diagnostic radiologist should regularly interpret radiographs and other images only when the radiologist reasonably participates in the quality of medical imaging, utilization review, and matters of policy which affect the quality of patient care."

including Radiological Physics, Therapeutic Radiological Physics, Medical Nuclear Physics, Diagnostic Radiological Physics, and Diagnostic Imaging Physics are also acceptable.)

C. Registered Radiologist Assistant

A registered radiologist assistant is an advanced level radiographer who is certified and registered as a radiologist assistant by the American Registry of Radiologic Technologists (ARRT) after having successfully completed an advanced academic program encompassing an ACR/ASRT (American Society of Radiologic Technologists) radiologist assistant curriculum and a radiologist-directed clinical preceptorship. Under radiologist supervision, the radiologist assistant may perform patient assessment, patient management and selected examinations as delineated in the Joint Policy Statement of the ACR and the ASRT titled "Radiologist Assistant: Roles and Responsibilities" and as allowed by state law. The radiologist assistant transmits to the supervising radiologists those observations that have a bearing on diagnosis. Performance of diagnostic interpretations remains outside the scope of practice of the radiologist assistant. (ACR Resolution 34, adopted in 2006)

D. Radiologic Technologist

See the ACR–SPR Practice Parameter for General Radiography [4]. Additional specific qualifications and responsibilities include:

1. The individual must meet the qualification requirements of any existing ACR practice parameter or technical standard for acquisition of a particular examination.

2. He or she must be trained to properly operate those portions of the image data management system with which he or she must routinely interact. This training should include as appropriate:
   a. Image acquisition technology
   b. Image processing protocols
   c. Proper selection of examination specific options.
   d. Image evaluation
   e. Radiation dose indicators
   f. Patient safety procedures

3. The technologist must:
   a. Be certified by the appropriate registry and/or possess unrestricted state licensure.
   b. Meet the qualification requirements of any existing ACR practice parameter or technical standard for acquisition of a particular examination.
   c. Be trained to properly operate those portions of the image data management system with which he or she must routinely interact. This training should include as appropriate:
      i. Image acquisition technology
      ii. Image processing protocols
      iii. Proper selection of examination specific options.
      iv. Image evaluation
      v. Radiation dose indicators

E. Imaging Informatics Professional

The Imaging Informatics Professional should be qualified to assess problems and provide input to solutions, to initiate repairs, and to coordinate system-wide maintenance programs that will assure sustainable high image quality and system functioning. The responsibilities and experience of an Imaging Informatics Professional include:

1. Maintenance of the network for all informatics systems, eg, radiology information system (RIS), PACS, speech recognition systems, computer servers and desktops.

2. Maintenance of the integrity and security of systems to ensure continuous and accurate operation of the informatics systems.
3. Coordination of the interaction/functionality of all data entry and management systems with the necessary radiology applications, programs and databases.
4. Knowledge of computer systems using common operating systems (Windows, Unix/Linux, Mac), data communications standards and equipment, network protocols, database management, internet protocols, and systems analysis methods and design.

A Qualified Imaging Informatics Professional is an individual who is competent to practice independently in the areas of informatics listed above and discussed in the section on Informatics Workflow. He or she should have a minimum of a bachelor's degree in computer science or equivalent, and continuing education and experience in imaging informatics to demonstrate that an individual is competent to practice as an Imaging Informatics Professional. Certification through the American Board of Imaging Informatics (ABII) can be used as validation of an individual's qualification as a Qualified Imaging Informatics Professional.

III. EQUIPMENT SPECIFICATIONS

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 it should provide image quality and availability appropriate to the clinical needs whether that need be official interpretation or secondary review. The equipment must also be capable of maintaining the security of patient information in accordance with the Health Insurance Portability and Accountability Act (HIPAA).

Compliance with the Digital Imaging and Communications in Medicine (DICOM) standard, the Integrating the Healthcare Enterprise (IHE) Radiology Technical Framework, and, where applicable, the IHE-Radiation Oncology Technical Framework (IHE-RO) is strongly recommended for all new equipment acquisitions, and consideration of periodic upgrades incorporating the expanding features of that standard should be part of the ongoing quality control program.

A. Acquisition or Digitization

Initial image acquisition should be performed in accordance with the appropriate ACR modality or examination practice parameter or technical standard.

1. Direct image capture

   The images data set acquired by the digital modality in the full spatial resolution (image matrix size) and pixel bit depth should be transferred to the image management system. It is recommended that the DICOM standard be used.

2. Scanned radiographic films

   Although films from prior patient studies may be digitized using modern film scanning systems, scanned films should be used only when digital image transfer is not available.

   Films from prior patient studies may be digitized using modern film scanning systems. When used, the pixel pitch of the scanner should be small enough to capture the limiting resolution of the film. For general purpose radiographic films, a pitch of less than 200 μm (2.5 cycles/mm limiting resolution) should be used. For high resolution film or mammography, a pitch of less than 100 μm (5.0 cycles/mm limiting resolution) should be used. The scanner should be capable of recording film optical densities up to at least 3.2 for general purpose radiographs and 4.0 for high resolution radiographs and mammograms. The digitization should have at least 12 bits of precision (0 to 4,095) and produce either

DICOM presentation values or values proportional to film density. Caution should be exercised when using photographic cameras because of their inherent distortion and possible optical artifacts.

