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COMPUTED RADIOGRAPHY (CR) AND DIGITAL RADIOGRAPHY (DR) STATE X-RAY INSPECTION PROTOCOL

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**COMPUTED RADIOGRAPHY (CR)
AND
DIGITAL RADIOGRAPHY (DR)
STATE X-RAY INSPECTION PROTOCOL**

Prepared by
**CRCPD's H-33 Task Force for the Inspection Protocol
of Diagnostic X-Ray Facilities
Using CR/DR Technology**

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FOREWORD

The Conference of Radiation Control Program Directors, Inc. (CRCPD) is an organization made up of the radiation control programs in each of the 50 states, the District of Columbia, and Puerto Rico, and of individuals, regardless of employer affiliation, with an interest in radiation protection. The primary purpose and goal of CRCPD is to assist its members in their efforts to protect the public, radiation worker, and patient from unnecessary radiation exposure. CRCPD also provides a forum for centralized communication on radiation protection matters between the states and the federal government, and between the individual states.

One method of providing assistance to the states, as well as to other interested parties, is through technical and administrative publications. Most technical publications of CRCPD are written by various committees, task forces or special working groups. Most administrative publications are written by staff of the Office of Executive Director (OED).

CRCPD's mission is "to promote consistency in addressing and resolving radiation protection issues, to encourage high standards of quality in radiation protection programs, and to provide leadership in radiation safety and education."

This particular publication, *Computed Radiography and Digital Radiography State X-Ray Inspection Protocol*, contains survey procedures developed by CRCPD's H-33 Task Force for the Inspection Protocol of Diagnostic X-ray Facilities Using CR/DR Technology. The intention is to provide guidance for state inspectors to test phototimed radiographic X-ray equipment that use CR and DR imaging systems. Measuring skin entrance exposure (ESE) for the AP abdomen, AP lumbar spine and PA chest is emphasized since the ESE in these digital modalities is sometimes higher than for a standard 400-speed film-screen system. Suggestions are given in the document to help a facility lower the ESE without adversely affecting image quality.



Adela Salame-Alfie, Ph.D., Chairperson
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PREFACE

In 2007 the CRCPD Board of Directors created the H-33 Task Force for the Inspection of Diagnostic X-ray Facilities Using CR/DR Technology, a working group within the Healing Arts Council, to develop guidance for state X-ray inspectors regarding the routine inspection of diagnostic X-ray facilities that use digital-based imaging equipment. Computed Radiography (CR) (also known as PSP technology, or Photo-Stimulable Phosphor Imaging Systems) and Digital Radiography (DR) are now commonplace in U.S. radiological practice. The Board directed the task force to address the collection of patient exposure indicators for selected common radiographic projections, and to provide guidance regarding the quality of practice.

This report contains the following features that state radiological offices can use to evaluate patient exposure-related aspects of clinical X-ray practice:

1. Procedures to assess patient-representative values for air kerma under routine clinical conditions
2. Suggested recommendations regarding improved quality control for X-ray equipment used to conduct CR and DR X-ray examinations, including methods to reduce patient exposure without a compromise in clinical image quality
3. Tabulations of suggested radiological phantoms for use in evaluating X-ray systems
4. Manufacturer-specific tabulations of exposure indices and imaging detector features

The primary task of this document is to provide guidance for state radiological programs that wish to assist clinical facilities with improving their digital X-ray practice. For those programs that wish to collect more comprehensive data, an abbreviated version of the 2002 NEXT survey protocol is included (Appendix B): Protocol for the Survey of A/P Abdomen and Lumbosacral Spine Radiography: Computed Radiography and Digital Radiography. These abbreviated NEXT procedures complement the main CR/DR protocol with additional data collection procedures that further characterize clinical practice.

The H-33 task force provided training on the procedures described in this protocol at the 41st annual National Conference on Radiation Control, which was held in Columbus, Ohio in May 2009. The procedures outlined in this report contain revisions based on comments from training participants and peer review by identified experts in the field of diagnostic radiology.

A hopeful outcome of this task force effort is increased confidence of state inspectors in evaluating CR and DR X-ray equipment and relating feedback to facilities regarding actions they can take to keep patient exposures as low as reasonably achievable.

Refer to the glossary for a definition of acronyms used in this document.

ACKNOWLEDGMENTS

We wish to thank our state advisors and resource individuals from FDA and AAPM for all their time and constructive thinking that went into this protocol document. Mike Tkacik (AAPM) participated in our May 2009 working group meeting in Columbus, Ohio. The original Chairperson of this Task Force, Steve Crawford of Oregon, deserves recognition for getting the ball rolling and mapping out the direction we took.

Several people were asked to provide peer review for the document, and they took the time to provide useful suggestions for change. They are Cass Kaufman of LA County, California, Ed Gloor of the State of California and Joel Gray of DIQUAD, Inc. Finally, the first hands-on application of this protocol was conducted during the annual CRCPD National Conference on Radiation Control in Columbus at the Martha Morehouse Imaging Department of Ohio State University. We appreciated their cooperation, flexibility and patience in allowing us to use their facility's X-ray units. Thank you, Tonette Orsini and Maxine Sims.

The task force members deserve recognition for finding the many hours and many days of work it took to create the extensive tables and appendices of this protocol, especially since they already had full time jobs! Lastly, we thank Lin Carigan of CRCPD for her efforts to create a professional looking document from our feeble efforts at writing technical material.

A handwritten signature in black ink, reading "M Odlaug", is centered on a light green rectangular background.

Mike Odlaug, Chairperson
Task Force for the Inspection Protocol
of Diagnostic X-Ray Facilities
Using CR/DR Technology

ABSTRACT

CRCPD H-33 Task Force for the Inspection Protocol of Diagnostic X-Ray Facilities Using CR/DR Technology, *Computed Radiography and Digital Radiography State X-Ray Inspection Protocol*, CRCPD Publication # E-10-2, (January 2010) (26 pp).

This protocol contains written guidance that state x-ray inspectors could use during the routine inspection of diagnostic x-ray facilities using CR/DR technology. The document addresses the collection of ESE (entrance skin exposure, i.e., patient exposure) measurements for some of the common projections on phototimed equipment, and provides expected values for these projections when CR/DR is used. In addition, the guidance document includes:

- 1) Methods to reduce ESE without compromising image quality.
- 2) QC recommendations for CR and DR equipment that a state inspector could suggest to a facility.
- 3) A table of available phantoms to use with phototimed radiographic systems.
- 4) A table of CR and DR manufacturers showing typical exposure index values.

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I. ROUTINE X-RAY MACHINE TESTS

A. LIGHT FIELD/ X-RAY FIELD ALIGNMENT

1. Place a 10 x 12 inch CR cassette directly on the X-ray table top, or if testing a DR system, proceed with step 2.
2. Collimate well within the edges of the CR cassette or to a nominal field size of 8" x 10" for a DR system, and put the coins at the inner edges of the light field.
3. Shoot an extremity technique using "Tabletop" mode on the control panel and process the image. Use an extremity algorithm for CR or DR image processing.
4. Review the image on the monitor and evaluate.

