Cleveland Clinic

Current Implementation Status of IEC Standard 62494-1: Exposure Index (EI) for Digital Radiography

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Disclosures

- None

Outline

- Review of IEC Standard 62494-1
- Vendor-specifics of verifying compliance with IEC Standard
- Vendor Implementation of IEC Standard
  - Determination of:
    - Relevant Image Region
    - Value of Interest
    - Implications for calculated Exposure Index
  - Deviation Index and Target Exposure Index Values

REX

IgM

S

EI

EXI

f#

TG-116 - An Exposure Indicator for Digital Radiography
Appendix C (p42)

One true index to unite them all...

IEC 62494-1

Edition 1.0 2008-08

INTERNATIONAL STANDARD

A unified EXPOSURE INDEX for all digital radiography systems is needed to simplify its usage, e.g. for the establishment of exposure guidelines, particularly when systems of different manufacturers are used within the same department.

This standard defines such a concept of the EXPOSURE INDEX.

IEC 62494-1 (page 5)

Exposure Index

- The exposure index (EI) shall be related to the value of interest (V) according to the formula:

$$EI = c_0 \cdot g(V)$$

  - c_0 = 100 μGy^{-1}
  - $g(V)$ is the equipment-specific inverse calibration function

IEC 62494-1

ORIGINAL DATA

The following corrections shall be made to the RAW DATA as in normal clinical use:

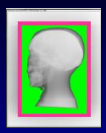
- *Bad or defective pixels*
- *Flat-field corrections*
- *Corrections for geometric distortion*

IEC 62494-1

ORIGINAL DATA

Determine the ***Relevant Image Region***

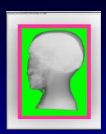
- *Image Segmentation*
- *Histogram Based*
- *Other*



IEC 62494-1

Determine the ***Relevant Image Region***

- *Image Segmentation*
- *Histogram Based*
- *Other*



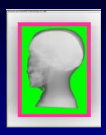
*The determination of the **RELEVANT IMAGE REGION** should be done by methods that identify the attenuated regions of the beam that are relevant to the diagnostic purpose of the acquired image.*

NOTE 2 While it is understood that the selection of the RELEVANT IMAGE REGION is an important step in the generation of the EXPOSURE INDEX and that a single unified method may be desirable, it is not feasible at this time. Future version of the standard may address this issue.

IEC 62494-1 (page 9)

IEC 62494-1

Determine the ***Relevant Image Region***



Calculate the ***Value of Interest***

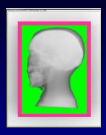
V

- *Mean*
- *Median*
- *Mode*
- *Trimmed mean*
- *Trimean*
- *Other*

Measure of Central Tendency

IEC 62494-1

Determine the ***Relevant Image Region***



Calculate the ***Value of Interest***

V

$$EI = c_0 \cdot g(V)$$

Calculate the ***Exposure Index***

Exposure Index Calibration

- The EI is to be calibrated such that under calibration conditions:

$$EI = c_0 \cdot K_{CAL}$$

  - c_0 = 100 μGy^{-1}
  - K_{CAL} is the image receptor air kerma in μGy under the calibration conditions

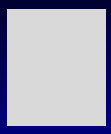
Calibration Conditions

- Fixed beam quality (~RQA5):
  - HVL of 6.8 ± 0.3 mm Al
  - Added filtrations of either:
    - 21 mm Aluminum
    - 0.5 mm Copper and 2mm Aluminum
  - X-ray tube voltage 66kVp – 74 kVp
    - Adjust tube voltage to obtain target HVL

Calibration Conditions

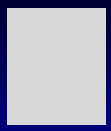
- Homogenous irradiation of the effective image receptor area
- Measurement of image receptor air kerma should be made free-in-air (no backscatter)

Calibration Conditions



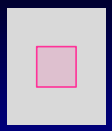
Homogenous irradiation of the effective image receptor area using FIXED BEAM QUALITY

