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ACR–AAPM–SIIM–SPR PRACTICE PARAMETER FOR DIGITAL RADIOGRAPHY

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 care¹. 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.

KEY POINTS

The intent of this document is to provide guidance and assistance in the understanding and clinical use of digital radiography equipment (other than mammography) in order to deliver necessary image quality at an appropriate radiation dose and to ultimately provide excellent safety and care for patients undergoing digital radiography examinations. An introduction to the realm of digital radiography, including definitions, is presented in section I. As new capabilities and complexities arise with digital imaging devices, the qualifications and responsibilities of personnel—including the physician, medical physicist, radiologist assistant, radiologic technologist, and image management specialist—are affected as outlined in section II.

I. INTRODUCTION AND DEFINITION

This practice parameter was developed collaboratively by the American College of Radiology (ACR), the American Association of Physicists in Medicine (AAPM), the Society for Imaging Informatics in Medicine (SIIM), and the Society for Pediatric Radiology (SPR).

This practice parameter is applicable to the practice of digital radiography. It defines qualifications of personnel, equipment guidelines, data manipulation, data management, quality control (QC), and quality improvement procedures for the use of digital radiography that should result in optimal radiological patient care. A glossary of relevant digital terms used in this document is located in Appendix A.

Medical imaging and patient information are 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 and outcomes.

For the purpose of this document, the practice of digital radiography refers to projection X-ray imaging that uses a digital X-ray detector to capture the X-ray image. Digital X-ray detectors are typically classified as either computed radiography (CR) or digital radiography (DR). CR uses a photostimulable storage phosphor that stores a latent image, which is subsequently read out using a stimulating laser beam. DR is used to describe any X-ray detector that electronically reads out an X-ray signal immediately after exposure. Despite the fact that DR has been used for a specific acquisition technology, both CR and DR refer to digital detection methods, and both should be considered as part of this practice parameter.

“CR” and “DR” are the commonly used terms for digital radiography detectors. CR is the acronym for computed radiography, and DR is an acronym for digital radiography. CR uses a photostimulable storage phosphor that stores the latent image, which is subsequently read out using a stimulating laser beam. It can be easily adapted to a cassette-based system analogous to that used in screen-film (SF) radiography. Historically, the acronym DR has been used to describe a flat-panel digital X-ray imaging system that reads the transmitted X-ray signal immediately after exposure with the detector in place. Generically, the term CR is applied to passive detector systems, while the term DR is applied to active detectors.

This practice parameter is applicable to the practice of digital radiography. It defines motivations, qualifications of personnel, equipment guidelines, data manipulation and management, and quality control (QC) and quality improvement procedures for the use of digital radiography that should result in high-quality radiological patient care.

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.

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

Individuals performing digital radiography procedures must be appropriately trained in the proper use of the imaging equipment and must have the appropriate level of knowledge necessary to obtain optimal information for

each requested procedure. In all cases, the operator should be a physician, a radiologist assistant, a licensed and/or registered radiologic technologist, or a radiation therapist. The radiologist assistant, technologist, or radiation therapist must be operating under the direct supervision of a qualified licensed physician.

A. Physician

See the [ACR–SPR Practice Parameter for General Radiography](#) [1]. Additional specific qualifications and responsibilities include:

1. Physicians using digital radiography should understand the basic technology of image acquisition, transmission, manipulation, processing, archiving, retrieval, and display, including the strengths, weaknesses, and limitations of different methods. They should be knowledgeable in how to optimally utilize 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 QC of digital image management systems².
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 imaging chain from acquisition to display that affect image quality and that have the potential for producing artifacts, and/or changes in image quality.

B. Qualified Medical Physicist

A Qualified Medical Physicist must be on site or available as a consultant. See the [ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Radiographic Equipment](#) [2].

C. Registered Radiologist Assistant

See the [ACR–SPR Practice Parameter for General Radiography](#) [1].