3. Video digitizer acquisitions

   Traditional fluoroscopy systems have used video recording cameras to acquire images from the output phosphor of an image intensifier. Recordings may be of individual spot exposures, pulsed fluoroscopic sequences, or continuous fluoroscopic frames. Analog video cameras produce a time varying voltage signal corresponding to a raster scan of the image. Analog to digital conversion systems are used to convert these signals to digital images formatted according to the DICOM standard. These systems are susceptible to degraded quality due to analog signal noise, timing, and drift. When used, the image quality should be closely monitored. In general, the use of digital recording cameras with image intensifiers or direct digital fluoroscopy panels is preferred.

4. General requirements
   a. At the time of patient imaging, the imaging modality must have capabilities for capturing demographic as well as imaging information such as accession number, patient name, identification number, date and time of examination, name of facility or institution, type of examination, patient or anatomic part orientation (eg, right, left, superior, inferior), amount and method of data compression, and total number of images acquired in the study. (In some cases the total number of images may not be known if the modality sends images as they are acquired.) It is beneficial to have the capability for capturing imaging technique factors, including patient dose parameters, applicable to the imaging modality. This information must be associated with the images when transmitted with a modality-specific information object descriptor (IOD). These fields should be formatted according to the DICOM standard. It is desirable to obtain this information using the DICOM modality work list services that communicate the correct information electronically.
   b. The ability to capture the patient date of birth, sex, indications for the examination, and a brief patient history is desirable.

B. Compression

Compression may be defined as mathematically reversible (lossless) or irreversible (lossy). Reversible compression may always be used, since by definition there is no impact on the image. Irreversible compression may be used to reduce transmission time or storage space only if the quality of the result is sufficient to reliably perform the clinical task. The type of body part, the modality, and the objective of the study will determine the amount of compression that can be tolerated.

The term “diagnostically acceptable irreversible compression” (DAIC) refers to mathematically irreversible compression that does not affect a particular diagnostic task [5]. DAIC may be used under the direction of a qualified physician with no reduction in clinical diagnostic performance by either the primary image interpreter or decision makers reviewing the images. From a practical perspective, this means that any artifacts generated by the compression scheme should not be perceptible by the human viewer or are at such a low level that they do not interfere with interpretation.

The ACR and this technical standard make no general statement on the type or amount of compression that is appropriate to any particular modality, disease, or clinical application to achieve the diagnostically acceptable goal. The scientific literature and other national guidelines may assist the responsible physician in choosing appropriate types and amounts of compression, weighing the risk of degraded performance against the benefits of reduced storage space or transmission time. The type and amount of compression applied to different imaging studies transmitted and stored by the system should be initially selected and periodically reviewed by the responsible physician to ensure appropriate clinical image quality, always considering that it may be difficult to evaluate the impact on observer performance objectively and reliably [6].

If reversible or irreversible compression is used, only algorithms defined by the DICOM standard such as Joint Photographic Experts Group (JPEG), JPEG-LS, JPEG-2000, or MPEG should be used, since images encoded with proprietary and nonstandard compression schemes reduce interoperability, and decompression followed by recompression with a different irreversible scheme (such as during migration of data) will result in significant image quality degradation [5]. The DICOM standard does not recommend or approve any particular compression scheme for any particular modality, image type, or clinical application.

The U.S. Food and Drug Administration (FDA) requires that when an image is displayed it be labeled with a message stating if irreversible compression has been applied and with approximately what compression ratio (and/or quality factor) [7]. In addition, the name or type of compression scheme used (for standard schemes such as JPEG, JPEG 2000, etc) should also be displayed, since this affects the interpretation of the impact of the compression. The DICOM standard defines specific fields for the encoding of this information and requires its persistence even after the image has been decompressed.

The FDA does not allow irreversible compression of digital mammograms for retention, transmission, or final interpretation, though irreversibly compressed images from prior studies may be used for comparison purposes, if deemed of acceptable quality by the interpreting physician [8]. For other modalities, the FDA does not restrict the use of compression, but it does require manufacturers of devices that use irreversible compression to submit data on the impact of the compression on quantitative metrics of image quality (such as peak signal-to-noise ratio (pSNR) [7]. The responsible physician, working with the Qualified Medical Physicist as appropriate, is responsible for ensuring that the image quality is sufficient to achieve a diagnostically acceptable goal.

C. Transmission

The environment in which the studies are to be transmitted will determine the type and specifications of the transmission devices used. In all cases, for official interpretation, the digital data received at the receiving end of any transmission must have no loss of clinically significant information. The transmission system should have a bandwidth commensurate with expected volumes to ensure images are delivered in a timely fashion. The transmission system must have adequate error-checking capability. Only the appropriate modality-specific DICOM service-object pair (SOP) classes should be used for transmission and storage.

D. Display

The consistent presentation of images on workstations is essential for electronic imaging operations. Images seen by technologists during acquisition, by radiologists during interpretation, and by physicians as a part of patient care should have similar appearance. The spatial and contrast resolution of images displayed for interpretation is particularly important. The presentation of images is influenced by workstation software, graphic controllers, and display devices.