Note: The image on the monitor may be scaled down and may throw off your usual measurements. If you use nickels (2 cm in diameter), then you can estimate any misalignment by seeing what portion of the nickel is inside or outside the X-ray beam edge on the monitor. If you make the exposure at an SID of 102 cm, and there's half a nickel's diameter discrepancy on each side, then you have a 2% error in alignment). Also, you may want to put a special marker coin on one side or the other so that when you see the image on the monitor, and have a misalignment, you will know which side it is on (sometimes, left is down, up is right, etc).

B. MACHINE PERFORMANCE (These tests may already be routine components of a state program's X-ray inspections, and are not discussed in this document.)

1. Centers alignment (is the beam centered to the image receptor?)
2. Do the longitudinal and transverse centers indicators and detents work?
3. For DR, is the maximum X-ray beam limited to the image receptor?
4. Exposure reproducibility, manual mode and AEC
5. mA Linearity
6. kVp accuracy
7. HVL

II. ESE MEASUREMENTS

Determine if radiographic exams are done with:

- Manually selected techniques,
- Programmed techniques, or

- AEC detectors and phototiming.

Note: Explain to the technologist that you will be making several exposures, and that you will probably need to have a “test” patient entered into the computer along with a few selected projections, e.g., extremities, lumbar spine, abdomen, chest, etc. Also, you should suggest that the “auto-send” feature on PACS be temporarily disabled or turned off, so that all your exposures do not inadvertently go to the radiologist’s display for diagnosis!

A. MANUAL OR PROGRAMMED TECHNIQUES (ABDOMEN OR LUMBOSACRAL)

Ask the technologist to set the SID at the distance commonly used for the exam and to set the techniques for an average-sized male AP view abdomen or lumbar spine. Be sure to center the tube over the image receptor both longitudinally and laterally. For a CR system, you or the technologist may have to insert a CR cassette into the bucky tray in order to allow the system to activate. Record the SID and the technique factors.

1. Using foam blocks, test stand, or other suitable material, place your detector (solid state, ion chamber, etc.) at 23 cm (9 inches) above the tabletop. Of course, you can set up your detector at any convenient distance (such as right on the tabletop) and simply use inverse square calculations to determine ESE at 23 cm.
2. Make the exposure and read the ESE directly from your instrument. See Section III below, “Post Survey Procedures and Follow-Up.”

B. PHOTOTIMED TECHNIQUES (ABDOMEN [AB] OR LUMBOSACRAL [LS])

You will need an appropriate phantom designed to trigger the phototimers as our “standard man” would (See Appendix A). The NEXT Abdomen-Lumbar Spine phantom is equivalent to an adult patient standing 5’8” tall, weighing 164 pounds, and having a 23 cm AP trunk. Provide this information to the facility technologist so that he or she can configure the X-ray equipment as they would for clinical exams (commonly, kVp, mA station and back-up time/mAs), including photocells selected and the density setting. Ask the technologist to set up these factors on the control panel. Record the technique factors.

Note 1: Usually a kVp is selected by the technologist or a default kVp shows up when the AP LS or AB view is selected. You may also note that the technologist selects a back-up time or mAs that is greater than what is to be expected. In addition, the technologist normally will select the center cell for the LS and the two side cells for the abdomen, and some density setting (e.g., -1, zero or +1).

Note 2: In your evaluation of techniques used at a facility, pay close attention to what kVp shows up on the control panel when a selection is made for an AP phototimed LS or AB. Determine from interviewing the chief technologist as well as other technologists if everyone is USING the default kVp setting for these exams, or if some technologists are CHANGING that default kVp setting. Many technologists will use their own techniques, bypassing the default kVp setting. Others will just use what the set-up has. One can see, then, that an issue of consistency might come up, and if you measure the ESE from a default setting of 75 kVp, for example, when many of the techs are changing that to 80, your ESE at 75 kVp will **not** be the “routine” true ESE characteristic of this facility. The objective of this protocol is to measure and report the ESE that is truly representative of what the facility is doing.

1. Ask the technologist to set up the table height and tube to the SID (usually 40 inches) at which the bucky AP LS/AB exams are conducted. The technologist should also bring the overhead tube into its lateral detent position and ensure that the bucky light is aligned longitudinally with the middle of the cassette tray and cassette.

Note: If the system is CR, be certain that the technologist (or you) inserts a **14 x 17 inch** CR cassette into the bucky tray. Do **not** do more than **4** exposures on a CR cassette before processing so as not to run the risk of any burn-in or ghosting.

2. If you are using the FDA/NEXT Abdomen-Lumbar Spine phantom, collimate the field size at the tabletop to 10 inches by 10 inches, per FDA/NEXT procedures (Appendix B). Verify that all relevant AEC cells are within the collimated field. If necessary, reposition the X-ray field so that all cells are within the field.
3. Place the Abdomen-Lumbar Spine phantom on the tabletop within the collimated field.

Note: Remember - the phantom simulates the radiation absorption and scatter properties presented by a real patient. It is acceptable to leave the table-pad on the table (if used by the facility) and place the phantom on the pad as normally the patient’s weight and the weight of the phantom will compress the pad enough so that there is no artificial “height” created by the pad. In short, the phantom should rest on the same surface as the patient.

4. Place your detector as follows:
 - a. If using a RADCAL MDH 6 cc ion chamber, place it in the probe holder attached to the phantom. Make the exposure and perform the calculation provided by FDA to determine the true patient exposure (see procedures in Appendix B). Proceed to Section III.

- b. If your state uses a small size detector such as the RTI R100-B to make ESE measurements, or ionization chambers that will not interfere with the photocell performance, you can position these devices above the phantom and make direct or calculated ESE measurements similar to the FDA protocol.
- c. If using a solid state detector such as *UNFORS* or Barracuda MPD, it is difficult to avoid covering a relevant photocell with the heavily attenuating detector, and it is difficult to place these detectors in the FDA's probe holder. Therefore, DO NOT place the detector in the beam or on top of the phantom for the exposure. *Make the exposure without it and record the mAs indicated on the control panel.* (See note #2 below if a mAs readout is not available.) Make a second phototimed exposure to assure yourself that the phototimer is giving reproducible results (you should get a second mAs readout within 10 % of your initial value). Then remove the phantom from the tabletop, and place your detector 23 cm (9 inches) above the tabletop using blocks of foam, test stand or other suitable material, and switch to manual mode on the control panel. Now, ask the technologist (or do it yourself) to select a manual technique (non-phototimed) at whatever kVp was used and whatever mAs was generated by your phantom.

Note 1: Sometimes, you will not be able to set the exact mAs you want, so select a value as close as possible. You may have to do a little math if you cannot obtain the desired mAs value. For example, if you obtained 42 mAs with the phototimed exposure, but you can only select 40 mAs in manual mode, then multiply your measured exposure value by the ratio of the desired mAs to the set mAs: $42/40$, to get the true ESE.

Note 2: If the control panel has no mAs read-out and you are using a solid-state detector, then you must position your instrument detector away from the relevant photocell, but still within the beam. Check to make sure you are not covering a photocell by taking one exposure with your detector in place and one without; the two exposures should be similar. Add to the height of the phantom so that when your detector is placed on top, it is 23 cm (9 inches) above the tabletop, or use a stand and clamp. (This is not necessary if you are using the RADCAL chamber and the FDA phantom holder).

Another way to determine the mAs used (if there is no read-out) is to set the detector close enough to the phantom to pick up scatter. You can then detect the duration of the exposure and determine the mAs by multiplying that time by the set mA.