D. Radiologic Technologist, and Radiation Oncology Therapist

The radiologic technologist or radiation oncology therapist must be certified by the appropriate registry and/or possess unrestricted state licensure.

See the [ACR–SPR Practice Parameter for General Radiography](#) [1]. 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.

²The 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.”

- d. Image evaluation
- e. Radiation dose indicators
- f. Patient safety procedures

E. Imaging Informatics Professional

See the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) [4]. The Imaging Informatics Professional 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.

The responsibilities and experience for an imaging informatics professional include:

Maintenance of the network for all informatics systems, eg, Radiology Information System (RIS), Picture Archiving and Communication System (PACS), speech recognition systems, and computer servers and desktops.

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 should provide image quality and availability appropriate to the clinical needs.

A. Image Availability and Information Standardization

To ensure the enterprise-wide availability of features and performance when purchasing digital radiographic and connected equipment, consideration of the manufacturers' statements of conformance with the current ACR–National Electrical Manufacturers Association Digital Imaging and Communications in Medicine (DICOM) standard is strongly recommended. Also, consideration of periodic upgrades incorporating the expanding features of that standard should be part of the ongoing QC program. Compliance with the Radiological Society of North America and Healthcare Information and Management Systems Society (HIMSS) Integrating the Healthcare Enterprise (IHE) Initiative, as embodied in the available technical frameworks, is also strongly recommended for all new equipment acquisitions.

Specifications and usage guidelines related to standards and interoperability include:

1. Digital radiographic devices must provide images that conform to the DICOM standard “CR” or “DX” service class objects. These objects' header fields specify 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 body part orientation (eg, right, left, superior, inferior), amount and method of data compression, and total number of images acquired in the study.
2. The use of DICOM modality work lists is recommended to help ensure the quality and accuracy of the information captured in the DICOM header.
3. The use of the DICOM “DX” service class object is recommended instead of the more limited “CR” object for digital radiography [5].
4. It is recommended to use DICOM grayscale soft-copy presentation state (GSPS) objects to transmit annotations, shutter, and display lookup tables (LUTs) [6]. Where GSPS is not available or not supported by a picture archiving and communication system (PACS), the use of a values-of-interest lookup table (VOI-LUT) within the “CR” or “DX” service class object is suggested.
5. Details related to image acquisition, such as tube potential (kV), tube current (mA), exposure time, beam filtration, source image distance, the International Electrotechnical Commission (IEC) 62494-1 detector exposure indicator (EI), target exposure index (EI_T), deviation index (DI), and organ-specific

postprocessing algorithm employed, should be recorded in the DICOM header. These elements should be exportable using the DICOM Structured Report.

B. Acquisition

Image acquisition should be performed in accordance with the [ACR–SPR Practice Parameter for General Radiography](#) or examination-specific ACR practice parameters and technical standards [1].

1. Use of antiscatter grids

Scattered radiation reduces contrast in radiography, limiting the available dynamic range of X-ray intensities at the beam exit side of the patient.

- a. Scanned slot DR detectors possess inherent scatter rejection capability and do not require the use of a grid.
- b. Area detectors employed in digital radiography should be used with an antiscatter grid in clinical imaging situations with increased scatter component. Grids are not required when imaging soft-tissue-equivalent thickness less than 12 cm. Grid uses for specific radiographic examinations are discussed in examination-specific ACR practice parameters and technical standards and relevant scientific literature [7]. Use of software scatter correction, especially in pediatric patients, is encouraged.
- c. When using stationary grids, consider the use of a high-strip-frequency grid of more than 60 lines/cm to avoid grid aliasing patterns caused by insufficient sampling. Consultation with a Qualified Medical Physicist or the vendor regarding an appropriate grid is recommended.
- d. When using anti-scatter grids with digital detectors, an increase in exposure tube current and/or time (mAs) is necessary only to compensate for attenuation of primary radiation by the grid.