1. Workstation characteristics

    a. Workstation displays can be separated into different categories determined by utilization. There are diagnostic displays, often referred to as primary interpretation displays, and non-diagnostic displays, often referred to as secondary displays, which include modality displays.

    b. Graphic bit depth: The operating systems of most workstations manage images with red, green, and blue channels having 8 bits (256 values). The number of available gray levels where the red, green, and blue values are equal is thus 256. Systems with increased bit depth, such as 30-bit graphics with 10 bits per channel, require support from the operating system, workstation software, graphics card, and monitor. Although subtle differences between 8-bit and 10-bit systems can be demonstrated using test patterns, no evidence has been found to date that diagnostic interpretations are affected by the use of higher than 8-bit systems.

c. Display technology: Nearly all workstation displays now use LCD or organic light emitting diode (OLED) panels. Their discrete pixels offer excellent resolution without distortion. The flat panel surfaces are able to absorb ambient light to minimize reflections and glare. However, lower cost LCD units using twisted nematic (TN) pixel structures severely alter image brightness, contrast, and color in relation to viewing angle. TN LCD devices should not be used for medical image viewing. Several advanced LCD pixel structures are now available to provide improved viewing angle performance (vertical alignment (VA), in-plane switching (IPS), plane to line structure (PLS), and multi-domain structures). The viewing angle characteristics of any LCD device should be evaluated prior to purchase.

d. Graphic interface: LCD and OLED devices are inherently digital with an internal buffer storing the data for each pixel in the rows and columns of the device. The interface between the graphic controller and the LCD device should transfer the image data using a digital format such as DVI-D (either single-link or dual-link) or Display Port. For optimal resolution, the graphic controller device driver should always be set to the native rows and columns of the LCD device. An analog video interface signal such as VGA or DVI-A is strongly discouraged since the digital to analog conversion in the graphic controller and the analog to digital conversion in the LCD device can introduce image degradation.

e. Image presentation size: The rows and columns of the displayed image are typically different than the rows and columns of the acquired image. The application software working in conjunction with the graphic controller interpolates from the acquired image data to get the displayed image data.

   For optimal image resolution, the interpolation of each displayed pixel, whether up-sampling or down-sampling, should consider more than the closest 4 acquired pixel values. Cubic spline and cubic polynomial interpolation algorithms are commonly used for high quality interpolation with the graphic controller providing acceleration so that images are presented with negligible delay. When down-sampling noisy images, the extended region considered in the interpolation also helps reduce noise in the presentation.

f. Presentation support features: The application software used to select and present imaging studies should provide features to allow rapid and easy review or interpretation of a study.
   i. Hanging protocols that address the selection of image series and display format should be flexible and tailored to user preferences with proper labeling and orientation of images.
   ii. Fast and easy navigation between new and old studies should be feasible.
   iii. Accurately associating the patient and study demographic information with the images of the study performed is essential.
   iv. Window and level adjustment tools must be available since the full dynamic range of most images cannot be displayed on most digital devices. Preset window/level settings (eg, bone or lung windows using set lookup table [LUT] transformations) are recommended to increase the speed of user interaction with the display device.
   v. Zoom (magnification) and pan functions capable of meeting guidelines for display at the originally acquired spatial resolutions (ie, direct presentation of acquired pixels on the display pixels) are essential so that the display monitor does not limit the intrinsic spatial resolution of the image. For some applications, the ability to present an image with anatomic structure having true size relative to the acquisition is important.
   vi. Rotating or flipping the images must preserve the correct patient orientation labels.
   vii. Calculating and displaying accurate linear measurements and pixel value determinations in values appropriate for the modality (eg, Hounsfield units for computed tomography [CT] images) are necessary, if those data are available and can be calibrated to the acquisition device.
   viii. Prior application of irreversible compression ratio, processing, or cropping on the image and/or overlay should be indicated.

ix. Clinically relevant technical parameters should be accessible, with overlay information on the display or with capabilities to view the DICOM header content.

g. Ergonomic factors

i. Adequate air flow, optimal temperature, and humidity control should be maintained in reading areas.

ii. Viewing conditions should be optimized to minimize eye fatigue by controlling the reading room ambient lighting. The ambient lighting should be set to minimize specular and diffuse reflection on the workstation display, which can be accomplished by setting the ambient illuminance to 25 to 50 lux [9,10]. Modern displays with improved reflection characteristics may allow the use of brighter ambient lighting conditions, though conformance with current recommendations from the AAPM and ACR should always be considered (see section III.D.2.a.i-ii and AAPM Task Group 18).

iii. Noise from computer equipment and other devices should be minimized.

iv. Proper chairs with lumbar support and adjustable height controls (including armrests) are recommended to avoid injuries and excessive fatigue.

v. The workstation table should be height adjustable, and the keyboard, mouse, and monitors should be designed to maximize comfort and efficiency. The display devices should be placed to maintain the viewers at an arm's length from the display (ie, about 2/3 meter or 60 cm).

vi. Dictation tools, internet access, and other reference tools should be readily accessible and easy to use during image interpretation.

vii. Guidelines on the maximum number of acceptable pixel defects are specified by ISO 9241 as a function of display class [12]. Documentation of allowed pixel defects should be provided by the display manufacturer. Displays should be evaluated for significant pixel defects initially and periodically (at least annually is recommended). Pixel defects should be evaluated for clinical relevance by the interpreting physician in consultation with a Qualified Medical Physicist.