Note 3: Mentally note the resultant mAs value for clinical appropriateness; you've done enough measurements and seen enough techniques to know whether 25 mAs is going to be "good," or 90 mAs will be "bad." If possible, determine if the mAs and ESE from your phantom exposure are typical of actual patient exposure techniques for this exam

(sometimes technique used will show up on the acquisition workstation display for patient images before they are sent to PACS).

5. Make an exposure using the manual techniques determined above and record the reading in mR from your instrument. Perform any necessary mathematical corrections due to a difference in mAs or geometry.

C. PHOTOTIMED TECHNIQUES (PA CHEST)

1. Use an appropriate phantom (example: the FDA-NEXT adult chest phantom) and with a cart or other stand, place it in patient position against the vertical bucky panel front.
2. Follow the above procedures, and modify them appropriately for this projection.

III. POST-SURVEY PROCEDURES AND FOLLOW-UP

A. ESE EVALUATION

1. Once you have obtained an ESE for the chosen radiographic exam at the facility, you can compare the measurement to national medians and 3rd quartile values and also AAPM published reference values. See the attached NEXT data in Appendix C. Your state may also have regulatory ESE limits or guidelines to which you will compare the results. The objective is to demonstrate to the facility where their patient exposures are relative to others in the medical imaging community.
2. Provide this data to the facility in writing so they can be aware of how much radiation exposure they are giving for this exam. Indicate that your measurement represents a typical adult patient. It is valuable here to determine if the mAs and ESE from the lumbar spine exam is typical of other exams done at this facility. Resultant phototimed technique is usually recorded on the technologist's workstation before images are sent to PACS, so you can review those. Also, some technologists can tell you what the mAs read-out usually is on certain exams.

B. ESE REDUCTION TECHNIQUES

1. If the patient exposure value exceeds the 3rd quartile, you can suggest ways to reduce exposures from a phototimed exposure. Following are some suggestions for equipment adjustments that can reduce patient exposure.

- a. A quick method is to recommend that the facility use a “-1” density for the phototimer instead of zero (or 1 or 2 steps less than what they are currently using).
- b. Suggest that the X-ray system vendor or other appropriate person review and if appropriate, re-program the default kVp setting on the control panel when the programmed or phototimed AP Lumbar Spine technique is selected. If the default kVp is too low (i.e., 70, 72, etc), the technique can be modified to 80 kVp or higher by the vendor or by the facility bio-engineering. This action will result in a lower mAs during the phototimed exposure and thus produce a lower ESE and yet maintain comparable image quality.
- c. Suggest that the X-ray system vendor adjust the sensitivity setting of the phototimer so that it triggers at a lower radiation level and results in a lower mAs, and produces a lower ESE.
- d. Suggest that the facility’s medical physicist conduct a review of the X-ray system’s exposure techniques and take appropriate actions.

Note: It is important to attempt to get the involvement of appropriate staff if the facility seems interested in making changes to radiographic techniques, patient exposure and clinical image quality. Make sure you suggest the participation and cooperation of any or all of these resource individuals available to the facility:

- Radiologists
 - Chief technologist or radiology manager
 - Medical physicist
 - Bio-medical engineering
 - X-ray equipment service engineer
 - CR system service engineer
 - (or DR system manufacturer if this is a DR system)
2. Whenever standard X-ray techniques are modified (such as by the actions suggested above), the radiologists should then evaluate clinical images to determine if they still are satisfactory. To demonstrate to the facility that the image quality can remain acceptable after a change in technique, you can image a test tool (either the yellow NEXT test tool or a commercial one) at the high mAs technique you measured, and then do so at a lower mAs. Then compare the contrast range of the two images with facility personnel to show them they really can reduce technique without compromising image quality. Be aware, however, that this simple comparison of test tool images may not be a sufficient basis for change, since the tool may not capture the subtle differences a radiologist might detect in clinical images and radiologists may not make changes based on phantom images alone. The objective is to get patient exposures below the 3rd NEXT quartile instead of above it and to maintain image quality appropriate to the exams.

C. INDEX NUMBERS

Check exposure index numbers for proper exposure (see Appendix E attached). Verify the index number obtained with your phantom exposure. The acquisition monitor may display this value or it usually can be obtained from the digital image. Find out what the exposure index (EI) target range is supposed to be (usually provided to the facility by the vendor). What is the facility's procedure when Exposure Indices fall significantly below the guideline, and also above the guideline? Remember that some manufacturers have an exposure index system set up *inversely* so that a higher EI means LESS radiation exposure.

Note 1. There is no reason to repeat a radiographic exam just because the index number showed a high patient exposure. Image quality was probably more than satisfactory (unless the exposure was so high that the detector was saturated).

Note 2. Index numbers are *not* the end-all; exposure and image quality are of paramount importance. Do not get "stuck" on using index numbers as a means to evaluate patient exposure.

Note 3. You will find that some DR systems have a selectable exposure index, right on the control panel display, usually in terms of "200," "400," "800." Be aware of this, and ask the facility's procedures for choosing a given "speed."

D. IMAGE REVIEW

Review typical exposure index numbers on recent patient images on the monitor with the radiologist or chief technologist. Are they achieving target index numbers for trunk exams, extremities, pediatrics, etc?

Also review images for evidence of collimation; note that you will have to "unmask" the finished clinical images to see the "raw" image showing collimation. PACS images may not have all the information you need.

E. QUALITY CONTROL (QC) & QUALITY ASSURANCE (QA)

1. Ask what QA program they have in place for internal, periodic review of the index numbers, and collimation achieved by the technologists. (Quarterly is recommended.)
2. Ask what QC program they have for the digital detectors or CR readers and CR plates. The manufacturer should have recommendations for periodic QC, and if not, the facility should have established their own. (Quarterly is recommended.) Determine whether the facility is following these procedures at the recommended frequencies. An excellent resource is AAPM Report #93, published in October, 2006, showing suggested QC procedures and frequencies for CR systems.

3. Ask how often the CR readers are evaluated by a medical physicist and calibrated by the service engineer. (Annually is recommended.)
4. Ask if the workstation monitors and the radiologists' interpretive workstation monitors are calibrated and tested periodically using the standard Society of Motion Picture and Television Engineers (SMPTE) pattern. (Quarterly is recommended.)
5. Ask about periodic, thorough erasure of the Imaging Plates (IP). (Monthly is recommended.)
6. When was the last time the AEC detectors under the table and behind the chest board were calibrated to determine if they are balanced and reproducible? (Annually is recommended.)
7. Find out what the facility's procedure is when artifacts are observed on the acquisition workstation. Pose this question to at least one technologist.
8. Does the facility conduct a retake analysis? (Quarterly is recommended.) Because it is easy in digital radiography for a technologist to delete bad images, ask the Chief Technologist or Director how the retake analysis is done.
9. Does the facility measure and evaluate patient exposure and exposure index numbers from representative radiographic exams in order to avoid dose creep? This is simple to do and some digital systems provide the ability to acquire the exposure index sorted by exam type, technologist, etc. (Thirty percent higher or lower than the target is considered significant.)
10. Finally, ask for a copy of the most recent physics survey report (including recommendations for correction of deficiencies found) on the facility's X-ray machines. Examine the report to see what tests were done, and verify that if any problems were found, that the facility has documentation of correction.