2. Detector exposure indicators for digital radiography

Considering the wide exposure latitude of digital radiographic devices, the visual appearance of brightness and contrast in radiographic images is a poor indicator of the appropriateness of the exposure delivered to the image receptor. Digital radiographic devices can create satisfactory images over a wide range of input exposures, including exposures that are significantly greater than are clinically necessary. For images acquired with higher than desired detector exposure, the patient unnecessarily receives excessive radiation dose. Images acquired at lower than required exposures may have unacceptably high noise levels. For these reasons, digital radiography system manufacturers should incorporate IEC standards on EI, EI_T, and DI (also supported by the AAPM Task Group 116 report) [8]. The EI reflects a proportional estimate of the incident air kerma at the detector, the EI_T is the examination-specific target exposure index value, and the DI is a calculated value to quantify how far the given EI is from the EI_T specific to the radiographic examination. This can provide feedback to technologists on the appropriateness of a chosen imaging technique or to a practice in determining its standard techniques. A parameter related to incident radiation dose such as Air-Kerma Area Product may be provided.

Currently, most digital radiography manufacturers provide a proprietary exposure indicator that is displayed alongside the image on the acquisition workstation, providing feedback to the technologist about the acquisition technique. This information should also be transmitted to the PACS in the DICOM header of the image. Generally, display of the acquisition technique factors has been of great benefit to the clinical imaging team in optimizing technique factors eventually to the benefit of the patient population. Image review stations should be configurable to display EI, EI_T and DI.

The various exposure indicators currently used by digital radiography manufacturers are not easily comparable. Incorporation of a single standard such as the IEC 62494-1 measures of EI, EI_T, and DI for various radiographic studies will help implement a uniform feedback mechanism for technologists, radiologists, and Qualified Medical Physicists across all platforms from various manufacturers of X-ray projection radiography systems. This will allow standardized communication, comparison across systems, and systems improvement.

The International Electro-technical Commission (IEC) released an international standard for the exposure index of digital X-ray imaging systems [9] that is consistent with AAPM Report 116 [8]. Presently, new DR systems and upgraded software versions for existing equipment are incorporating the IEC standard. In addition to the traditional exposure index, a deviation index is reported that describes how the exposure index deviates from a target value. Users should review the target values for all views of all body parts that the system will be used to image. Target values should be selected to minimize the exposure to the patient while providing diagnostic images (ie, with sufficiently low noise) for interpretation

3. Exposure creep

In digital radiography, excessive exposure to the detector can produce high-quality images with improved noise properties. Unless there is an understanding that these higher quality images come at the cost of increased patient exposure and strategies are in place to control patient exposure, a radiologic practice may experience “exposure creep” [10]. Exposure creep results when there is negative radiologist feedback for high-noise images made with low exposures but a lack of negative feedback or even positive feedback for low-noise images made with high exposures. As technologists respond to this feedback, patient exposures may gradually increase over time. The Qualified Medical Physicist should help implement a program to monitor exposure creep on a consistent, ongoing basis. Use of modern radiation dose–monitoring software platforms may help in monitoring the radiation dose distribution for various examinations and various age groups.

A method to prevent exposure creep is to develop validated radiographic techniques as a function of patient size for all performed examinations. Technique charts should encourage the use of appropriate automatic exposure control (AEC) settings (single cell versus a combination of multiple AEC cells) for most of the body radiographic examinations. The AEC system is designed to deliver calibrated and reproducible doses to the image receptor across a wide range of operating conditions, including X-ray beam quality and patient size. Often these factors are entered into the anatomical programming of X-ray generator controls. If the technologist uses these programs, the facility is very likely to use appropriate radiographic technique factors with the appropriate level of radiation exposure. Consistent and optimal AEC performance is critical to radiation dose management and image quality. Qualified Medical Physicists should perform appropriate tests to ensure the expected performance of AEC modules [11].

4. Radiographic technique considerations for digital radiography

a. Determining proper technique charts for standard examinations

Exposure (technique) charts are part of the standard of care expected by the Joint Commission and are required by law in many states. It is necessary to check state and/or local regulations for any specific requirements. Computation of estimates for entrance skin exposures for these charts may also be required.