Calibration Conditions

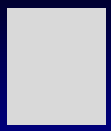


Determine the
Relevant Image Region

- *Central 10% of image area*



Calibration Conditions



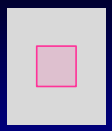
Determine the
Relevant Image Region

Calculate the
Value of Interest

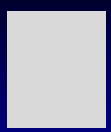
V_{CAL}

- *Mean*
- *Median*
- *Mode*
- *Trimmed mean*
- *Trimean*
- *Other*

Measure of Central Tendency



Calibration Conditions



Determine the
Relevant Image Region

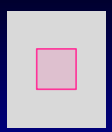
Calculate the
Value of Interest

V_{CAL}

Calculate K_{CAL}

$$K_{CAL} = g(V_{CAL})$$

$$EI = c_0 \cdot K_{CAL}$$



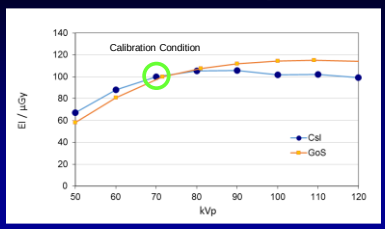
Inverse Calibration Function

- $g(V_{CAL})$ is the inverse calibration function:

$$K_{CAL} = f^{-1}(V_{CAL}) = g(V_{CAL})$$

- The specified inverse calibration function shall have an uncertainty of less than 20% under calibration conditions

Beam Quality Dependence



21 mm Al

CsI data acquired on GE Flashpad DR Detector
GoS data acquired on Fuji FDR D Evo II DR Detector

Deviation Index

- If target exposure index (EI_T) values are provided by the system, the deviation index (DI) shall be automatically calculated according to:

$$DI = 10 \cdot \log_{10}\left(\frac{EI}{EI_T}\right)$$

NOTE 1 For this purpose, the TARGET EXPOSURE INDEX values for different examinations/applications need to be available on the digital x-ray imaging system, e.g. in a data base. Such values may be established by professional societies or by the responsible organization. IEC 62494-1 (page 12)

Summary *IEC 62494-1*

- The IEC Exposure index (EI) is linear with incident detector air kerma
- The standard explicitly defines the conditions under which the EI shall be calibrated
  - Relationship between EI and incident detector air kerma will vary with beam quality

Summary *IEC 62494-1*

- The standard does not define the method by which the vendor:
  - Determines the *Relevant Image Region*
  - Calculates the *Value of Interest*

Summary *IEC 62494-1*

- The standard does not attempt to establish Target Exposure Index (EI_T) values
  - Leaves this to professional societies and responsible organizations
  - States that they should be available on the system for the purposes of calculating the Deviation Index (DI)
  - Acknowledges that EI_T values may depend on:
    - Type of detector
    - Type of examination
    - Diagnostic question

Implementation Status

2008 → 2017

- Who has implemented IEC 62494-1?
- What do you need to know for verifying compliance with IEC 62494-1?
- Differences in vendor approaches to implementation?

Who has implemented IEC 62494-1?

Vendor	Legacy Exposure Indicator	IEC Compliant Exposure Index
Agfa	lgM *(No longer in use)*	EI
Canon	REX	EI
Carestream	EI*	EI
Fuji	S	EI
GE	DEI *(No longer in use)*	EI
Konica	S	EI
Philips	EI*	EI_s
Siemens	EXI	Clinical EXI*

*Not to be confused with the IEC exposure index (EI)
**The Clinical EXI is normalized to calibration conditions (Physical EXI is NOT, unless requested by site), note, however, that the Clinical EXI is determined from histogram analysis as opposed to a fixed ROI

Vendor Implementation

- The IEC standard explicitly states that the following items shall be documented:
  - The filter and x-ray tube voltage used for calibration
  - The method used for the selection of the relevant image region
  - The method used to calculate the value of interest
  - The inverse calibration function and the range of image receptor air kerma for which the inverse calibration function can be used to calculate the image receptor air kerma from the value of interest under calibration conditions

