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The American College of Radiology will periodically define new practice guidelines and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice guidelines and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice guideline and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Commission on Quality and Safety as well as the ACR Board of Chancellors, the ACR Council Steering Committee, and the ACR Council. The practice guidelines and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice guideline and technical standard by those entities not providing these services is not authorized.

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## **ACR TECHNICAL STANDARD FOR ELECTRONIC PRACTICE OF MEDICAL IMAGING**

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### **PREAMBLE**

These standards are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these standards 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 physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the standards, 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 the standards 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 the standards. However, a practitioner who employs an approach substantially different from these standards 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 these standards 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 these standards is to assist practitioners in achieving this objective.

### **I. INTRODUCTION**

Increasingly, medical imaging and patient information are being managed utilizing 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.

These standards are 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 radiologic images from one location to another for the purposes of interpretation and/or consultation.

This standard 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.

In all cases for which an American College of Radiology (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 (Appendix A) and a reference list are included.

## II. GOALS

The electronic practice of medical imaging is a rapidly evolving technology. New goals will continue to emerge. 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 interpreted images to referring providers.
9. Supporting telemedicine by making radiologic consultations available in medical facilities without on-site radiologic support.
10. Providing supervision of off-site imaging studies.
11. Providing timely availability of radiologic images, image consultation, and image interpretation in emergent and nonemergent clinical care areas by:
  - a. Facilitating radiologic interpretations in on-call situations.
  - b. Providing subspecialty radiologic support as needed.
12. Enhancing educational opportunities for practicing radiologists.
13. Minimizing the occurrence of poor image quality.

Appropriate database management procedures applicable to all of the above should be in place. It is anticipated that the goals of digital image data management will continue to evolve.

## III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

Qualified personnel trained in the examination to be performed must perform the radiologic examination at the transmitting site. In all cases this means a physician, a licensed and/or registered radiologic technologist, a radiation therapist, a nuclear medicine technologist, or a sonographer. The technologist, radiation therapist, or sonographer must be under the supervision of a qualified licensed physician.

It is desirable to have a Qualified Medical Physicist and/or image management specialist as a consultant.

### A. Physician

1. Physicians utilizing the image data management system for official interpretation<sup>1</sup> should understand the basic technology of image acquisition, transmission, manipulation, retrieval, and display, including the strengths, weaknesses, and limitations and who is knowledgeable 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 exposure to both patients and radiological personnel, and patient and personnel monitoring requirements. 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.<sup>2</sup>
2. The physician must demonstrate qualifications as delineated in the appropriate ACR guideline or 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.

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<sup>1</sup>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.

<sup>2</sup>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."

## 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 and 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 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 for MRI, by the American Board of Medical Physics (ABMP) in magnetic resonance imaging physics.

The appropriate subfields of medical physics for this standard are Therapeutic Radiological Physics, Diagnostic Radiological Physics, Medical Nuclear Physics, and Radiological Physics.

A Qualified Medical Physicist should meet the [ACR Practice Guideline for Continuing Medical Education \(CME\)](#) (ACR Resolution 17, 1996 – revised in 2008, Resolution 7) and should include continuing education in radiation dosimetry, radiation protection, and equipment performance related to the use of fluoroscopy.

## 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

The technologist must:

1. Be certified by the appropriate registry and/or possess unrestricted state licensure.

2. Meet the qualification requirements of any existing ACR guideline or standard for acquisition of a particular examination.
3. 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

## E. Electronic/Computer Assistant

Assistants should be trained to properly operate those portions of the image data management system with which they must routinely interact.

## F. Image Management Specialist

The image management specialist should be qualified to assess and provide problem-solving input, initiate repair, and coordinate system-wide maintenance programs to assure sustainable high image quality and system function. This individual should also be directly involved with any system expansion programs.

This specialist, as well as any necessary support personnel, should be available in a timely manner in case of malfunction to facilitate return to optimal system functionality.

## IV. EQUIPMENT SPECIFICATIONS

Specifications for equipment utilized in digital image data management will vary depending on the application and the individual facility’s needs but in all cases should provide image quality and availability appropriate to the clinical needs whether that need be official interpretation or secondary review.