Because of the wide latitude of digital image receptors and the availability of image processing to alter the brightness and contrast of images, the visual appearance of images can be made similar over a wide range of acquisition techniques. The primary effects of modifying an acquisition technique are changes in:

- i. The level of noise in the image
- ii. The exposure duration and potential for patient motion artifacts
- iii. Patient radiation exposure
- iv. Potential artifacts (in DR) related to detector saturation and image lag

Baseline or initial exposure technique charts are typically provided by equipment manufacturers, either as prescriptions for manual radiographic technique or programmed examination-specific options in the X-ray generator.

Exposure technique charts must be tailored for each digital radiography X-ray generation detector and processing combination as well as patient population and size [12]. There is considerable variability in image receptor response owing to varying scatter sensitivity, the use of grids with different grid ratios, collimation, beam filtration, the choice of kilovoltage, source-to-image distance, and image receptor size.

In addition, exposure charts should be designed to function over a wide range of adult and pediatric patient sizes [11]. This task of building optimized technique charts is a team effort involving the technologist, radiologist, administrative leadership, and the Qualified Medical Physicist, and is a continuous process requiring collaborative efforts of each member of the team [13].

b. Automatic exposure control

AEC systems are designed to turn off the X-ray generator when the desired dose has been received at the image receptor. This dose may vary as a function of X-ray beam energy, with the presence or absence of an anti-scatter grid, or with the sensitivity (often misstated as “speed”) setting of the AEC. AEC works well when the AEC system is properly calibrated and the body part being imaged is centered over the active AEC region(s). AEC may fail to deliver the desired receptor dose if the desired anatomy is not centered over the active region(s), if the incorrect region(s) is selected, or if an object within the active region(s) of the AEC system is of a markedly different density than tissue (eg, a prosthesis in the hip of a patient or gonadal shielding) [12,14]. If the AEC system is covered by such an object (eg, gonadal shielding), the backup timer should terminate the exposure prior to the regulatory maximum mAs being delivered [15].

c. Assessing appropriateness exposure

As described in section III.B.2, the DI should be reviewed for each clinical exposure and compared to the desired range for the specific body part and view acquired. These ranges can be used to develop radiographic technique charts or to monitor for dose creep in a practice. For absolute DI values to be clinically meaningful, the target exposure indicator (EI_T) must be set appropriately. In typical clinical practice, wide distributions of the DI are observed. It is important that each practice review DI data to establish recommended limits and targets for quality improvement (QI). Clinical radiographs can be acceptable across a wide range of receptor doses, and a DI value that is extreme should not be cause for immediately repeating an image without careful review and a potential consult with a radiologist. Extreme DI values should be logged for review at periodic QI committee meetings.

d. Pediatric imaging considerations

As with all imaging examinations involving ionizing radiation, digital radiography should be performed using the lowest radiation exposure to the patient that is consistent with image quality requirements. This is especially important when imaging pediatric patients, who are more sensitive to ionizing radiation than adults [14,18]. However, reducing exposure without assessing image quality increases the possibility of unacceptably high quantum noise. Also, the appropriate reduction in exposure to the image receptor depends on how well the digital system is optimized for pediatric imaging, and on the nature of the particular condition being diagnosed [19].

Commitment and effort on the part of the technologist to achieve exposure reduction in pediatric imaging consistently is of paramount importance. Optimization issues in pediatric imaging and relevant topics are addressed in more detail elsewhere [17].

Pediatric patients present unique challenges when imaged with digital radiography. Patients range in size from the neonate to the young adult, requiring a wide range of radiographic technique factors. Spatial resolution demands are higher in pediatric imaging owing to the smaller body parts. Clinical use of AEC with children offers additional challenges since the pediatric organs being

small may result in partial coverage of AEC cells, resulting in artificially shortening of the radiographic exposure.