Vendor Questionnaire

- What is the inverse calibration function and range of image receptor air kerma for which the inverse calibration function can be used to calculate the image receptor air kerma from the value of interest under calibration conditions?
- What are the vendor's calibration conditions for verifying accuracy of the IEC exposure index (EI)?
  - Recommended beam quality (filter, HVL, kVp) and SID?
- What exam tag(s), image processing parameters, and/or tools should be used to ensure a fixed region of interest at the center of the image is used when verifying accuracy of the EI ?
  - Size of VOI used to determine EI under these conditions?
- What is the vendor's tolerance for accuracy of the EI?
- If EI is out of tolerance, what is the methodology for calibrating the EI to bring back it in tolerance (if it exists)?
- For clinical images, how is the relevant image region and value of interest (VOI) determined?
  - Are there specific assumptions made that the user should be aware of that can affect the EI that is displayed?
- Does the vendor recommend Target Exposure Index values for various exams / anatomical regions?
  - If so, do these come pre-programmed and can they be modified?

Vendor Implementation

Filter and beam quality used for calibration verification

Vendor	Calibration Filter	Beam Quality
Agfa	21 mm Al or 0.5 mm Cu+ 2 mm Al (recommended but not provided)	RQA5 (HVL of 6.8± 0.3 mm Al)
Canon	21 mm Al (recommended but not provided)	~RQA5 (HVL of 7.1± 0.1 mm Al
Carestream	21 mm Al or 0.5 mm Cu + 2 mm Al (recommended but 0.5 mm Cu & 1 mm Al provided)	RQA5 (HVL of 6.8± 0.3 mm Al)
Fuji	21 mm Al or 0.5 mm Cu + 2 mm Al (recommended but not provided)	RQA5 (HVL of 6.8± 0.3 mm Al)
GE	20 mm Al (filter provided by manufacturer)	RQA5 (HVL of 6.8± 0.3 mm Al)
Konica	21 mm Al or 0.5 mm Cu+ 2 mm Al (recommended but not provided)	RQA5 (HVL of 6.8± 0.3 mm Al)
Philips	21 mm Al (filter provided by manufacturer)	RQA5 (HVL of 6.8± 0.3 mm Al)
Siemens	0.6 mm Cu (insert internal filtration)	~RQA5 (HVL of 6.8± 0.3 mm Al)

Vendor Implementation

Method used for the selection of the relevant image region*

*For Verification of EI Under Calibration Conditions

Vendor	Exam Tag	How to Define a FIXED ROI	Size of ROI
Agfa	"*System Diagnosis with Flat Field*"	Use manual ROI tool	User defined
Canon	Service Tag "*AEC*" (used for AEC calibration)	n/a (determine by exam tag)	10cm x 10cm (center of detector)
Carestream	"*Pattern*"	Use manual ROI tool	User defined
Fuji	"*Sensitivity*"	n/a (determine by exam tag)	10cm x 10cm (center of detector)
GE	n/a	Enable "Technical Mode"	10cm x 10cm (center of detector)
Konica	"*S-Value*"	n/a (determine by exam tag)	10cm x 10cm (center of detector)
Philips	n/a	Use "Simple Ranger Tool"	User defined
Siemens	n/a	Physical EXI*	According to DIN 6868 Part 58 (center of detector)

*The Clinical EXI is normalized to calibration conditions (Physical EXI is NOT, unless requested by site), note, however, that the Clinical EXI is determined from histogram analysis as opposed to a fixed ROI

Vendor Implementation

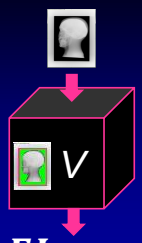
What if my EI is out of tolerance?

Vendor	Tolerance on EI Accuracy	Method to Re-Calibrate EI?
Agfa	± 20% (per IEC)	No
Canon		No
Carestream		Yes
Fuji		Yes
GE		Yes (fixed rooms) No (mobile units)
Konica		Yes (formerly No)
Philips		No
Siemens		Yes*

*Separate calibration factors for Clinical EXI and Physical EXI, vendor procedures only address calibration of Clinical EXI

ACCEPTANCE TESTING IS IMPORTANT

Vendor Implementation



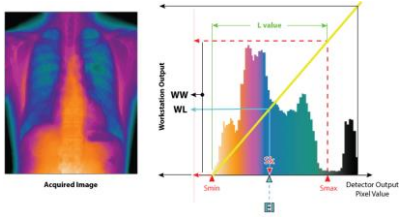
?