Compliance with the current National Electrical Manufacturers Association (ACR-NEMA) Digital Imaging and Communications in Medicine (DICOM) standard 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. Compliance with recommendations of the Radiological Society of North America and the “Integrating the Healthcare Enterprise Initiative” (IHE) initiative of the Healthcare Information and Management Systems Society is also strongly recommended for all new equipment acquisitions. These recommendations are embodied in available technical frameworks.

Display device guidelines are currently divided into two basic categories of digital image data set size when used for rendering the official interpretation: small matrix size (e.g., computed tomography [CT], MRI, ultrasound, nuclear medicine, digital fluorography, and digital angiography), and large matrix size (e.g., digital radiography, computed radiography, digitized radiographic films, and digital mammography).

For both small-matrix and large-matrix digital image data, the initial data set should provide full resolution data for processing, manipulation, and subsequent display. Ideally, the image display's resolution abilities should be at least as good as those of the acquisition matrix.

*Small-matrix:* the initial digital image data set should provide a minimum of 256 x 256 matrix size at a minimum 10-bit pixel depth for processing, or manipulation with no loss of matrix size or bit depth at display.

*Large-matrix:* the digital image data set should be acquired with a minimum of 2.5 lp/mm spatial resolution at a minimum 10-bit pixel depth. An increased spatial resolution of 5 lp/mm at a minimum 10-bit pixel depth should be considered for pediatric imaging or the imaging of small body parts.

#### A. Acquisition or Digitization

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

##### 1. Direct image capture

The image 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. This is the most desirable method of digital image acquisition.

##### 2. Secondary image capture (analog-to-digital conversion)

- a. Small-matrix images: Each individual image should be digitized to a matrix size as large as or larger than that of the original image on the imaging modality. The images should be digitized to a minimum bit depth of 10 bits per pixel or greater. Film digitization or video frame grab systems conforming to the above specifications can be acceptable.
- b. Large-matrix images: These images should be digitized to a matrix size corresponding to 2.5 lp/mm or greater in the original

detector plane. These images should be digitized to a minimum bit depth of 10 bits per pixel or greater.

#### 3. General requirements

- a. At the time of acquisition (small or large matrix), the system 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 of acquisition, type of examination, patient or anatomic part orientation (e.g., right, left, superior, inferior), amount and method of data compression, and display of the total number of images acquired in the study. This information must be associated with the images when transmitted. These fields should be formatted according to the DICOM standard.
- b. The ability to record patient date of birth, sex, and a brief patient history is desirable.

#### B. Compression

Data compression may be performed to facilitate transmission and storage. The type of medical image, the modality, and the objective of the study will determine the degree of acceptable compression. Several methods, including both reversible and irreversible techniques (lossless and lossy are also common terms), may be used under the direction of a qualified physician or practitioner, with minimal if any reduction in clinical diagnostic image quality. If compression is used, algorithms recommended by the DICOM standard such as wavelet or JPEG-2000 compression methods should be used. The types and ratios of compression used for different imaging studies transmitted and stored by the system should be selected and periodically reviewed by the responsible physician to ensure appropriate clinical image quality. Regulatory bodies may require the compression ratio used to be indicated on the compressed image. The Food and Drug Administration (FDA) does not allow compression of digital mammograms at this time for retention, transmission, or final interpretation.

#### 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 negligible if any loss of clinically significant information when compared to uncertainties introduced by the detector and display devices. The transmission system shall have adequate

error-checking capability. The DICOM Transmission and Storage Standard Digital X-ray Image Information Object and relevant substandards should be used for best practice implementation and incorporated by all digital imaging equipment vendors, as appropriate.

#### D. Display Capabilities

1. Display workstations used for official interpretation for small-matrix and large-matrix systems should be capable of the following:

- a. The ratio of the maximum luminance to the minimum luminance of a display device for images other than mammography should be at least 50. Maximum luminance of the grayscale monitors not used for mammography therefore should be at least 50 foot lamberts ( $171 \text{ cd/m}^2$ ). The contribution of ambient light reflected from the display surface should be included in luminance measurement considerations since some level of ambient light is always present.
- b. Maximum luminance of the grayscale monitors used for mammography should be at least 73 foot lamberts ( $250 \text{ cd/m}^2$ ), while 131 foot lamberts ( $450 \text{ cd/m}^2$ ) is recommended for optimized contrast. The contrast response of the display should comply with the AAPM Task Group 18 recommendations. High display contrast ratio with low minimum luminance level ( $0.5 \text{ cd/m}^2$ ) is most desirable. Contrast response should not deviate from the DICOM Grayscale Display Function (GSDF) contrast values by more than 10%. Relative luminance contrast between successive gray levels in relation to the expected DICOM GSDF should vary on average by no more than 1.0 and in no case by more than 2.0.
- c. A minimum of 8-bit luminance resolution (bit depth) is required. Nine-bit or higher is recommended if the “for processing” image data is greater than 8 bit. In general, the higher the luminance ratio of the display, the larger the bit-depth resolution that is advised.
- d. Selection of image sequence and display format. Hanging protocols should be flexible and tailored to user preferences with proper labeling and orientation of images.
- e. Fast and easy navigation between new and old studies should be feasible.

- f. Accurately associating the patient and study demographic information with the images of the study performed is essential.
  - g. 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 (e.g., bone or lung windows using set lookup table [LUT] transformations) are recommended to increase the speed of user interaction with the display device.
  - h. Zoom (magnification) and pan functions capable of meeting guidelines for display at the originally acquired spatial resolutions should be used rather than the user moving closer to the display.
  - i. Rotating or flipping the images, provided labeling of patient orientation is preserved.
  - j. Calculating and displaying accurate linear measurements and pixel value determinations in values appropriate for the modality (e.g., Hounsfield units for CT images), if those data are available and can be calibrated to the acquisition device.
  - k. Displaying prior application of irreversible compression ratio, processing, or cropping.
  - l. The following elements of display information should be available:
    - i. Matrix size should be as close to the “for processing” image data as possible, or obtainable with magnification (image zoom and pan functionality) without sacrificing too much of the image field of view.
    - ii. Bit depth should be at least 8 bits.
    - iii. The total number of images acquired in the study needs to be accessible during interpretation.
    - iv. Clinically relevant technical parameters should be accessible.
2. The small matrix monitors used for primary diagnosis should be capable of providing the following elements of display:
- a. Matrix size should be as close to the “for processing” image data as possible, or attainable with magnification.
  - b. Bit depth should be at least 8 bits (higher dynamic range is advisable with higher luminance values).
  - c. The total number of images acquired in the study needs to be accessible during interpretation.
  - d. Clinically relevant technical parameters should be accessible.

3. The large matrix monitors used for primary diagnosis should provide the following elements of display capability:
  - a. A 5 MP (2,048 x 2,560) monitor exceeds the ACR standard of a displayed resolution of at least 2.5 lp/mm when viewing a 14" x 17" image and thus is sufficient for viewing all types of CR/DR images. The FDA recommends that only monitors that have been cleared for digital mammography use by FDA's Office of Device Evaluation be used for interpreting digital mammograms.
  - b. A 2 MP (1,200 x 1,600) or 3 MP (1,535 x 2,048) monitor needs a 2X magnification when viewing 14" x 17" images but no magnification when viewing 8" x 10" image).
  - c. Similarly, a 1K x 1.2K (1,024 x 1,280) will not permit a 10" x 12", 12" x 14", or a 14" x 17" image with at least 2.5 lp/mm resolution without zooming or magnifying the image. The choice of monitor will be determined by many factors. The display requirements of the monitor will largely be determined by the needs of the clinical task. Of primary importance is the ability of the monitor and video card to display the acquired image at full resolution and adequate bit depth. For monitors that cannot display the full field of view of the acquired image, this requires that the entire image data set be stored by panning a region of interest. Note that this process may not be convenient and may impact the productivity of clinicians.
  - d. Conform to the current DICOM grayscale display function standard.
  - e. The MTF at the Nyquist frequency of the display should be greater than 35% as recommended in documents of the American Association of Physicists in Medicine (AAPM) Task Group 18.
  - f. A display device should not add more than a third of the noise of a typical image, limiting the display relative noise to 0.6% to 0.8%.
  - g. Veiling glare or the spread of light within the display can reduce contrast. Thus the glare ratio should be greater than 250.
  - h. Reflections from ambient light sources should be kept at a minimum even when displays have antiglare coatings. Indirect and backlight incandescent lights with dimmer switches rather than fluorescent are recommended. Light colored clothing and lab coats can increase reflections and glare. The intrinsic minimum luminance of the device should not be smaller than the ambient luminance.
    - i. The color tint of the display (blue, gray, yellow, etc.) is based on user preferences, but should be uniform across the display area and monitor pairs should be matched from the same manufacturing batch.
4. The FDA requires that any electronic device used within 2.5 meters (about 10.8 feet) or less of a patient must have UL2601 certification.
5. When the display systems are not used for the official interpretation, they need not meet all the characteristics listed above. Additional display considerations include:
  - a. LCD versus CRT displays with regard to static and dynamic image display and viewing angle needs and restrictions.
    - i. Flat-surface displays are preferred over those with curved surfaces.
    - ii. On-axis viewing is comparable for CRTs and LCDs, but off-axis distortions are still possible with many LCDs and should be taken into account when viewing images on LCDs from nonorthogonal angles. Angular performance should not lead to a deviation of the contrast response from the DICOM GSDF by more than 30% within the operating ranges of the viewing angles (<30 degrees usually).
    - iii. Protective shields on LCDs add to reflections and should not be used if possible.
    - iv. Both CRT and LCD displays require about 30 minutes of warmup time to reach maximum performance.
  - b. Monochrome versus color displays with regard to luminance capabilities – Color LCD displays are now approaching the luminance output of grayscale LCD displays with similar grayscale rendition accuracy for 3 megapixel and 2 megapixel display formats, and should be acceptable for use as long as minimum luminance requirements are satisfied and the monitor/video card provides capabilities for DICOM calibration. The user must be aware of the luminance and resolution specifications of any monitor used for primary diagnosis, and validate performance for all imaging and in particular for radiographic modalities (e.g., chest, bone, mammography).
    - i. Color displays are advantageous for displaying color-encoded functional imaging information from modalities such as positron emission tomography (PET), nuclear medicine (NM), ultrasound (US), and magnetic