Judicious consideration of gonadal shielding is warranted, providing shielding does not compromise clinical objectives of the study. The ICRP tissue-weighting factor for gonads has substantially decreased, from 0.25 in Publication 26 in 1977 to 0.20 in Publication 60 in 1990 and most recently to 0.08 in Publication 103 in 2007. Gonadal shields cannot protect against internal scatter, may be positioned incorrectly, may obscure the area of interest, and, if they cover the AEC chamber(s), may increase radiation exposure. The decision to use an antiscatter grid must be carefully considered as a function of patient size. If a grid is employed, use of a source-to-image distance consistent with grid focus is recommended to optimize image quality and dose [20,21]. Use of additional filtration, such as 0.1-mm copper or more, is recommended to reduce entrance skin air kerma at the patient surface for pediatric patients. The use of additional filtration may require optimizing the image processing parameters to account for a different x-ray energy spectrum incident upon the image receptor. A clinical team composed of a diagnostic Qualified Medical Physicist, an application specialist from the equipment manufacturer, an experienced technologist, and a radiologist will help achieve this objective in an efficient fashion.

Standard positioning aids used to immobilize pediatric patients may generate unacceptable artifacts when used with digital image receptors. Because the X-ray pattern resulting from a pediatric chest has a different dynamic range and other characteristics [18] compared with an adult chest, image processing and display parameters used by the digital acquisition device to properly display the digital image may need to be configured as a function of patient size. Image processing and display parameters may require further alteration if gonadal shielding or orthopedic implants appear in the displayed image. Finally, because scoliosis examinations are common in children, the digital image receptor must provide an efficient method to generate images up to 36 inches in length without doubly exposing some sections of the patient's anatomy. Use of newer technology, such as slot scan units for orthopedic imaging, may further reduce dose associated with these examinations. Additional information regarding pediatric imaging best practices can be found at the Image Gently website: www.imagegently.org.

C. Image Processing

For digital imaging, image processing can be divided into 2 parts.

Preprocessing is performed on the raw output of the digital detector and accounts for various performance and engineering deficiencies of the image receptor.

Postprocessing is used to optimize the contrast, sharpness, and latitude of the image to be displayed at the radiologist review work station [22].

1. Preprocessing

The image receptor on most digital radiography systems stores an electronic charge that is monotonically related to the amount of radiation energy absorbed. At this stage, the signal (charge) is a linear function of the incident radiation exposure. Preamplifiers and an analog-to-digital converter transform the charge from each detector element to an integer representing the raw data image value. The detector output with no processing applied is referred to as a raw image. This image is typically not accessible to physicists. Several corrections are applied to the raw image values to obtain values suitable for image processing. These corrections include interpolating account for bad pixels, and to adjusting adjustments for nonuniformity of response of the image receptor in the form of gain correction, and offset corrections to account for dark signal.

DR system users should ask the supplier for information indicating the number and type of bad pixels that are being corrected. QC programs should include a process to report any new bad pixels that may develop during the lifetime of the system. Nonuniformity corrections generally require running a system utility program periodically, during which uniform exposures are acquired. Users should identify the required procedure for each type of system being used and ensure that the procedures are being followed. Some manufacturers require calibration to be performed by the technologist, whereas for others it is the service engineer's responsibility [23,24]. The calibration process establishes a relationship between the pixel values and the deposited X-ray energy. Depending on the equipment manufacturer, this relationship may be linear or logarithmic. The type of calibration, number of calibration exposures, and bit depth available varies between different vendors. The output of preprocessing a raw image is an image referred to as *For Processing* or *Original* image [8]. This image should be available to the Qualified Medical Physicist for quantitative image quality assessment.

For Processing images

Most DR systems transform the preprocessed value to a value proportional to the logarithm of the input exposure. Logarithmic signals have the property that a fractional change in signal, due to the contrast of adjacent structures, produces a fixed change in the raw image value independent of subject penetration and input exposure. These values are the *For Processing* images values and may be stored in DICOM image objects. The AAPM further recommends specific units for normalized *For Processing* image values [8].