Relevant Image Region

Value of Interest

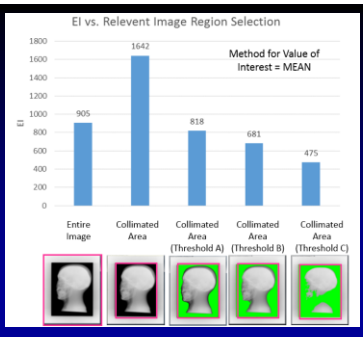
$$EI = c_0 \cdot g(V)$$

Relevant Image Region

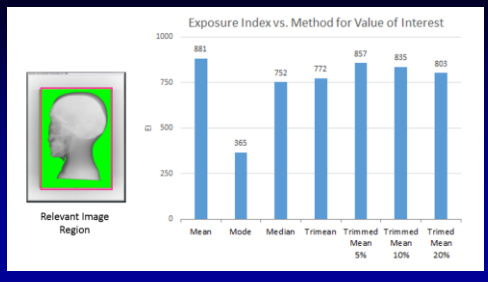


FUJIFILM
Value from Innovation

Relevant Image Region



Value of Interest Calculation



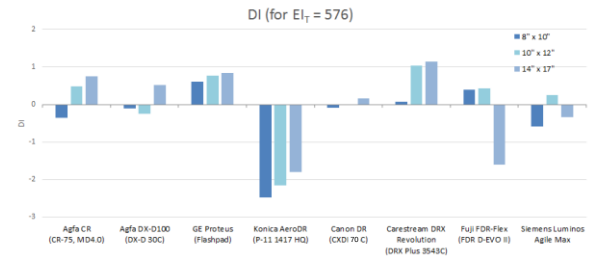
Vendor Implementation

Method used to calculate the value of interest

Vendor	Relevant Image Region Determination (Clinical)	Value of Interest Calculation Method
Agfa	• Image Pixel Histogram • Clinical features • Geometric location & exposure level • Noise, signal & tissue variation measurements	Median
Canon	• Exposure field identification • Histogram analysis	Mean
Carestream	• Exposure field identification • Histogram analysis • Clinical Features	Trimmed Mean
Fuji	• Exposure field identification • Histogram analysis	Mean
GE	• Exposure field identification • Histogram analysis	Median
Konica	• Uses the same ROI as used in automatic gradation processing • Split pattern recognition • Exposure field identification • Histogram analysis	2-point average of Reference Values (L and H)
Philips	• Exposure field identification • Histogram analysis	Trimean
Siemens	• Exposure field identification • Histogram analysis	Mean

Multi-Vendor Head Phantom Study

- Imaged head phantom on various DR panels
  - 8"x10"
  - 10"x12"
  - 14"x17"
- Consistent positioning and collimation
- Same detector dose in all images
- Recorded Exposure Index values
  - scaled and corrected for input dose & panel sensitivity
- Theoretically, differences in EI should be mostly due to differences in vendor approach



Target EI

Factory preset EI$_T$?

Vendor	Vendor EI$_T$ values	Implementation of DI
Agfa	Recommended Values – Configured by Apps (editable)	Yes
Canon	Not currently provided (editable)	Yes
Carestream	Preprogramed (editable)	Yes
Fuji	Preprogramed (editable)	Yes
GE	Preprogramed (editable)	Yes
Konica	Preprogramed (editable)	Yes
Philips	No	No
Siemens	Preprogramed (editable)*	Yes*

Conclusions

- IEC Standard 62494-1 is widely implemented by vendors
  - Sometimes in tandem with legacy dose indicators
- Vendor documentation can be hard to come by
- Differences in vendor methods of implementation can lead to appreciable variation in EI values
  - Range of more than 2.5x with head phantom for same input AK
  - Differences in vendors likely to be exam specific as well
- Shows need for vendor specific Target Expose Indexes at this time
- Panel EI sensitivity may need to be accounted for
  - Some vendors don't allow recalibration
- Variation in implementation can make quality control efforts difficult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