- resonance imaging (MRI), as well as 3-D color imaging of volumetric datasets from cross-sectional image stacks.
  - ii. Emerging guidelines and standards are becoming available for calibrating color displays for grayscale radiographic image presentation, but not definitive recommendations can be made at this time. The DICOM GSDF can be applied to color displays for accurate conformance to grayscale rendition, but the issue of color display calibration is still not fully addressed. Monitors displaying images that require strict color rendition accuracy should have alternate methods of color calibration and testing.
  - c. Desirable display features include remote performance monitoring, calibration, and quality control.
  - d. Monitor set matching of contrast ratio, brightness, and color are generally accomplished with the DICOM GSDF, although color does not have a standard calibration method to date that has been accepted by the medical imaging community.
  - e. Viewing conditions should be optimized by controlling reading room lighting to eliminate reflections on the monitor and lowering the ambient lighting level as much as is feasible.
  - f. Time to bring an image up on the workstation should be 3 seconds or less for images stored on an internal network with spinning disk storage. Times for other images may take longer depending on the electronic network storage and archive architecture and on image management and retrieval methods.
  - g. Ergonomic considerations
    - i. With digital display it is necessary to insure adequate air flow, optimal temperature and humidity control.
    - ii. Noise considerations (computer fans, for example) are also important to minimize with digital workstations.
    - iii. Proper chairs with lumbar support and adjustable height controls (including armrests) are recommended to avoid injuries and excessive fatigue. The workstation table should be height adjustable, and the keyboard, mouse, and monitors should be designed to maximize comfort and efficiency.
  - iv. Dictation tools, internet access, and other reference tools should be readily accessible and easy to use during image interpretation.
- E. Archiving and Retrieval
1. Digital imaging data management systems should 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 the acquisition and transmitting 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 must 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. Prior examinations must be retrievable from archives 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 currently exist for the protection of hardcopy storage media to preserve imaging records.
  5. The exchange of imaging information should be conducted in accordance with the Integrating the Healthcare Enterprise (IHE) initiative through use of current standards developed by DICOM and Health Level Seven (HL7).
- F. Security
- Medical images are subject to U.S. privacy laws such as the Health Insurance Portability and Accountability Act (HIPAA) of 1996 and applicable state privacy requirements. Digital image data management systems should provide network and software security protocols to protect the confidentiality of patients' identification and imaging data as well as appropriate user accessibility and authentication. There should be measures to safeguard the data and to ensure data integrity against intentional or unintentional corruption of the data. For teleradiology purposes the use of additional software and hardware devices such as virtual private networks may be required to maintain patient privacy.