2. Display characteristics

a. Luminance response

The brightness and contrast of grayscale medical images result from the luminance in relation to the image gray level values [13].

i. Ambient luminance (L_{amb}): When the power to the display device is off, the display surface will still show some brightness due to diffusely reflected room lighting. This is called the ambient luminance. The ambient luminance should be less than one-fourth of the luminance of the darkest gray level.

ii. Minimum luminance (L_{min}): Since the contrast response of the adapted human visual system is poor in very dark regions, the luminance of the lowest gray value, L_{min}, should not be extremely low. The minimum luminance including a component from ambient lighting, $L'_{min} = L_{min} + L_{amb}$, should be at least 1.0 cd/m^2 for diagnostic interpretation**,** 1.2 cd/m^2 for mammographic interpretation, and 0.8 cd/m^2 for secondary displays.

iii. Maximum luminance (L_{max}): The perceived contrast characteristics of an image on a display depend on the ratio of L'_{max} (the luminance for the maximum gray value including the component for ambient lighting) to L'_{min}. This is the luminance ratio (LR), which is not the same as the contrast ratio often reported by monitor manufacturers. Ideally, all display devices in a facility should have the same LR so that the presentation is consistent for all viewers of a study.

The LR must be large for good image contrast; however, an excessively large LR will exceed the range of the adapted human visual system. A LR of 350, which is equivalent to a film OD range from 0.20 to 2.75, is effective. For acceptable contrast, LR should always be greater than 250.

The L'_{max} of diagnostic monitors used for interpretation should be at least 350 cd/m^2 with an L'_{min} of 1.0 cd/m^2. For the interpretation of mammograms, L'_{max} should be at least 420 cd/m^2 with an L'_{min} of 1.2 cd/m^2. The monitors used for other purposes should have an L'_{max} of at least 250 cd/m^2 with an L'_{min} of 0.8 cd/m^2. For brighter monitors, L'_{min}, should be proportionately larger to maintain the same LR.

iv. Luminance versus gray level: In addition to having similar LR, the luminance of intermediate gray values between L'_{min} and L'_{max} should follow the same response function for all monitors in a facility. It is strongly recommended that the DICOM grayscale display function (GSDF) be used to set the intermediate gray values.

v. Calibration: The luminance response, including both the LR and contrast curve, of some medical and professional graphics monitors can be selected using the monitor on screen display (OSD) controls. Other medical/professional devices require software from the monitor manufacturer to load look-up tables (LUTs) to the monitor that set the luminance of each gray level. For consumer-grade monitors used as secondary displays, the calibration can be achieved by loading a LUT to the driver of the graphic control card.

vi. Quality control: Displays should be evaluated for acceptable performance initially and periodically (at least annually is recommended) and after major upgrades or repairs to the display workstations (eg, major software upgrade, graphics card replacement). Visual test patterns (eg, TG18 test patterns) can be used for qualitative evaluation of display performance, though it is difficult to accurately characterize a display only by visual inspection. Advanced tests, done on an annual or quarterly basis, measure the luminance in relation to gray value and evaluate the contrast response curve. The contrast response of monitors used for diagnostic interpretation should be within 10% of the DICOM GSDF over the full luminance response. For secondary displays, the contrast response should be within 20% of the DICOM GSDF over the full luminance response.

vii. White point: The color characteristics of a display with respect to the presented color space are not considered in this technical standard. However, the white point associated with presentation of grayscale images is important for medical imaging systems. It is recommended that monitors be set to a white point corresponding to the CIE daylight standard D65 white point. D65 is often cited as having a correlated color temperature (CCT) of 6500 K. However, it should be noted that not all displays with a CCT of 6500 K have a white point of D65. For this reason, CCT alone should not be used to characterize a display's color characteristics.

viii. If the monitor(s) does (do) not meet these specifications after corrective action is attempted, then the decision to continue using these monitors should be determined by the lead interpreting physician in consultation with a Qualified Medical Physicist. Justification for the recommended course of action should be documented.

b. Pixel pitch and display size

The spacing of pixel structures, referred to as the pixel pitch, determines how much detail can be presented. The size of the active display region in combination with pixel pitch determines the number of pixels in the display device. Although it has been common to classify monitors based on the number of pixels (ie, 1 megapixel [MP], 2 MP, 3 MP, 5 MP**,** or 10 MP), it is recommended that the pixel pitch and display size be used when considering the capabilities of a particular device.

i. Pixel pitch: The pixel pitch of a monitor determines the maximum spatial frequency that can be presented in an image. Using the sampling theorem, the maximum spatial frequency that can be described by digital signals with a constant pitch, P in mm, is 1/(2P) cycles/mm. It is desirable to have the pixel pitch sufficiently small so as to present all of the spatial frequencies that the human visual system can perceive. At an arm's length viewing distance (2/3 meter, 60 cm), the eye can perceive displayed spatial frequencies up to a maximum of 2.5 cycles/mm.

For monitors used in diagnostic interpretation, it is recommended that the pixel pitch be about 0.200 mm and not larger than 0.210 mm. For this pixel pitch, individual pixels and their substructure are not visible and images have continuous tone appearance. No advantage is derived from using a smaller pixel pitch since higher spatial frequencies are not perceived.

For the presentation of images with acquired detector element size different from the pixel pitch, zoom and pan display features should be used rather than moving closer to a display. Since the human visual system has maximum contrast sensitivity at about 0.5 cycles/mm, image zoom with interpolation can often reveal subtle detail not seen at true size.

Monitors used by technologists and clinical care staff are often not viewed at a desk, and the viewing distance is larger than for diagnostic interpretation. For these monitors, a pixel pitch of 0.250 mm (not larger than 0.300 mm) is appropriate.

ii. Display size: When interpreting images, the attention of the viewer is not limited to the center of the display but extends to the edges as well via peripheral vision. Good visualization of the full scene is achieved when the diagonal display distance is about 80 percent of the viewing distance. At 2/3 meter, this corresponds to a diagonal size of 53 cm (21 inches). Monitors with a pixel array size of 1,500 × 2,000 and a pixel pitch of 0.210 will have a diagonal size of 52.5 cm.

