Exposure Indicators

CR and DR systems assess the recorded signal to indicate whether the radiographic technique used is appropriate.
- Tests using defined beam conditions are used to verify that correct indicators are being reported.
- Recommended indicator ranges are used by technologists to check each radiographic exposure.

Screen-Film system indicators

For traditional screen-film systems, overall film density is used as an indicator.
For CR & DR systems, image processing aligns the grayscale with the signals. However, the image processing adjusts the grayscale. Images with low signals are noisy, and images with high signals are associated with high dose.

Exposure Indicators describe image quality in terms of the signal to noise ratio (SNR). SNR is independent of mAs and is therefore the same for simulations.

The signal recorded by the detector is indicative of the image signal to noise ratio (SNR). Systems vary in the region used to assess the signal for an image.

- Full Image
- Regular regions
- Anatomic regions

Region to assess signal indicator
Gray histogram for the entire image.
Black histogram for the anatomic region (relevant region).

Exposure indicators are typically computed from the probability distribution of signal values.

- **IEC 62494-1**: The indicator shall be computed using the mean, median, mode, trimmed mean, trimean, or other recognized statistical method for the description of central tendency of the signal(s) in the relevant image region.

- **AAPM TG 116**: “The median is recommended rather than the mean or mode because it is less affected by data extremes and outliers.”

**Ado CR**
- 75 kVp
- 1.5 mm Cu
- 400 Speed Class
- $\lg M = 1.96 + \log(\mu G/2.5) + \log(Speed/400)$
  
  $\lg M = 1.9607 + \log(\mu G/2.5) + \log(Speed/400)$
**Fuji & Konica CR**
- 80 kVp
- No added filtration - "3 mm Total Filtration"
- "Semi" EDX mode (Fuji)
- "Sensitivity" processing
- $S = 200 \div \text{Kcal} = 1 \text{ mR}$
- $S = 200/\text{mR}$

Recommend using 0.5 mm Cu + 1 mm Al
FSE will argue - be prepared to call corporate HQ

**Kodak CR & DR**
- 80 kVp
- 0.5 mm Cu + 1 mm Al
- $\text{EI} = 2000 \div \text{Kcal} = 1 \text{ mR}$
- May have an offset at low exposure

$\text{EI} = 1000\times\log_{10}(\text{mR}) + 2000$

**Imaging Dynamics**
- 80 kVp
- 1 mm Cu
- $S = 200 \div \text{Kcal} = 1 \text{ mR}$
- Defined target speeds, $S_T$
- $S_T = 200/\text{mR}$

$f# = \log(S/\text{S}_T)$

**Philips DR**
- 70 kVp (RQ45)
- 21 mm Aluminum
- HVL = 7.1 mm Al
- $\text{EI} = 4000 \div \text{Kcal} = 0.26 - 0.32 \text{ mR}$
- EI coarsely rounded, KV correction applied

$\text{EI} = 1000/\mu G$
GE DR (Definium)
- 80 kVp
- 1 mm Al in collimator filter slot/wheel
- 20 mm Al (with system) at collimator face
- Uncompensated detector µG (standard beam)
- Compensated detector µG ((kVp, grid, filter))
- DEI – ratio of PV to target PV.
**AAPM TG 116**

An exposure indicator for digital radiography: AAPM Task Group 116 (Executive Summary)

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**IEC Standard**

IEC published a standard for Exposure Index definitions in August of 2008

IALSTANDARD

IEC 62484-1

INTERNATIONAL STANDARD

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**Topics**

A. Exposure Indicators
   B. Manufacturer Indices
   C. IEC – AAPM Standardization
      i. Beam Spectrum (kVp & filtration)
      ii. Measurement of entrance exposure
      iii. Exposure Index & Deviation Index
TG116 & IEC used RQA5 as a reference for the beam quality:

- 70 kVp
- RQA5 pre-filtered beam
- 21 mm added pure Al filtration
- 6.8 mm Al HVL

Both groups recognized that RQA5 is impractical for field measurements and sought an alternative.

### AAPM TG116 beam conditions

- 70 ± 4 kVp
- 0.5 mm Cu + (0 – 4) mm Al (type 1100)
- Brass acceptable as a Cu substitute
- 21 mm pure Al acceptable.
- HVL = 6.8 mm Al (type 1100)
- Adjust Al and (if necessary) kVP to get HVL

### IEC Beam condition differences

- 0.5 mm Cu + 2 mm Al
- No added Al filter adjustment
- HVL = 6.8 ± 0.3 mm Al

TG116 showed reported equivalent spectral shape with RQA5 conditions and Cu/Al filtration:

- HVL: 6.8 mm Al
- Normalized Spectra, Cu/Al spectrum is about 2X that of RQA5

TG116 illustrated how the addition of different Al filters to a Cu filter could compensate for differences in the unfiltered beam quality.
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Beam setup – step 1
- Prior to any measurements verify that the x-ray source has acceptable exposure reproducibility (coefficient of variation < 0.03) and kV accuracy (within ± 3%) at the standardized condition.
- Add 0.5 mm copper filtration at the face of the collimator.