See attached appendices for information on phototiming phantoms available, normal target ranges for exposure index values of various CR/DR manufacturers, a detailed protocol for use of the FDA-CRCPD-NEXT phantom, and NEXT ESE values, as well as a bibliography and an explanation of the acronyms used in this document.

GLOSSARY

AAPM - American Association of Physicists in Medicine

The American Association of Physicists in Medicine was founded in 1958 to promote the application of physics to medicine and biology, and to encourage interest and training in medical physics and related fields as well as to prepare and disseminate technical information.

ACR - American College of Radiology

The mission of the ACR is to serve patients and society by maximizing the value of radiology, radiation oncology, interventional radiology, nuclear medicine and medical physics by advancing the science of radiology, improving the quality of patient care, positively influencing the socio-economics of the practice of radiology, providing continuing education for radiology and allied health professions and conducting research for the future of radiology.

AEC - Automatic Exposure Control

Automatic exposure controls are programmed to terminate the radiographic exposure time. The main function of an AEC is to eliminate the need for the radiographer to set an exposure time. Although an AEC is commonly referred to as a phototimer, the term actually refers to the use of ionization chambers. When using an AEC, it is critical that the location of the ionization chamber be determined and the precise positioning of tissue over the location be achieved.

AP - Anteroposterior

An x-ray picture in which the beams pass from front to back.

ASRT - American Society of Radiologic Technologists

A professional society within the radiologic technology profession whose mission is to foster the professional growth of radiologic technologists by expanding knowledge through education, research and analysis; promoting exceptional leadership and service; and developing the radiologic technology community through shared ethics and values.

CDRH - FDA's Center for Devices and Radiological Health

One of the centers under the Food and Drug Administration (FDA) is the Center for Devices and Radiological Health and they regulate the manufacturer of electronic products that emit ionizing electromagnetic or particulate radiation and assures they meet radiation safety standards. They make sure that new devices are safe and effective before they are marketed.

CR - Computed Radiography

Computed Radiography is an indirect type of imaging system. The receptor used within a CR cassette is called a photostimulable imaging plate (See PSP below) and it absorbs the radiation exiting the patient. The exposed plate is processed in a CR reader, where the absorbed energy is extracted. The information stored in the CR imaging plate must be processed before viewing can occur. The resultant latent image data is converted from an analog to a

digital signal and a digital image is created. Computed Radiography x-ray systems predominantly use conventional x-ray tube systems.

CRCPD - Conference of Radiation Control Program Directors

The Conference of Radiation Control Program Directors is a non-profit, non-governmental professional organization that brings together the radiation protection programs in all fifty states. It is an association of state and local radiation control agencies and is an effective voice for the states when national and international issues are discussed. The CRCPD committees are responsible for a variety of public health, worker and environmental protection advances in radiation protection.

DR - Direct Radiography or Digital Radiography

Direct or Digital Radiography is a form of x-ray imaging, where digital x-ray sensors are used instead of traditional photographic film. The image brightness and contrast can be modified by digital processing of the acquired image data. Inadequate or excessive exposure is manifested as higher or lower image noise levels instead of as a light or dark image. Digital imaging systems can produce adequate image contrast over a much broader range of exposure levels than film-screen imaging systems. The broad dynamic range is one of the benefits of digital detectors. Conventional x-ray tube systems are predominantly used with digital radiography.

EI - Exposure Index

Exposure index (EI) is the measure of the amount of exposure received by the image receptor (IR). It is dependent on mAs, total detector area irradiated, and beam attenuation. The exposure index is indicative of the image quality. EI is derived from the mean detector entrance exposure which is in turn derived from the mean pixel value of the image. Although EI is always derived from the IR exposure, equipment manufacturers calculate the numeric value differently, resulting in different ranges and definitions.

ESE - Entrance Skin Exposure

The Entrance Skin Exposure is an important dosimetric indicator of the radiation received by the patient in a single radiographic exposure. The ESE can be measured by either direct measurement on phantoms using an ionization chamber (or other appropriate dosimeter) or on patients using thermoluminescent dosimeters (TLDs), or by using calculations based on a mathematical model. Factors that can cause differences in measured values include instrument calibration, backscatter, collimation, estimation of focal spot location, choice of phantom, and location of dosimeter in the primary beam. The ESE is the benchmark of safety and is the measure of risk.

FDA - Food and Drug Administration

As one part of the FDA's mission statement: The FDA is responsible for protecting the public health by assuring the safety, efficacy and security of human and veterinary drugs, biological products, medical devices, our nations food supply, cosmetics and products that emit radiation.

HVL – Half-Value Layer

The half-value layer of an x-ray beam is that thickness of absorbing material, when introduced into the path of a given beam of radiation, reduces the x-ray intensity (quantity) to half its original value. The HVL is a measure of beam quality. The factors that directly affect x-ray quality are kilovoltage and filtration.

IP – Imaging Plate

Imaging plates contain photostimulable storage phosphors, which store the radiation level received at each point in local electron energies. Imaging plates are processed through a CR reader.

kVp – Kilovoltage, peak

The voltage applied between the cathode and anode of an x-ray machine. The kVp determines the maximum x-ray energy that will be produced and the spectrum of x-ray energies produced.

LS – Lumbosacral

The low back officially begins with the lumbar region of the spine directly below the cervical and thoracic regions and directly above the sacrum. The sacral spine refers to the large irregular triangular shaped bone made up of the five fused vertebrae below the lumbar region.

mA – Milliampere

A unit of electrical current. In x-ray machine operation it refers to the current supplied to the cathode of the x-ray tube and is linearly related to x-ray intensity produced.

mAs – Milliampere-second

A unit determined by multiplying the milliamperes by the time the x-ray tube is generating x-rays. On many x-ray machines this is a technique factor selected by the operator that together with kVp determines the exposure of patient and image receptor.

NEXT – Nationwide Evaluation of X-ray Trends

The Nationwide Evaluation of X-ray Trends is a national program conducted jointly by the Conference of Radiation Control Program Directors and the FDA's Center for Devices and Radiological Health, with financial support from the American College of Radiology since 1998, to measure the x-ray exposure that a standard patient receives for selected x-ray examinations.

ORA – The Food and Drug Administration Office of Regulatory Affairs

The FDA's Office of Regulatory Affairs is the lead office for all FDA Field activities as well as providing FDA leadership on imports, inspections, and enforcement policy.

PA – Posteroanterior

An x-ray picture in which the rays pass through the body from back-to-front.

PACS - Picture archiving and communication system

In medical imaging, PACS are computers, commonly servers, dedicated to the storage, retrieval, distribution and presentation of images. The medical images are stored in an independent format.

PSP - Photo-Stimulable Phosphor

A radiographic screen containing a special class of phosphors which when exposed to X-rays, stores the latent image as a distribution of electron charges, the energy of which may later be freed as light by stimulation with a scanning laser beam. The light is directed to a photomultiplier tube, and the output electrical signal is digitized. The final result is a digital projection radiograph. The photostimulable phosphor plate is also known as an imaging plate, storage phosphor imaging plate, and digital cassette.

QA - Quality Assurance

An all-encompassing program, including quality control, that extends to administrative, education, and preventive maintenance methods. It includes a continuing evaluation of the adequacy and effectiveness of the overall imaging program, with a view to initiating corrective measures when necessary.

QC - Quality Control

A series of distinct technical procedures that ensure the production of a satisfactory product. Its aim is to provide quality that is not only satisfactory and diagnostic, but also dependable and economical.