A number of manufacturers have developed 8 and 10 megapixel widescreen displays for mammography (and other applications). These are generally suitable for the majority of radiologic images, including full-field digital mammography (FFDM) and digital breast tomosynthesis (DBT) viewing, as they make it feasible to display 2 images (eg, right and left CC or MLO) or large series of images (eg, multiple MR sequences) simultaneously on the same display.

An aspect ratio, width to height, of 3:4 or 4:5 is well suited for the presentation of diagnostic images. Such a portrait presentation requires image rotation from the graphic controller. However, the displays currently being manufactured typically have a wide format, 16:9 or 16:10. These can be used similar to a dual monitor workstation if the application software can present images in two regions with 8:9 or 8:10 aspect ratio.

E. Archiving, Retention, and Retrieval

1. Digital imaging data management systems must provide storage capacity capable of complying with all facility, state, and federal regulations regarding medical record retention. Images stored by either a transmitting or receiving site should meet the jurisdictional requirements of both the transmitting and receiving site. Images interpreted off-site need not be stored at the receiving facility provided they are stored at the transmitting site or its designee. However, if the images are retained at the receiving site, the retention period of that jurisdiction must be met as well. The policy on record retention should be in writing.
2. Each examination data file must have an accurate corresponding patient and examination database record that includes patient name, identification number, accession number, examination date, type of examination, and facility at which the examination was performed. It is desirable that space be available for a brief clinical history.
3. Current and prior examinations must be retrievable in a time frame appropriate to the clinical needs of the facility and medical staff.
4. Each facility should have policies and procedures for archiving and storage of digital image data equivalent to the policies that exist for the protection of hardcopy storage media to preserve imaging records.
5. For facilities practicing electronic radiology, quality patient care depends on the stability and reliability of the digital image data management system. Written policies and procedures must be in place to

ensure continuity of care at a level consistent with those for hard-copy imaging studies and medical records within a facility or institution. They should include internal redundancy systems, backup telecommunication links, disaster recovery, emergency downtime contingency plan, and business continuity plan.

F. Image Sharing

1. Each facility should have a mechanism for image sharing on physical media, including CD, DVD, and USB media, and should be able to export and import data compliant with the IHE Portable Data for Imaging (PDI) profile [14,15]. PDI requires that DICOM images be recorded in a standard manner and also permits additional "web content," such as in the form of prerendered (JPEG) images. Even if a facility has a means of sharing images over a network, standard physical media are required for those recipients not able to use the network. Physical media containing proprietary formatted images should not be used. Physical media may contain an executable viewer. If present, an embedded viewer should be capable of displaying the standard DICOM PDI images and not depend on the presence of proprietary formats [14]. Each facility should comply with the recommendation of the American Medical Association Expert Panel on Medical Imaging, which put forward the following statement that embodies the standard the medical imaging community must achieve: "All medical imaging data distributed should be a complete set of images of diagnostic quality in compliance with IHE-PDI." The panel further stated that "this standard will engender safe, timely, appropriate, effective, and efficient care; mitigate delayed care and confusion; enhance care coordination and communication across settings of care; decrease waste and costs; and, importantly, improve patient and physician satisfaction with the medical imaging process." The statement was signed by the American Medical Association, the American Association of Neurological Surgeons, the Congress of Neurological Surgeons, the American Academy of Neurology, the American College of Radiology, the American Academy of Orthopedic Surgeons, and the American College of Cardiology.

2. Each facility should have a mechanism for secure image sharing over the Internet. The network exchange of imaging information should be conducted in accordance with the IHE Cross Document Sharing (XDS.b) profile (and XDS-I.b for imaging objects) [15]. Depending on the needs of the recipient, the images exchanged may be of original diagnostic quality, in which case DICOM PS 3.10 images are required, or may be prewindowed and prerendered. Every facility should have a mechanism for providing both a full set of diagnostic quality DICOM images and a subset of prerendered images of the appropriate quality for this purpose, consistent with the AMA's recommendations for the analogous exchange on physical media.

3. Each facility should have a mechanism for importing images and associated information in standard DICOM form from physical media and from the Internet, with reconciliation of foreign identifiers, accession numbers, and procedure descriptions or codes such that they do not collide with local identifiers. Each facility should make it possible to display such foreign images with the same fidelity and side by side in the same user interface as locally acquired images. This allows for better patient care and fewer unnecessarily repeated studies (hence avoiding the cost, inconvenience, and safety risk from contrast and radiation of repeating a study). The importation should be performed in accordance with the IHE Import Reconciliation Workflow (IRWF) profile.

G. Security, Privacy, Reliability, and Redundancy

See the ACR–AAPM–SIIM Practice Parameter for Electronic Medical Information Privacy and Security [2].

H. Informatics Infrastructures and Workflow Processes

Electronic practice of diagnostic radiology involves a number of processes that should be coordinated by systems using the DICOM, HL7, IHE, and IHE-RO informatics standards to ensure that information associated with the

imaging study and patient record is accurate, that errors are minimized, and that the processes are efficient. These include:

- Patient demographic data should be obtained on admission (registration) rather than repeatedly reentered at each step of the workflow.
- The appropriate modality and modality-specific imaging protocol should be selected during scheduling.
- The demographic and scheduling information should be communicated electronically to the modality in a standard form.
- Complete and consistent demographic data should be transferred across all systems.
- Relevant data about the acquisition should be included in the electronic radiology record (preferably in an automated and structured manner).
- Relevant data about the acquisition should be made available for correct coding of the examination for billing, tracking, and quality control.
- Relevant observations by the technical staff and interpreting radiologist should be retained and distributed in a standard form.