## G. Reliability and Redundancy

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, and a disaster plan.

## V. DOCUMENTATION

Physicians officially interpreting examinations<sup>3</sup> using digital image data management systems should render reports in accordance with the [ACR Practice Guideline for Communication of Diagnostic Imaging Findings](#).

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.

## VI. LICENSING, CREDENTIALING, AND LIABILITY

The interpreting physician is responsible for the quality of the images being reviewed.<sup>4</sup>

Physicians who provide the official interpretation of images transmitted by teleradiology should maintain the licensure required for providing radiologic or telemedicine service at both the transmitting and receiving sites. Physician practicing teleradiology should conduct their practice in a manner consistent with the bylaws, rules, and regulations for patient care at the transmitting site and receiving jurisdiction. 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

<sup>3</sup>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.

<sup>4</sup> 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."

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 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.

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

## VII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, radiologic technologists, and all supervising physicians have a responsibility to minimize radiation dose to individual patients, to staff, and to society as a whole, while maintaining the necessary diagnostic image quality. This concept is known as "as low as reasonably achievable (ALARA)."

Facilities, in consultation with the medical physicist, should have in place and should adhere to policies and procedures, in accordance with ALARA, to vary examination protocols to take into account patient body habitus, such as height and/or weight, body mass index or lateral width. The dose reduction devices that are available on imaging equipment should be active; if not, manual techniques should be used to moderate the exposure while maintaining the necessary diagnostic image quality. Periodically, radiation exposures should be measured and patient radiation doses estimated by a medical physicist in accordance with the appropriate ACR Technical Standard. (ACR Resolution 17, adopted in 2006 – revised in 2009, Resolution 11)

## VIII. 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 Concerns appearing elsewhere in the ACR Practice Guidelines and Technical Standards book.

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. Performance testing and monitoring of official or primary interpretation 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 should be followed.
2. Performance testing and monitoring of computed radiography equipment should be performed in accordance with 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 testing methods and frequencies contained in AAPM Task Group Report No. 10: Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems should be followed.
3. As a minimum quality check for acquisition workstation, small matrix, and secondary display devices, a test image, such as the SMPTE test pattern should be captured, transmitted, archived, retrieved, and displayed at appropriate intervals to test the overall operation of the system under conditions that simulate its normal operation. As a spatial resolution test, at least 2.5 lp/mm resolutions should be confirmed for both small

and large-matrix official interpretation. As a test of the display fidelity, SMPTE pattern data files sized to occupy the full area used to display images on the monitor should be displayed. The overall SMPTE image appearance should be inspected to assure the absence of gross artifacts (e.g., blurring or bleeding of bright display areas into dark areas or aliasing of spatial resolution patterns). All display monitors used for primary interpretation should be tested at least monthly. As a dynamic range test, both the 5% and the 95% areas should be seen as distinct from the respective adjacent 0% and 100% areas.

4. Hardcopy imager accuracy and stability testing should also be performed and documented.
5. The viewbox luminance should be sufficient to meet the diagnostic needs of the imaging procedure and applicable industry standards and/or recommendations, when available.

The use of digital imaging and digital image data management systems does not reduce the responsibilities for the management and supervision of 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

### ACKNOWLEDGEMENTS

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9. CCD (charge-coupled device) - a photoelectric device that converts light information into electronic information. CCDs are commonly used in television cameras and image scanners and consist of an array of sensors that collect and store light as a buildup of electrical charge. The resulting electrical signal can be converted into digital values and processed digitally in a computer to form an image.
  10. CCD scanner - a device that uses a CCD sensor to convert film images into electronic data.
  11. Clock - a component in a computer's processor that supplies an oscillating signal used for timing command execution and information handling.
  12. Clock speed - the rate at which the clock oscillates or cycles. Clock speed is expressed in MHz, equal to 1 million clock cycles per second.
  13. 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.
  14. Consultation system - a teleradiology system used to determine the completeness of examinations, to discuss findings with other physicians, or for other applications with the knowledge that the original images will serve as the basis for the final official interpretation rendered at some later time by the physician responsible for that report.
  15. Co-processor - a device in a computer to which specialized processing operations are delegated, such as mathematical computation or video display. The advantage of a co-processor is that it significantly increases processing speed.
  16. CPU (central processing unit) - the device in a computer that performs the calculations. It executes instructions (the program) and performs operations on data.
  17. CR (computed radiography) - a system that uses a storage phosphor plate contained in a cassette instead of a film-screen cassette. A laser beam scans the exposed plate to produce the digital data that is then converted into an image.
  18. CRT (cathode ray tube) - the monitor or display device in the teleradiology system.
  19. Data carrier - the signal that is used to transmit the data. If this signal is not present, there can be no data communication between modems.
  20. Data communication - all forms of computer information exchange. Data communication may take place between two computers in the same building via a local area network (LAN), across the country via telephone, or elsewhere by a wide-area network (WAN).
  21. 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 or irreversible.