SID - Source-to-Image Distance

The Source-to-Image Distance is also known as the focal film distance and is the distance from the source of radiation to the image receptor. The SID alters the intensity of the beam reaching the image receptor, according to the inverse square law. The inverse square law affects density in inverse proportion to the square of the distance. When the distance is doubled, the quantity of radiation reaching the image receptor is reduced by one fourth. Resolution is improved when the SID increases and degraded when the SID decreases.

SMPTE - Society of Motion Picture and Television Engineers. This organization developed a test pattern that can be used to determine gray-scale image quality on video and computer display monitors. Spatial resolution, brightness, contrast and aliasing can be evaluated using this test pattern.

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APPENDIX A.

SUGGESTED RADIOGRAPHIC PHANTOMS FOR PHOTOTIMED (AEC) EQUIPMENT

Name of Phantom	Source	Cost / Model	Available	Wt	Used For	Contact Information	Dimensions	Comments
CDRH / FDA Abdomen/Lumbar Spine	CDRH / FDA	See Comments	Not comm. available	30 lbs	AP Abdomen and AP Lumbar Spine (Adult) and is equivalent to a 23 cm patient.	CDRH / FDA David Spelic: David.Spelic@fda.hhs.gov	Phantom consists of a 25.4x25.4 cm piece of clear acrylic totaling 16.9 cm thick in the soft tissue region with a raised spine section of an additional 2.4 cm totaling 19.3 cm. This thickness or height of 19.3 cm includes an embedded 0.46 cm strip of aluminum (1100 alloy) in the spinal region. The acrylic is made from polymethyl methacrylate (PMMA).	Many state programs in Radiation Protection have this CDRH / FDA phantom from prior studies for the NEXT program. A yellow colored image quality test tool and circular aluminum disk test tool is included with the phantom. The phantom is made of acrylic (Lucite brand name) and aluminum.
Abdomen/Lumbar Spine (Conforms to AAPM recommendations in Report No. 31 - Modified ANSI Phantom)	Fluke Bio- Medical	\$468.00 Model # 76- 212	83 working days	37 lbs	AP Abdomen and AP Lumbar Spine (Adult)	Fluke Bio-Medical 6045 Cochran Road Cleveland OH 44139 (440) 248-9300 (800) 850-4608 www.flukebiomedical.com/rms	Phantom consists of five sheets of 25x25x2.54 cm and one sheet of 25x25x5.08 cm clear acrylic totaling 17.78 cm thick. A 7 cm x 25 cm x 0.46 cm thick piece of high purity aluminum is included in the spinal region.	In the AAPM Report No. 31, on Page 8, the length x width is indicated as 30.5x30.5 cm for the Modified ANSI Abdomen/Lumbar Spine Phantom. However, on Page 11 of the same report, there is a clarification that states, "The ANSI phantom size (length x width) can be reduced to 25 cm x 25 cm without affecting the ESE results."
Make-Your-Own Phantom Modular Kit (Includes Modified ANSI Abdomen/Lumbar Spine Phantom)	Fluke Bio- Medical	\$682.00 Model # 76- 215	In stock or 27 days	34 lbs	Chest, Abdomen/Lumbar Spine, Skull, Extremity Phantom (Adult)	Fluke Bio-Medical 6045 Cochran Road Cleveland OH 44139 (440) 248-9300 (800) 850-4608 www.flukebiomedical.com/rms	This kit contains all the components needed to make any one on the four phantoms. It includes: Five sheets 25x25x2.54 cm thick acrylic; One sheet 25x25x5.08 cm thick acrylic; One sheet 25 cm x 25 cm 1 mm thick aluminum; One sheet 25 cm x 25 cm x 2 mm thick aluminum; One sheet 7 cm x 25 cm x 4.5 mm thick aluminum and spacers for a 5.08 cm air gap.	These four phantoms can also be purchased individually.
Oregon's Phantom	Contact the state program rep.	\$125.00	Not comm. available	10 lbs	Lumbar Spine only	Contact the state program representative	Phantom is made of pieces of acrylic (Plexiglass brand name) and measures 7.5 x 7.5 inches square and has a height of 7 inches or about 17.80 cm. One 4.5 mm sheet of aluminum is added for the spine that is 3 inches wide x 7.5 inches long. The CDRH / FDA yellow colored image quality test tool is used with this phantom.	The configuration of the height of this phantom correlates to the height of the Modified ANSI Phantom.
Washington's Mini-Me Phantom	Contact the state program rep.	\$125.00	Not comm. available	10 lbs	Lumbar Spine only	Contact the state program representative	Phantom is made of pieces of acrylic (Plexiglass brand name) and measures 6 x 6 inches square and has a height of 7 inches or about 17.80 cm. One 4.5 mm sheet of aluminum is added for the spine that is 3 inches wide x 6 inches long. The CDRH / FDA yellow colored image quality test tool is used with this phantom.	The configuration of the height of this phantom correlates to the height of the Modified ANSI Phantom.
Pennsylvania's Aluminum with Copper Phantom	Contact the state program rep.	\$425.00	Al and Cu available from various vendors	6 lbs	AP Abdomen and AP Lumbar Spine (Adult)	Contact the state program representative	For the Lumbar Spine, the phantom is made of two Patient Phantom Penetrometer System aluminum blue blocks, that measure 7 x 7 inches square by 3/4 inch thick each, for a total height of 1.5 inches. A one mm thick sheet of copper is added that measures 8 x 8 inches square. For the Abdomen, the phantom is made of only two blue blocks of aluminum as noted above. The aluminum is high purity 1100 and the copper is alloy type 110 soft temper.	The phantoms have been tested during an intercomparison study with the Modified ANSI Abdomen/Lumbar Spine Phantom.

The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the CRCPD or any federal agency.

APPENDIX B. QUALITY ASSURANCE TEST PHANTOMS AVAILABLE

Name of Phantom	Source	Cost / Model	Available	Wt	Used For	Contact Information	Dimensions	Comments
Fuji FCR 1 Shot Phantom	Fujifilm USA	\$750.00 Part # X-SMS- OPTION-02	In stock	10 lbs	Computed Radiography (CR) Systems	Fujifilm USA CT (800) 431-1850 CA (800) 431-2861 HI (808) 677-3854 IL (800) 323-2546	Phantom measures 14 x 17 inches.	The Fuji FCR 1 Shot Phantom enables a system-wide quality analysis by incorporating eight performance tests into a single exposure. This phantom provides valuable evaluation of the Imaging Plate, CR Image Reader, Exposure Room, Hard Copy Printer and Imaging Workstations. The phantom is made of (Lexan brand name) plastic.
Fuji FCR 1 Shot Phantom Plus	Fujifilm USA	\$3,300.00 Part # X- PHNTM-Plus- ADTNL	In stock	4 lbs	Computed Radiography (CR) and Digital Radiography (DR) Systems	Fujifilm USA CT (800) 431-1850 CA (800) 431-2861 HI (808) 677-3854 IL (800) 323-2546	Phantom measures 10 x 12 inches.	The Fuji FCR 1 Shot Phantom Plus is an advanced QC program with automated tests, software and reports specifically for use with Fujifilm CR and DR systems as well as the QC workstations. This phantom is an advanced quality analysis system incorporating extensive test parameters into an automated program. The phantom is made of acrylic.
Radiography Fluoroscopy Accreditation Phantom	CIRS (Computerized Imaging Reference Systems)	\$2,038.00 Model # 903 (Add a case for an extra \$396.00)	4 weeks	43 lbs no case	For Radiography / Fluoroscopy QA and can be used for initial QA assessment and routine monthly QA testing.	CIRS - Tissue Simulation & Phantom Technology 2428 Alameda Ave #316 Norfolk, VA 23513 (800) 617-1177 or (757) 855-2765 www.cirsinc.com	The overall phantom measures 25x25 cm and is 20.7 cm high and consists of three attenuation plates, one test object plate and a detachable stand.	Phantom is manufactured from PMMA equivalent epoxy that offers the same x-ray attenuation properties as acrylic with significantly greater durability.
EZ CR/DR "DIN" Test Tool	Fluke Bio-Medical	\$587.00 Model # 07- 605-7777	5 days	7 lbs	Computed Radiography (CR) and Digital Radiography (DR) Systems	Fluke Bio-Medical 6045 Cochran Road Cleveland OH 44139 (440) 248-9300 (800) 850-4608 www.flukebiomedical.com/rms	Phantom measures 14x17 inches and is 1/2 inch in height.	The EZ CR/DR "DIN" Test Tool is used as a preventative maintenance quality control test tool. It can also be used to take regularly scheduled measured data points from the image, such as line pair resolution measurements, ROIs (regions of interest) and geometry symmetry.