The DICOM and HL7 [14,16] standards provide the building blocks for such an infrastructure, and the IHE Radiology Technical Framework [14] defines profiles for using those standards to implement the required processes.

Some of the processes associated with diagnostic radiology workflow and the standards that should be used are given below.

1. Ordering and scheduling of procedures, performance of the acquisition, and transfer of images and associated information to the PACS should be in compliance with the IHE Scheduled Workflow (SWF) profile. This profile establishes the continuity and integrity of basic departmental imaging data, specifies transactions that maintain the consistency of patient and ordering information, provides the scheduling and imaging acquisition procedure steps, and makes it possible to determine whether images and other evidence objects associated with a particular performed procedure step have been stored (archived) and are available to enable subsequent workflow steps, such as reporting. The SWF profile may also provide central coordination of the completion of processing and reporting steps as well as notification of appointments to the placer of the order.

2. Correction of incorrect identification used during acquisition should be performed in compliance with the IHE Patient Information Reconciliation (PIR) profile. PIR extends the SWF profile by providing the means to match with the patient's record, images, diagnostic reports, and other evidence objects acquired for a misidentified or unidentified patient (for example, during a trauma case).

3. In selecting a procedure, the ordering physician should be assisted by appropriateness use criteria, such as the ACR Appropriateness Criteria®, or a clinical decision support system.

4. Standard terminology and codes for ordering should be used, including:
   a. Systematized Nomenclature of Medicine – Clinical Terms (SNOMED-CT) (see http://www.ihtsdo.org/snomed-ct).
   b. RadLex – Lexicon for Uniform Indexing and Retrieval of Radiology Information Resources (see http://www.radlex.org).
   c. Logical Observation Identifiers Names and Codes

5. Each facility should use a standard set of predefined image acquisition protocols. Many image acquisition systems (eg, CT, MRI, NM) have complex protocols that need to be defined by the radiologist in consultation with the Qualified Medical Physicist prior to the acquisition. The appropriate protocol needs to take into consideration the order information (eg, history, patient type), modality capabilities, and the technologist's knowledge of the equipment/protocol. By requiring the definition of the appropriate protocol prior to the acquisition, the examination can be optimized to use the lowest radiation dose sufficient to achieve the necessary image quality and the parameters matched to the

equipment and clinical needs of the patient. Evolving standards are being defined by professional organizations to optimize the use of radiation dose for a particular indication, for example, in CT scanning [17]. Using standard codes, such as those defined by the RadLex PlayBook [18], the choice of protocol should be communicated to the acquisition modality using the IHE Assisted Protocol Setting option to the SWF profile [14].

6. Each facility should store annotations made by staff on images in a standard form as defined by DICOM in presentation states, structured reports, or structure sets. The IHE Consistent Presentation of Images (CPI) profile specifies the use of DICOM presentation states. It also requires that displays be calibrated according to the DICOM grayscale standard display function (GSDF) for the purpose of approaching consistency of perceived grayscale contrast on different displays and in different viewing environments (see also section III, Equipment Specifications). The IHE Simple Image and Numeric Report (SINR) specifies the use of the DICOM Structured Report to store a simple structure consisting of a title, an observation context, and 1 or more sections, each with a heading, observation context, text, image references, and coded measurements. Its use facilitates searches and serves as the input to the formal diagnostic report, thus avoiding re-entry of information.

IV. DOCUMENTATION

Physicians officially interpreting examinations[4] using digital image data management systems should render reports in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [19].

If reports are incorporated into the data management system, they should be retrievable with the same conditions of timeliness and security as those for the imaging data.

V. LICENSING, CREDENTIALING, AND LIABILITY

The interpreting physician is responsible for the quality of the images being reviewed.[5]

Physicians who provide the official interpretation of images transmitted by teleradiology should be familiar with the licensure requirements for providing radiologic or telemedicine service at both the transmitting and receiving sites and obtain licensure as appropriate. Physicians practicing teleradiology should conduct their practice in a manner consistent with the bylaws, rules, and regulations for patient care at the transmitting and receiving site jurisdictions. Regulations should not restrict the ability of radiologists to provide second opinion consultations when requested in a jurisdiction where the consulting radiologist is not licensed. When interpreting images from a hospital, physicians should be credentialed and obtain appropriate privileges at that institution. Physicians providing domestic and international teleradiology services should consult with their professional liability carrier to ensure coverage in both the sending and receiving sites (state or jurisdiction). The malpractice insurance coverage and claims jurisdiction should be determined by those contracting to receive teleradiology services. Some states may require specific patient consent for telemedicine consultation. Disclosing the use of international telemedicine to the patient and referring physician should be considered if patient confidentiality is not assured by the international provider. Physicians providing emergency interpretations should be immediately available for consultation. For nonemergent interpretations, the physician should be available for consultation or have a method to communicate and authenticate his or her findings.

Images stored at either site should meet the jurisdictional requirements of the transmitting site. Images interpreted off-site need not be stored at the receiving facility, provided they are stored at the transmitting site. However, if

[4] The ACR Medical Legal Committee defines official interpretation as that written report (and any supplements or amendments thereto) that attach to the patient's permanent record. In health care facilities with a privilege delineation system, such a written report is prepared only by a qualified physician who has been granted specific delineated clinical privileges for that purpose by the facility's governing body upon the recommendation of the medical staff.