In some operations, users may archive *For Processing* images so that they may be processed at a later date. For example, when reading a current digital mammography image it may be desirable for a prior mammogram to be processed using the same method. Another use case involves CAD systems that require *For Processing* images.

2. Postprocessing DR image processing operations

a. Histogram analysis

The objective of histogram analysis is to determine the span of original image pixel values that correspond to anatomical image information. The histogram shapes vary significantly depending upon the anatomy under consideration. An important aspect of histogram analysis is the identification and segmentation of the background and collimated regions, which have no anatomical information. These useful pixel values are passed on to the postprocessing algorithm for contrast and edge enhancement. The IEC exposure index is based on measures of the clinically relevant histogram in the original image.

b. Contrast and frequency enhancement

Image processing operations are performed on *For Processing/Original* images to obtain *For Presentation* images suitable for interpretation. Suppliers of digital imaging equipment may provide image processing software that can restore the sharpness of edges, enhance detail contrast for images with a wide range of input exposures, and reduce noise [25]. Detail contrast can be enhanced by multifrequency processing that equalizes image brightness over broad areas by operating on low spatial frequencies.

The parameters used to process images need to be specifically determined for all body parts and views that will be encountered. This also may vary with radiologist preference. Consequently, close cooperation between the equipment manufacturer's installation engineer, application specialist, site technologist, radiologist, administrator, and the Qualified Medical Physicist is critical to optimization of the image postprocessing process for various examinations in an efficient fashion.

As a part of the operations that transform *For Processing* images to *For Presentation* images, the image values in the anatomical regions of interest, referred to as the values of interest (VOI), are identified and used to compute a look-up table (LUT) used to display the *For Presentation* values. Earlier systems applied the VOI-LUT in the DR systems and sent these image values within the

DICOM object. As described in section A above, it is preferable that the VOI-LUT be sent and that the image display software transform the values at the workstation. This allows the user at the workstation to make further adjustment in the grayscale of the image. The VOI are also used to calculate the EI and DI associated that are used as indicators of proper radiographic technique (see section B.2). The edges of the collimated regions of the image should be recognized by the system and the regions outside of the collimators masked to prevent presentation of large bright regions to the radiologist, and to ensure accurate computation of the EI. It is preferable that this mask be encoded in the DICOM image as an overlay so that if needed it can be removed to see information that might be near the collimated edge, such as a marker.

3. Electronic Collimation

Electronic collimation is used to electronically mask areas of the digital image prior to being sent for interpretation or archiving. Although there is controversy regarding the use of electronic collimation, there are situations in which it is necessary and appropriate.

Depending upon the image histogram, the segmentation of the collimated or background regions may not be accomplished properly by the automated algorithm. In such circumstances the technologist may need to electronically collimate to exclude these areas to improve the grayscale rendering and reduce possible veiling glare from areas that appear very bright. It is desirable to visualize the penumbra of the physical collimators to verify appropriate X-ray beam collimation. This is visualized by a thin, bright band around the image [26]. This millimeter-wide white margin around the image appears bright on the radiographic image because no X-rays hit the detector beyond the edges of the collimated beam.

Electronic collimation can be used for inappropriate purposes, such as to hide poor X-ray beam limitation (eg, using too large a field-of-view for a given protocol). Such uses are contrary to good radiation safety practices and pose ethical challenges. Electronic collimation should never be used to mask areas of the image having anatomical information.

D. Image Data Integrity and Transmission

1. Compression

Data compression may be performed to facilitate image transmission and storage. The type of medical image, the modality, and the objective of the study will determine the degree of acceptable compression. For more information on image compression, see the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) [4].

2. Data transmission

The environment in which imaging studies are to be transmitted will determine the types and specifications of the transmission devices used. In all cases, for official interpretation, the digital data received at the end of any transmission must have minimal loss of clinically significant information. The transmission system must also have adequate error-checking capability.

Additional consideration should be given for devices that rely on wireless networking capabilities. Such systems are increasingly common in digital radiography, especially those used for bedside radiography.