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APPENDIX C.
PROTOCOL FOR THE SURVEY OF A/P ABDOMEN
AND LUMBOSACRAL SPINE RADIOGRAPHY:
COMPUTED RADIOGRAPHY AND DIGITAL RADIOGRAPHY

Adapted from:

Nationwide Evaluation of X-ray Trends
NEXT 2002
Protocol for the Survey of A/P Abdomen
and Lumbosacral Spine Radiography

Food and Drug Administration (FDA)
Center for Devices and Radiological Health (CDRH)
Rockville, Maryland

In association with

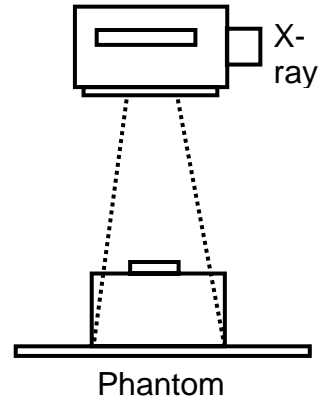
CRCPD H-33 Task Group on Inspection Protocol for Diagnostic
X-ray Facilities using CR/DR Technology
Conference of Radiation Control Program Directors, Inc. (CRCPD)

Note: The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the CRCPD or any federal agency.

A. Abdomen (LS spine) Exam: MDH Exposure and Time Measurements

You will acquire ONE hardcopy image of the phantom with the test tool. For CR surveys inform the technologist that you will require one imaging plate of a size appropriate for routine adult abdomen exams.

1. Ask the facility technologist to configure the following x-ray gantry parameters for a typical adult A/P abdomen (lumbar spine) projection: X-ray tube position, grid configuration, bucky/table top positioning.
2. Measure and record (in cm) the distance from the focal spot indicator to the surface that the patient rests against during the exam (*source-patient support distance*).
3. Measure and record the source-image receptor distance (*SID*). For CR systems this is measured to the image plate (as would be done for a conventional film cassette). For DR systems a value for SID will likely be displayed- consult with facility staff for assistance.
4. Collimate the beam down to a 10 inch x 10 inch area at the image receptor surface (this is the phantom's footprint on the receptor surface). **NOTE:** If AEC is used, adjust the position of the beam so that all appropriate AEC cells are within the collimated area. Refer to the diagram at the right (table top example). For upright exams using a wall bucky (e.g., LS spine), you will likely need a support platform for the phantom.
5. Place the *Radcal* MDH probe into the probe holder on the phantom. Set the mode selector to **"PUL/SE EXPOSURE"** and the function selector to **"MEASURE."**
6. Set the threshold thumb-wheel to **0.2** for single phase units. For three-phase, high-frequency, and constant potential units, set the threshold to **0.5**.



NOTE regarding the use of solid-state detectors (SSD's)

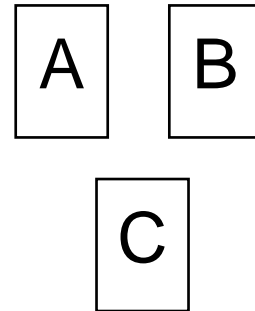
These survey procedures specify the use of the MDH model 1015/1515 electrometer/ionization chamber series (10X5-6). If you intend to use a solid-state detector, you may need to make your measurement in a manually-terminated exposure because most commercially available SSD's will interfere with nearby AEC detectors, and as well may typically require positioning along the beam axis. Review the operation manual for your SSD to ensure appropriate use prior to collecting data.

7. **CR systems only:** Insert an unexposed CR imaging plate (IP) appropriate for adult abdomen exams into the bucky / cassette holder.
8. Configure the exposure console for the technique factors routinely used for an adult A-P abdomen (lumbar spine) projection. Capture all pre-exposure selected technique factors on a data form, including kVp, mA, mAs, exposure time, AEC/manual, and AEC detectors used. You can use the diagram below to indicate AEC configuration. Post-exposure values for mAs can be captured as part of the survey protocol. Also inquire with facility staff as to the equivalent system speed (if applicable) the particular protocol is configured at.



Detector configuration codes

- | | | |
|---|---|------------------------------|
| 1 | = | A & B only |
| 2 | = | A or B only |
| 3 | = | C only |
| 4 | = | A,B and C |
| 5 | = | A & C or B & C |
| 6 | = | Other (specify on worksheet) |



9. Make an exposure and record **ONLY** the MDH exposure (in mR) - do **NOT** record the time measurement from the MDH meter at this time. This first exposure serves to initialize the MDH for subsequent exposures.
10. Make three additional exposures. For CR systems, remove the cassette after the second exposure and conduct a primary erasure to avoid damage/burn-in. Return the cassette to the bucky for the 3rd and 4th exposures.

After each exposure switch the MDH selector to **PUL/SE DURATION** and record the exposure time in milliseconds (ms). Switch the MDH selector back to **PULSE EXPOSURE**. NOTE: No useful image is required from these four exposures.

11. CR only: After the 4th exposure remove the CR cassette and ask the technologist to conduct a PRIMARY ERASURE on it. Reinstall the image plate into the bucky/cassette holder.

B. IMAGE QUALITY PROCEDURES

1. Remove the ionization chamber from the probe holder.
2. Place the yellow test tool on the phantom as appropriate for the particular exam being surveyed at a slight oblique angle with respect to the beam axis (to minimize Moiré effects):
 - > For Abdomen: Place the test tool on either side of the raised spine section,
 - > For LS spine: Place the test tool on the raised spine section.
3. Make an exposure using the same clinical settings as used previously for the exposure measurements.
4. Ask the technologist to produce a hardcopy film following the procedures they normally would for clinical adult exams.
5. **CR exams only:** Ask the technologist to again perform a primary erasure on the cassette. The cassette can then be returned to clinical service.
6. Inspect the hardcopy film for appropriate density: films that are significantly light or dark should be investigated before evaluating.