[5] The ACR Rules of Ethics state: "it is proper for a diagnostic radiologist to provide a consultative opinion on radiographs and other images regardless of their origin. A diagnostic radiologist should regularly interpret radiographs and other images only when the radiologist reasonably participates in the quality of medical imaging, utilization review, and matters of policy which affect the quality of patient care."

images are retained at the receiving site, the retention period of that jurisdiction should be met as well. The policy on record retention should be in writing.

Computer aided diagnosis (CAD) systems used to assist primary diagnosis must have FDA approval for the modality used.

VI. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, registered radiologist assistants, radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection and application of dose limits) and the principles of proper management of radiation dose to patients (justification, optimization and the use of dose reference levels) http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf.

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unwarranted radiation exposure.

Facilities should have and adhere to policies and procedures that require varying ionizing radiation examination protocols (plain radiography, fluoroscopy, interventional radiology, CT) to take into account patient body habitus (such as patient dimensions, weight, or body mass index) to optimize the relationship between minimal radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used whenever appropriate. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available at the Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org) websites. These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be measured and patient radiation dose estimated for representative examinations and types of patients by a Qualified Medical Physicist in accordance with the applicable ACR technical standards. Regular auditing of patient dose indices should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry, the NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends. (ACR Resolution 17 adopted in 2006 – revised in 2009, 2013, Resolution 52).

Exposures to patients from digital x-ray equipment (including projection radiography, fluoroscopy, angiography, and CT) should be recorded digitally by the modality in a standard form (such as the DICOM Radiation Dose Structured Report [RDSR]) and transmitted and monitored using the IHE Radiation Exposure Monitoring (REM) profile. Facilities should also contribute de-identified digital records of patient radiation exposure to the appropriate dose index registry (such as the ACR's Dose Index Registry (DIR) component of the National Radiology Data Registry [NRDR]) for the purpose of establishing, maintaining, and comparing facility performance against national Diagnostic Reference Levels (DRLs). Facilities that have legacy technology not supporting standards such as DICOM RDSR and IHE REM should employ tools using techniques such as Optical Character Recognition (OCR) to extract the numeric exposure information from modality manufacturer's dose screens or other mechanisms, where possible.

VII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control,

and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Educ*ation on the ACR website (http://www.acr.org/guidelines).

Any facility using a digital image data management system must have documented policies and procedures for monitoring and evaluating the effective management, safety, and proper performance of acquisition, digitization, processing, compression, transmission, display, archiving, and retrieval functions of the system. The quality control program should be designed to maximize the quality and accessibility of diagnostic information.

1. Quality control and quality assurance of display devices should be performed in accordance with any relevant ACR modality accreditation program Quality Control Manual recommendations, the equipment manufacturer specifications, applicable industry guidelines, and state and federal regulations. In the absence of adequate manufacturer procedures, guidelines, or standards, the recommendations for the performance evaluation of display devices testing methods and frequencies contained in AAPM Task Group 18: Assessment of Display Performance for Medical Imaging Systems [20] (or its successors) should be followed.
2. As a minimum quality check for display devices, a test image should be displayed at regular intervals to test the overall performance of the system under conditions that simulate normal operation. This test image should contain features that evaluate low contrast performance, uniformity, bit-depth or contouring artifacts, and correct pixel mapping (eg, the AAPM Task Group 18-QC test pattern). The image should be properly sized to occupy the full area of the display.
3. When applicable, hardcopy imager accuracy and stability testing should also be performed and documented.
4. If a viewbox is utilized for clinical interpretation, the viewbox luminance should be sufficient to meet the diagnostic needs of the imaging procedure and applicable industry standards and/or recommendations should be followed

The use of digital imaging and digital image data management systems does not reduce the responsibilities for managing and supervising radiologic examinations. Locations and physicians providing remote imaging services should participate in a documented ongoing quality assurance program at least equivalent to that of the originating facility. Summaries of the quality control monitoring should be provided to the originating facility.