## 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 a specific purpose of providing either short-term or long-term (permanent) storage of images. Erasable or nonerasable media may be utilized in an archive.
3. Baud - the number of events processed in 1 second, usually expressed in bits per second (bps) or kilobits per second (kbps). Typical rates are 14.4 kbps, 28.8 kbps, and 56 kbps.
4. 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.
5. Bit depth - the number of bits used to encode the signal intensity of each pixel of the image.
6. Bits per second - see throughput, baud.
7. Byte - a grouping of 8 bits used to represent a character or value.
8. Carrier - see Data carrier.

22. Data transfer rate - the speed at which information is transferred between devices, such as a scanner and a computer; between components within a device, such as between storage and memory in a computer; or between teleradiology stations.
23. Dedicated line - a telephone line that is reserved for the exclusive use of one customer. It can be used 24 hours a day and usually offers better quality than a standard dial-up telephone line but may not significantly increase the performance of data communication.
24. DICOM (Digital Imaging and Communications in Medicine) - 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.
25. Digital signal - a form of information transmission in which the signal varies in discrete steps, not in a continuous manner.
26. Digitize - the process by which analog (continuous value) information is converted into digital (discrete value) information. This process is a necessary function for computer imaging applications because visual information is inherently in analog format and most computers use only digital information.
27. Direct image capture – known as digital radiology (DR), the capture or acquisition of digital image data that has 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.
28. Diskette drive - the device on a computer that can read and write to diskettes. It is used to import and export data.
29. dpi (dots per inch) - while in conventional radiography resolution is commonly expressed in line pairs per millimeter (lp/mm), film digitizer resolution is commonly expressed as dots (pixels) per inch.
30. Dynamic range - the difference in signal intensity, or frequency, between the largest and smallest signals a system can process or display. The optical density is the difference between the lightest and darkest useful regions of the image. Increasing the number of bits per pixel in a digital image increases the dynamic range of the image.
31. File - a set of digital data that have a common purpose, such as an image, a program, or a database.
32. Floppy diskette - a data storage device made of metal-coated plastic that can store computer information and can be physically transported from one place to another. The storage capacity of floppy diskettes is usually in the range of 360 K to 1.5 MB, which is too small to be of use in imaging applications.
33. G (giga) - stands for the number 1 billion. It is used primarily when referring to computer storage capacities; for example, 1 GB = 1 billion bytes or 1,000 megabytes.
34. 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.
35. Grayscale monitor - a black-to-white display with varying shades of gray, ranging from several shades to thousands, thus being suitable for use in imaging. This type of monitor also may be referred to as a monochrome display. (See also monochrome monitor)
36. Hard disk drive - an internal computer device used for storage of data.
37. Hardware - a collective term used to describe the physical components that form a computer. The monitor, CPU, disk drives, memory, modem, and other components are all considered hardware. If you can touch it, it is hardware.
38. HIS (hospital information system) - an integrated computer-based system to store and retrieve patient information, including laboratory and radiology reports.
39. IDE (integrated device electronics) - a type of interface used for hard disk drives that integrates the control electronics for the interface on the drive itself. Its purpose is to increase the speed at which information can be transferred between the hard disk and the rest of the computer.
40. IMACS - Image Management and Communication System.
41. Image - a computer's digital representation of a physical object.
42. Image compression - reduction of the amount of data required to represent an image. Encoding the spatial and contrast information more efficiently or discarding some non-essential information or both accomplishes this.
43. Interface - the connection between two computers or parts of computers. It consists mainly of electronic circuitry.
44. Irreversible compression - some permanent alteration of digital image data. This is sometimes referred to as lossy.
45. ISDN (integrated services digital network) - a switched network with end-to-end digital connection enabling copper wiring to perform functions such as high-speed transmission, which frequently requires higher capacity fiberoptic cable.
46. K (kilo) - stands for the number 1,000. It is used primarily when referring to computer storage and