The wireless transmission of information may be between the digital detector and the acquisition workstation (ie, wireless DR detectors) or between the acquisition workstation and the institutional PACS (ie, bedside imaging) or both. Provisions should be made for:

- a. The prevention of signal interference and corruption between different systems communicating on the same wireless network
- b. Appropriate signal encryption to protect patient health information (PHI)

- c. A strategy for loss-prevention and image recovery for images that have interrupted transmission or corrupted transmission, especially for the communication between the detector and acquisition workstation, which is less likely to use a DICOM standard transaction with storage-commitment functionality.
- d. A strategy to protect PHI if mobile viewing devices are lost (eg, remote data wipe)

For further details refer to the [ACR–AAPM–SIIM Practice Parameter for Electronic Medical Information Privacy and Security](#) and the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) [4,27].

3. Security

See the [ACR–AAPM–SIIM Practice Parameter for Electronic Medical Information Privacy and Security](#) [27].

4. Archiving and retrieval, reliability and redundancy, and work and room environmental and ergonomic considerations

See the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) [4].

5. Display capabilities

The consistent presentation of images across different workstation display monitors is essential for a quality imaging practice. Image quality is influenced by workstation software, graphic controllers, and display devices, which vary substantially across a range of parameters and display characteristics as described in the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) [4]. The preferred method to achieve similar display characteristics and consistent image appearance is to implement the DICOM Part 14 Grayscale Standard Display Function (GSDF) [28] calibration procedure for all image display monitors in order to preserve the perceptual variations in pixel values of an image as perceived by a human viewer, even when viewing monitors with different luminance values. Although GSDF calibration is typically a standard practice for primary diagnosis display monitors on medical-grade PACS workstations, manufacturers of radiography devices and technologist quality control imaging workstations should also provide calibration procedures and demonstration of quantitative conformance to the DICOM GSDF as part of acceptance testing and periodic quality control procedures for their displays. At a minimum, third-party GSDF calibration software should be made available and implemented for all radiography display devices and QC workstations.

Images are viewed by technologists during acquisition, by radiologists during interpretation, and by referring physicians as a part of patient care and should have a similar appearance for all viewers. The following uses emphasize the importance of choosing appropriate display equipment and settings, as well as the importance of regular calibration and maintenance as part of a QC program.

- a. Image modifications are most often made by the technologist at the acquisition workstation. Technologists may modify image processing to try to match the appearance desired by radiologists. If the acquisition display does not meet the specifications for consistent presentation of images (as described in the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) [4]) or is not calibrated or maintained properly, this image modification process is particularly challenging.
- b. A primary method for a radiology technologist to discern whether a low-exposure image acquisition needs to be repeated is by comparison of the noise levels in the image with the desired diagnostic appearance. Visualizing image noise may be difficult on poor performing displays. Noise evaluation can be accomplished visually using the TG 18-AFC test pattern and following the methods described in the AAPM Task Group Report 18 document [29].
- c. Owing to the nature of use of point-of-care digital radiographic devices (ie, DR mobile X-ray systems), they are often used for primary diagnostic tasks. Digital Given that digital images are available for immediate review, it is not uncommon for digital radiographic devices to be used at

the point of care, such as in mobile imaging. If images are to be interpreted at the device rather than on a diagnostic interpretation workstation, digital radiography manufacturers should provide high interpretation-quality display options as outlined in the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) for displays on these devices which diagnostic or primary interpretation tasks might be performed or one which images are modified [4].

- d. If the technologists are using QC stations for post-acquisition image analysis prior to sending the images to PACS, then appropriate display monitors should be provided at the technologist QC station. Ideally these monitors should satisfy the minimum specifications as outlined in the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) [4].

Guidelines for viewing digital radiography images can be found in the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) and for mammography in the [ACR–AAPM–SIIM Practice Parameter for Determinants of Image Quality in Digital Mammography](#) [4,30].