Beam setup – step 2
- Collimate the x-ray beam to only cover the ion chamber with no more than 1 inch margin.
- For DR systems, the detector should be covered with a lead apron or similar barrier when making the exposures for HVL determination and adjustment.
- Measure the HVL of the filtered beam and adjust the kVP and/or aluminum filtration within the limits specified in Table 1 to obtain a HVL as close as possible to 6.8 mm Al.

Beam setup – step 3 (DR)
- The detector should be placed as far from the x-ray source as is practical, at least 100 cm.
- If present, remove the grid and any other components between the ion chamber and the image detector. If any components cannot be removed, obtain the attenuation factor from the DR system or component vendor.
Beam setup – step 3

- If the detector is a CR plate, the cassette should be separated from any surface that may increase backscatter from that surface entering the cassette, as recommended in AAPM Report 93 (TG10). Use lead behind the plate to further reduce backscatter.
- If the detector is not square, the long axis of the detector should be perpendicular to the x-ray tube A-C axis.

Beam setup – step 5

- Place a calibrated ion chamber at the center of the beam approximately midway between the source and detector (Position A).
- All distances should be measured from the focal spot as indicated on the x-ray tube housing.

Beam setup – step 6

- Use lead to protect a DR detector.
- Make an exposure to determine the air kerma at the detector (KSTD) using an inverse square correction.
- Apply the grid attenuation factor, if necessary.
- Change the mAs setting to obtain the desired air kerma at the detector. In general, the desired air kerma will produce a value of KSTD that is in the middle of the detector response range.

- Move the ion chamber perpendicular to the x-ray beam such that it is at the edge of the field of view (Position B).
- Place the ion chamber as close to the edge of the x-ray beam as possible within the field of view of the detector. Ensure that the entire ion chamber is in the radiation beam and is not shadowed by a collimator blade.
- Make an exposure using the mAs found earlier and determine the ratio of the air kerma at Position A to that at Position B.
- Determine the protective lead and expose the receptor.
- Correct the recorded exposure for position and distance to determine the detector air kerma.
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Indicated equivalent air kerma (K_{\text{IND}}):

An indicator of the quantity of radiation that was incident on regions of the detector for each exposure made.

The value reported may be computed from the median for processing pixel values in defined regions of an image that correlates with an exposure to the detector.

The median value is then converted to the indicated air kerma (K_{\text{IND}}) from a standardized radiation exposure that would produce the same detector response, i.e., result in the same median for processing signal value Q in a predefined ROI.

The value should be reported in µGy units with three significant figures of precision.

Exposure Index – TG116

Normalized for-processing pixel values Q_{o} are for-processing pixel values Q which have been converted to have a specific relation to a standardized radiation exposure (K_{\text{STD}}).

After conversion of Q_{o} to Q_{K}, the relationship between air kerma at the input surface of the detector and the Q_{K} value is:

\[ Q_{K} = 1000 \log_{10} \left( \frac{K_{\text{STD}}}{K_{0}} \right) \]

where K_{\text{STD}} is in microgray units, K_{0} = 0.001 µGy, and K_{\text{STD}} > K_{0}.

Exposure Index (EI):

A measure of the detector response to radiation in the relevant image region of an image acquired with a digital x-ray imaging system.

For a fixed radiation quality, the signal generated in the detector is proportional to the image receptor air kerma.

The exposure index EI shall be calibrated for the digital x-ray imaging system over the specified operating range of image receptor air kerma such that:

\[ EI = 100K_{R} \]

where K_{R} is the image receptor air kerma in µGy under the calibration conditions.
Deviation Index (DI)

AAPM TG116 & IEC

\[ DI = 10 \log \left( \frac{K_{NO}}{K_{TA}} \right) \]

- \( K_{NO} \) is a target index value that is to be determined for each body part, view, procedure type, and clinical site.
- When \( K_{NO} = K_{TA} \), \( DI = 0 \).
- \( DI = +3.0 \) for 2x target exposure.
- \( DI = -3.0 \) for 0.5 target exposure.
- ±1 is one step on a standard generator mAs control or AEC compensation (ISO R5 scale).

Exposure Indices

- Exposure Index
  - Air-kerma at the receptor
  - \( K_{IND} = K_{rec} \) (uGy)
  - \( EI = K_{cal} \times 100 \mu G_{y}^{-1} \) (unitless)

Calibration

- Energy
  - RQA-5: 66 - 74 kVp

Filtration

- RQA-5 Equivalent
  - 0.5 mm Cu (+ 0-3 mm Al)
  - 21 mm Al
  - 6.8 + 0.2 mm Al HVL

Deviation Index

\[ DI = 10 \log \left( \frac{K_{NO}}{K_{TA}} \right) \]

Di format

- Signed decimal string with 1 decimal point

Unspecified