- memory capacities: for example, 1 kbps = 1,024 bytes.
47. LAN (local area network) - computers in a limited area linked by cables that allow the exchange of data.
  48. Laser film scanner - a device that uses a laser beam to convert an image on X-ray into digital image data.
  49. Leased line - same as a dedicated line.
  50. Lossless - see reversible compression.
  51. Lossy - see irreversible compression.
  52. M (mega) - stands for the number 1 million. It is used primarily when referring to computer storage and memory capacities: for example, 1 MB = 1 million bytes. 1 MB = 1,024 thousand bytes or 1,000 kbytes.
  53. Matrix size: Small - defined as images from CT, MR, ultrasound, nuclear medicine, and digital fluorography. Large - defined as images from digital radiography and digitized radiographic films.
  54. Memory - electronic circuitry within a computer that stores information.
  55. Modem - a device that converts digital signals from a computer to pulse tone signals for transmission over telephone lines.
  56. Monochrome monitor - a computer display in which an image is presented as different shades of gray from black to white. (see also gray-scale monitor).
  57. Mouse - an input device that allows the computer user to point to objects on the screen and execute commands.
  58. Operating system - software that allocates and manages the resources available within a computer system. UNIX, MS-DOS, Macintosh, and Windows are examples of operating systems.
  59. Optical disk - a computer data storage disk used primarily for large amounts (GB) of data.
  60. PACS - Picture Archiving and Communication System.
  61. Peripheral - a device that is connected to a computer and performs a function. Scanners, mouse pointers, printers, keyboards, and monitors are examples of peripherals.
  62. Phosphor - the coating on the inside of a CRT or monitor that produces light when it is struck by an electron beam.
  63. 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.
  64. Protocol - a set of guidelines by which two different computer devices communicate with each other.
  65. 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.
  66. 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.
  67. Reversible compression - no alteration of original image information upon reconstruction. This is sometimes referred to as lossless.
  68. RIS - radiology information system.
  69. Roam and zoom - the ability to select and magnify a region in the display.
  70. ROM (read-only memory) - a permanent memory which is an integral part of the computer. Programs and information stored in ROM are not lost when the power is removed.
  71. SCSI (small computer systems interface) - SCSI is an interface protocol that is used to link dissimilar computer devices so that they can exchange data. SCSI interfaces are most common in image scanners and mass storage devices. This type of interface is well suited for imaging applications.
  72. Secondary image capture - the capture in digital format of image data that originally existed in another primary format (e.g., a digital image data file on a CT scanner, or a screen-film radiographic film) through the process of video capture or film digitization.
  73. SMPTE - the Society of Motion Picture and Television Engineers.
  74. Software - a name given to the programs or sets of programs that are executed on a computer.
  75. Tera (T) - stands for approximately 1 trillion ( $10^{12}$ ). It is used primarily when referring to archive storage capabilities; for example, 1 TB=1 trillion bytes, 1 million MB, or 1,000 GB.
  76. Throughput - a measure of the amount of data that is actually being communicated, expressed in bits per second. It is related to the baud rate, but is usually somewhat less in value due to non-ideal circumstances. Typically, modems with higher baud rates can attain a higher throughput.
  77. Video capture - the process by which images are digitized directly from the video display console of a modality, such as CT, MRI, or ultrasound. The video signal is converted to a digital signal. This process is more efficient and produces better quality images than scanning films that are produced by the same equipment.
  78. Voxel (volume element derived from pixel) - a voxel is a three-dimensional version of a pixel. Voxels are generated by computer-based imaging systems, such as CT and MRI. Using voxels, imaging systems can be reconstructed with three-dimensional simulations of objects.
  79. WAN (wide-area network) - a communication system that extends over large distances (covering more than

a metropolitan area), often employing multiple communication link technologies such as copper wire, coaxial cable, and fiberoptic links. The cost of these WANs is presently dominated by transmission costs.

80. WORM (write once, read many times) - a peripheral memory device that stores information permanently.

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