C. Image Quality Evaluation

1. Use a viewing device that is typically used by the facility for clinical image review.
2. Score the number of visible holes: score a hole if the circular periphery is visible- include the center hole in your evaluation.
3. Score a mesh pattern if the rectangular pattern is visible.
4. Although background optical density is less meaningful for digital systems, background optical density can be measured from the hardcopy:
 - > For **abdomen:** measure the density on both sides of the raised spine portion and average.

- > For **LS spine**: measure the optical density for the raised spine segment of the image.

D. Entrance skin exposure calculation

Use the procedure below to compute the entrance skin exposure. This is the exposure that an adult patient with an abdomen of 23 cm (A-P) would typically receive using the same clinical factors and conditions you made your exposure measurements with.

- a. Compute the average exposure resulting from your four exposure measurements.
- b. Use the measured source-patient support distance (CM) and your mean exposure value to compute the entrance skin exposure to the standard NEXT patient.

IMPORTANT: Your value for *source-to-patient support distance* should be expressed in centimeters, otherwise the below calculation will be incorrect. $CM = IN \times 2.54$

$$ESE(mR) = \left(\frac{\text{Source-patient support distance} - 40.9cm}{\text{Source-patient support distance} - 23cm} \right)^2 \times \text{Average Exposure}(mR)$$

APPENDIX D. NEXT DATA TRENDS

Entrance-skin air kerma (mGy) for adult AP abdomen, adult AP lumbosacral spine, and adult PA chest radiographic projections. Values are from the 2002 (abdomen and lumbosacral spine) and 2001 (adult chest) NEXT survey reports available at www.crcpd.org.

Note: Values can be converted to mR using the conversion factor 0.00876 mGy/mR.

Adult AP Abdomen	N	Mean	SD	1st Q	Median	3rd Q	Min	Max
Screen-film	121	2.7	1.8	1.7	2.3	3.2	0.5	14.7
CR & DR	57	2.9	1.5	1.8	2.5	3.6	0.3	8.4
Adult AP Lumbosacral spine								
Screen-film	205	3.3	2.2	2.0	2.8	3.9	0.5	14.7
CR & DR	47	3.2	1.6	2.4	2.9	4.3	0.2	8.3
Adult PA Chest								
Screen-film	231	0.12	0.06	0.08	0.11	0.15	0.02	0.46
CR	57	0.17	0.12	0.10	0.15	0.19	0.03	0.75
DR	18	0.11	0.03	0.08	0.10	0.13	0.07	0.17
CR & DR	75	0.16	0.11	0.09	0.13	0.18	0.03	0.75

APPENDIX E. MANUFACTURER-SPECIFIC EXPOSURE INDICES FOR CR AND DR X-RAY EQUIPMENT

CR (Computerized Radiography) Exposure Index by Manufacturer (clinical ranges expected-not acceptance testing data)
Info in **RED (italic)** was taken from AAPM Task Group 116 preliminary draft version 9c of Nov. 25, 2007

Manufacturer	Exposure Indicator	Optimum Range	Comments
Agfa	LGM Number	1.90-2.50 (all exams)	Exposure ↑ → LGM ↑ Double mAs to increase LGM by 0.3 Half mAs to decrease LGM by 0.3 <i>LGM indicates the deviation, expressed as the logarithm of the median exposure level in a calculated ROI, from the expected value.</i>
<i>Alara CR</i>	<i>Exposure Indicator Value (EIV)</i>	<i>2000 (all exams)</i>	<i>EIV ↑ by 300 → Exposure ↑ by 2 X</i>
All Pro Imaging			Info requested but no reply to date. These are inexpensive CR readers for lower volume private office applications. Imaging plates are removed by hand and inserted in reader.
Carestream/Kodak	Exposure Index (EI)	1500-1800 (all exams)	Exposure ↑ → Exposure Index ↑ $E(mR) = 10^{(x-2000)/1000}$ where E is exposure in mR and x is the exposure index AEC systems are set up with an exposure index of 1740-1840. If exposure index is 1640-1740 then increase AEC exposure 25% If exposure index is 1840-1940 then reduce AEC exposure 20% "Low Exposure Optimization" algorithm provides less noise in areas of low exposure <i>EI ↑ by 300 → Exposure ↑ by 2 X and vice versa</i> <i>EI values are different for general purpose imaging plates than they are for detail (HR) plates</i>
Orex (older) (a Kodak company) pre version 2.5.1 (approx. 2007 and ↓)	Q Value	75-1000 (exam dependent)	Exposure ↑ → Q value ↑ Q value ranges for various exams: Chest PA/AP: 75-300; Chest lateral: 75-200; Lumbar spine lateral: 100-400 Abdomen: 100-400; Skull: 200-600; Extremities: 600-1000

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Manufacturer	Exposure Indicator	Optimum Range	Comments
Orex (newer) (a Kodak company) version 2.5.1 and → (approx. 2008 and →) called PoC (Point of Care) readers	Exposure Index (EI)	1500-1800 (all exams)	Exposure ↑→Exposure Index ↑ (not linear) EI = 1000xlog10[E(mR)] + 2000 Overall range possible is 1700-2300 but applications personnel state 1500-1800 EI ↑ by 300 → Exposure ↑ by 2 X and vice versa Exposure to detector of 0.1mR gives an EI of 1000; 1 mR gives EI of 2000; 10 mR gives EI of 3000
Fuji (all) and Philips (older) (Fuji manufacturers Philips CR reader)	S number L number	S: 100-700 (exam dependent) L: 1.7-2.3	Exposure ↑→S number ↓ (think of it as the S number being the amount of manipulation the computer has to do on the image to make it acceptable-the lower the dose, the more work or manipulation required, hence a higher S number) "L" number is also significant. L number is the width of the usable histogram from which the S number is calculated. Out of range L numbers alter the S number L numbers typically should be between 1.7-2.3 S value ranges for various exams: Abdomen: 100-400; Pediatric abdomen: 200-700; General chest: 200-600; Portable chest: 100-400; Pediatric chest: 200-700; GI: 100-300 Spine: 100-400; Extremities: 75-200; Skull: 100-400
Philips versions (newer) starting with Eleva 1.1 software and later	S number L number	S: 100-700 (exam dependent) L: 1.7-2.3	As above
(Fuji manufacturers Philips CR reader)	AND Exposure Index (EI_s)	200-800	Exposure to detector ↑→EI_s ↑ (Linear relationship) Is a <u>range</u> and <u>guideline</u> . EI_s is according to IEC standard. EI_s = 100 x K[μGy] where K is detector exposure Example: 250EI_s is 2.50μGy to detector. 500 EI_s is 5μGy. 800 EI_s is 8.0μGy System calibrated at 70kVp with 21mm Al. filter for an EI_s of 350 kVp,mAs,time, and dose area product (DAP) are also displayed post exposure. There is no direct relationship between DAP and EI_s therefore use kVp, mAs, and time to determine patient exposure. Images should not be repeated on EI_s indexes alone. Examine image quality first. Typical clinical EI_s values are 200-400 but wide variances can occur

Manufacturer	Exposure Indicator	Optimum Range	Comments
iCRco	Exposure Index	Built in table of anatomic specific target exposures	Exposure Index $\propto \log [X \text{ (mR)}]$ Negative values represent underexposure; positive values represent over exposure. f#'s between -1 and +1 are the goal. 0 is ideal. f#'s may be thought of as somewhat similar to AEC density settings Color coded on acquisition WS: -2 to +2 is green; outside that range is red
Konica-Minolta	S number	100-400 (200 ideal-all exams)	Exposure \uparrow → S number \downarrow S number = 200/mR

DR (Direct Radiography) Exposure Index by Manufacturer (clinical ranges expected-not acceptance testing data)

Info in **RED (italic)** was taken from AAPM Task Group 116 preliminary draft version 9c of Nov. 25, 2007

S. Jeff Shepard and Jihong Wang, co-chairs. Members: Michael Flynn, Eric Gingold, Lee Goldman, Kerry Krugh, Eugene Mah Kent Ogden, Donald Peck, Ehsan Samei, and Charles E. Willis

The purpose of the report is to "recommend a standard indicator which reflects the radiation exposure that is incident on an image receptor after every exposure event that reflects the noise levels present in the image data. The intent is to facilitate the production of consistent, high quality digital radiographic images at acceptable patient dose based not on image optical density but on feedback regarding the image receptor exposure provided and actively monitored by the imaging system."