IV. DOCUMENTATION

Physicians officially interpreting examinations³ using digital image data management systems should render reports in accordance with the [ACR Practice Parameter for Communication of Diagnostic Imaging Findings](#) [31].

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

V. 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

³The 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.

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).

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

Policies and procedures related to quality control and improvement, 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 Education* 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 QC program should be designed to maximize the quality and accessibility of diagnostic information.

Equipment performance monitoring should be in accordance with the [ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Radiographic Equipment](#) [2].

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Development Chronology for this Practice Parameter

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 Amended 2009 (Resolution 11)
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Glossary

For additional definitions, see the [ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging](#) [4].

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. Bit (binary bit) - 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.
3. Bit depth - the number of bits used to encode the signal intensity of each pixel of the image
4. Charge-coupled device (CCD) - 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 in a computer to form an image.
5. Digital signal - a form of information transmission in which the signal varies in discrete steps, not in a continuous manner
6. Exposure class - similar to the term “speed” used with SF systems. Exposure class is used to describe the nominal radiation exposure required to obtain a proper radiograph. The new term is used instead of speed to reflect the significantly different energy response that digital detectors have when compared to SF systems.
7. Exposure indicators - a quantitative method to estimate the nominal *incident* radiation exposure required to obtain a proper radiograph. This is a manufacturer-dependent value. Fuji CR uses the *sensitivity number (S number)*, a value that is similar to SF speed and inversely related to incident exposure. Agfa CR uses *IgM*, the log of the median exposure determined from the segmented area on the imaging plate, which increases logarithmically with the incident exposure. Kodak CR uses *exposure index*, a value that represents the relative measure of the X-ray exposure in the segmented, anatomical regions of the image and increases logarithmically with the digital values in the image. Konica CR uses *S value*, a value similar to the *S number* with similar relationships to incident exposure, but estimated and calculated in a different manner compared with Fuji. Imaging Dynamics (a DR company) uses *f-number*, a relative value based upon the same concept as photography in describing relative light intensity ranges, where in this situation, negative values represent lower exposures and positive values represent higher exposures than the desired “nominal” exposure. Other manufacturers have their own unique exposure value estimates. Users of a particular digital system must understand the meaning of the incident exposure index in order to determine that the exposure was appropriate. The manner in which the vendor identifies the parts of the image that have received direct X-ray exposure or are collimated has an effect on the calculated exposure index and may lead to errors.
8. Exposure latitude - the range between the minimum and maximum exposures that will produce an acceptable range of densities for diagnostic purposes. Furthermore, it is considered the “margin for error in setting a proper technique.” Exposure latitude is distinguished from the term “latitude” which is defined similarly as “the range of X-ray exposures that deliver ODs in the usable range.” Thus, for the same screen-film detector, the exposure latitude is necessarily a smaller ratio than the latitude, because the exposure latitude takes into account the full extent of X-ray exposures and corresponding densities within the range. Similarities in these 2 terms lead to errors in communication between technologists, medical physicists, and radiologists.
9. Fill-factor - the ratio of the active charge collection area to the total physical space occupied by the detector element. Digital flat-panel detectors with better resolution (smaller del dimension) often have a lower fill-factor and poorer charge collection efficiency.
10. Lookup table (LUT) - a table used to map image index numbers to output display values on a digital device

11. Speed class - the concept of conventional screen-film speed (eg, 100, 200, 400, 600, 800) applied to the incident exposure that a digital radiography device operates to produce an image of “acceptable” clinical image quality. The speed class for a digital radiography device depends on the device itself (how efficiently X-rays are absorbed and converted into a useful signal), the system gain adjustment (how much amplification is applied to the signals prior to digitization), and the examination requirements (how much exposure is required to achieve appropriate image quality; eg, extremity radiographs are typically acquired with a 100 speed class setting, whereas chest x-rays are typically acquired with a 200 to 400 speed class setting). Operation of a system at a higher speed class requires less exposure to the patient but produces higher quantum mottle (noise) and lower SNR in the image. (Also see “exposure indicators”)