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APPENDIX A

Glossary

1. Analog signal – a form of information transmission in which the signal varies in a continuous manner and is not limited to discrete steps.
2. Archive – a repository for digital medical images in a picture archiving and communications system (PACS), typically with the specific purpose of providing either short-term or long-term (permanent) storage of images. Erasable or nonerasable media may be used in an archive.
3. Bit (binary digit) – the smallest unit of digital information that a computing device handles. It represents off or on (0 or 1). All data in computing devices are processed as bits or strings of bits.
4. Bit depth – the number of bits used to encode the signal intensity of each pixel of the image.
5. Compression ratio – the ratio of the number of bits in an original image to that in a compressed version of that image. For example, a compression ratio of 2:1 would correspond to a compressed image with one-half the number of bits of the original.
6. CR (computed radiography) – a system that uses a storage phosphor plate instead of film-screen in a cassette. A laser beam scans the exposed plate to produce the digital data that is then converted into an image.
7. CRT (cathode ray tube) – an older technology monitor or display device used for viewing digital softcopy images. A CRT uses a controlled beam of electrons incident on a phosphor to generate a luminous image.
8. CT (computed tomography) – A computerized tomography (CT) scan combines a series of x-ray images taken from different angles and uses computer processing to create cross-sectional images, or slices.
9. Data communication – all forms of computer information exchange. Data communication may take place between 2 computers in the same building via a local area network (LAN), across the country via telephone, or elsewhere by a wide-area network (WAN).
10. Data compression – methods to reduce the data volume by encoding it in a more efficient manner, thus reducing the image processing and transmission times and storage space required. These methods may be reversible (lossless) or irreversible (lossy).
11. Diagnostic displays – displays used for the primary interpretation of medical images.
12. Digital imaging and communications in medicine (DICOM) – a standard for interconnection of medical digital imaging devices, developed and sponsored by the American College of Radiology and the National Electrical Manufacturers Association, consisting of a standard image format and a standard communications protocol.
13. Digital signal – a form of information transmission in which the signal varies in discrete steps, not in a continuous manner.
14. Digitize – the process by which analog (continuous value) information is converted into digital (discrete value) information.
15. Direct image capture – the capture or acquisition of digital image data that have been acquired in digital format by an imaging modality. The image produced from the data, regardless of the modality that produced it (CT, MRI, CR, US), should include the full spatial resolution and bit depth of the original.
16. Dynamic range – the difference in signal intensity, or frequency, between the largest and smallest signals a system can process or display. Increasing the number of bits per pixel in a digital image increases the dynamic range of the image.
17. File – a set of digital data that have a common purpose, such as an image, a program, or a database.
18. Grayscale – the number of different shades of levels of gray that can be stored and displayed by a computer system. The number of gray levels is directly related to the number of bits used in each pixel: 6 bits = 64 gray levels, 7 bits = 128 gray levels, 8 bits = 256 gray levels, 10 bits = 1,024 gray levels, and 12 bits = 4,096 gray levels.
19. GSDF (grayscale standard display function) – a standard luminance contrast response curve as defined in Part 14 of the DICOM standard.
20. Hardware – a collective term used to describe the physical components that form a device such as a computer. The monitor, CPU, disk drives, memory, modem, and other components are all considered hardware.

21. Image matrix size – the size of an image described as the number of rows and the number of columns of pixels.
22. Image sampling: Up-sampling – small matrix images are typically sampled more finely than the acquired pixel spacing in order to increase the number of rows and columns and increase the presented size. Down-sampling - Large matrix images are typically sampled more coarsely than the acquired pixel spacing in order to decrease the number of rows and columns so that the full image area can be presented.
23. Irreversible compression – some permanent alteration of digital image data. This is sometimes referred to as lossy compression.
24. LCD (liquid crystal display) – a modern monitor or display device technology used for viewing digital softcopy images.
25. Lossless compression – see reversible compression
26. Lossy compression – see irreversible compression
27. Medical imaging workstation – the term "medical imaging workstation" describes a computer system that allows a user to search, retrieve, display and manipulate images that have been created from various imaging modalities, such as: digital x-ray computed radiography, direct digital radiography, computed tomography (CT) scanner, magnetic resonance imaging (MRI) scanner, ultrasound (US) or any of the other digital imaging modalities found in recent imaging departments. The workstations that are used for the final interpretation of clinical images are often called Review Workstations (RWS). The workstations that are used during image acquisition for the specific imaging modality are often called acquisition workstations (AWS).
28. Modality displays – displays that typically are an integral component on the onsite imaging modality. They are used during the acquisition and modification of images prior to primary interpretation.
29. Monochrome monitor – a computer display in which an image is presented as different shades of gray from black to white (see also grayscale).
30. Mouse – an input device that allows the computer user to point to objects on the screen and execute commands.
31. MRI (magnetic resonance imaging) – MRI is a technique that uses a magnetic field and radio waves to create detailed images of the organs and tissues within the body.
32. NM (nuclear medicine) – NM is the medical specialty that uses the tracer principle, most often with radiopharmaceuticals, to evaluate molecular, metabolic, physiologic and pathologic conditions of the body for the purposes of diagnosis, therapy and research.
33. OLED (organic light emitting diode) – a modern monitor or display device technology used for viewing digital softcopy images.
34. PACS – picture archiving and communication system
35. Phosphor – the coating on the inside of a CRT or monitor that produces light when it is struck by an electron beam.
36. Pixel (picture element) – the smallest piece of information that can be displayed on a CRT. It is represented by a numerical code within the computer and displayed on the monitor as a dot of a specific color or intensity. An image is composed of a large array of pixels of differing intensities or colors.
37. Protocol – a set of guidelines by which 2 different computer devices communicate with each other, or a set of instructions or procedures
38. RAM (random access memory) – a type of temporary memory in a computer in which programs are run, images are processed, and information is stored. The amount of RAM that a computer requires varies widely depending on the specific application. Information stored in RAM is lost when the power is shut off.
39. Resolution – spatial resolution is the ability to distinguish small objects at high contrast. It is related to and in some cases limited by the pixel size. Contrast (grayscale) resolution is the ability of a system to distinguish between objects of the same size having different signal intensity. It is related to and in some cases limited by the bit depth.
40. Reversible compression – no alteration of original image information upon reconstruction. This is sometimes referred to as lossless.
41. Secondary image capture – the capture in digital format of image data that originally existed in another primary format (eg, a digital image data file on a CT scanner, a screen-film radiographic film) through the process of video capture or film digitization
42. SMPTE – the Society of Motion Picture and Television Engineers

43. Software – a name given to the programs or sets of programs that are executed on a computer
44. US (ultrasound) – diagnostic ultrasound, also called sonography or diagnostic medical sonography, is an imaging method that uses high-frequency sound waves to produce images of structures within the body.

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*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

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