Manufacturer	Exposure Indicator	Optimum Range	Comments
Canon 14x17 detector supplied to various OEM's	Reached Exposure Ind (REX)	<i>Unitless</i>	Exposure to detector \uparrow → REX \uparrow <i>Linear relationship</i> <i>REX is a function of the brightness and contrast selected by the operator.</i> <i>Clinical REX numbers are not stated, but for a brightness of 16 and a contrast of 10, REX = 106</i> <i>Exposure cannot be judged simply by comparing REX values</i>

Manufacturer	Exposure Indicator	Optimum Range	Comments
Carestream (Kodak)	Exposure Index (EI)	1500-1800 (all exams) or slightly lower	<p>Exposure ↑ → Exposure Index ↑</p> <p>$E(mR) = 10^{(x-2000)/1000}$ where E is exposure in mR and x is the exposure index</p> <p>AEC systems are set up with an exposure index of 1740-1840. If exposure index is 1640-1740 then increase AEC exposure 25%</p> <p>If exposure index is 1840-1940 then reduce AEC exposure 20%</p> <p>"Low Exposure Optimization" algorithm provides less noise in areas of low exposure</p> <p><i>EIV ↑ by 300 → Exposure ↑ by 2 X</i></p>
GE Healthcare Definium 8000 Definium 700 (portables)	DEI (Dose Exposure Index)	0.20-2.50 (exam dependent)	<p>Exposure to detector ↑ → DEI ↑ <i>DEI ~ 2.4 x mR</i>. Adjustable for each site.</p> <p>GE detector is approximately equivalent to a 400 speed film/screen system.</p> <p>Defines exposure to detector, not to patient. Is only a <u>guideline</u> for an acceptable <u>range</u>. (continues on pg 18)</p>
GE Healthcare (contin)			<p>Can differ from facility to facility, from patient to patient, just like F/S technique charts but generally, DEI ranges for different size patients are about the same.</p> <p>kVp, mAs, mA, time are displayed post exposure. Use these to determine patient exposure</p> <p>DEI for portable detector same as for fixed rooms. (Not displayed on tomography images)</p> <p>Typical DEI ranges for various exams at a large midwestern university medical center: Cervical spines: 0.20-0.61; Skulls/sinuses: 0.36-1.07; T-spines: 0.46-1.38; Knee: 0.42-1.27 Ankle: 0.24-0.73; Wrist: 0.41-1.24; Arms: 0.41-1.27; Abdomen: 0.56-1.68; L-spines: 0.6-1.98; PA chest: 0.20-0.60; Lat chest: 0.26-0.78</p> <p>Manual techniques often produce better results than AEC in fixed rooms.</p> <p>Portables have organ programming for techniques-may be overridden.</p>
Imaging Dynamics	Accutech (f#)	-1 to +1	<p><i>Negative values represent underexposure; positive values represent over exposure.</i></p> <p><i>f#s between -1 and +1 are the goal. 0 is ideal. -2 to +2 are possible</i></p> <p><i>f#s may be thought of as somewhat similar to AEC density settings</i></p>

Manufacturer	Exposure Indicator	Optimum Range	Comments
Naomi (CCD sensors) This is an inexpensive retrofit (or original) install commonly seen in private offices	None indicated	NA	<p>These units originally came in "Lite" or "High Grade" resolution. Only High Grade now.</p> <p>Resolution $\uparrow \rightarrow$ # of detectors \uparrow</p> <p>The "sensor sensitivity" can be changed by the user via the software.</p> <p>Sensitivity $\uparrow \rightarrow$ Exposure required \downarrow (linear for mAs)</p> <p>Default sensitivity for High Grade is 500; for Lite is 125</p> <p>While there is no exposure indicator post exposure it is possible to <u>manually</u> enter the technique factors and send to the image where it is displayed and stored.</p> <p>Example of a technique chart at a sensitivity of 400: Bone/Abdomen/Extremity: SID = 100cm, with grid, 24cm patient, 75kVp/50mAs Thorax: SID = 200cm, with grid, 24cm patient, 120kVp, 4mAs</p> <p>Example of a technique chart at a sensitivity of 125: Bone/Abdomen/Extremity: SID = 100cm, with grid, 24cm patient, 92kVp/100mAs Thorax: SID = 200cm, with grid, 24cm patient, 120kVp, 14mAs</p>
Philips Med. Systems Digital Diagnost	Exposure Index (EI_s)	200-800	<p>Exposure to detector $\uparrow \rightarrow$ EI_s \uparrow (Linear relationship) Is a <u>range</u> and <u>guideline</u>.</p> <p><u>Older systems had EI_s $\downarrow \rightarrow$ Exposure \uparrow. That is no longer applicable</u></p> <p>EI_s is according to IEC standard. EI_s = 100 x K[μGy] where K is detector exposure</p> <p>Example: 250EI_s is 2.50μGy to detector. 500 EI_s is 5μGy. 800 EI_s is 8.0μGy</p> <p>System calibrated at 70kVp with 21mm Al. filter for an EI_s of 350</p> <p>kVp, mAs, time, and dose area product (DAP) are also displayed post exposure.</p> <p>There is no direct relationship between DAP and EI_s therefore use kVp, mAs, and time to determine patient exposure.</p> <p>Images should not be repeated on EI_s indexes alone. Examine image quality first.</p> <p>Typical clinical EI_s values are 200-400 but wide variances can occur</p>
Siemens Med. Solutions "Aristos" 17x17 detector but Siemens uses 3 different detectors in their product line including Canon	Exposure Index Ind. (EXI)	200-800	<p>Exposure to detector $\uparrow \rightarrow$ EXI \uparrow <i>Is linear: Double exposure \rightarrow double EXI</i></p> <p>With AEC (Iontomat) service sets up EXI at install to 378, at 70kVp, 2.1mmCu, no grid</p> <p>EXI can vary significantly. Use post exposure kVp/mAs to measure patient exposure.</p> <p>EXI of approx. 400 is typically seen but 100-1200 is possible</p> <p>There are no "typical" EXI indexes stated for various clinical exams.</p> <p>The same technique can result in a significantly different EXI between patients.</p> <p>If calibrated correctly and nothing is in the field, the EXI would be 1200-1600</p>
Swissray	Dose Indicator (DI)	Unitless	Info requested-no reply