MAHIDOL UNIVERSITY
Wisdom of the Land

How to start working with your Digital Imaging

Napapong Pongnapang, Ph.D.
Department of Radiological Technology
Faculty of Medical Technology
Mahidol University

Content

- Optimization of DR Image
  - Exposure
  - Positioning
  - Collimation
  - Image Processing
  - Grid
- General Guidelines

What do we need?

- Technical and Clinical Image Quality
  - Anatomical coverage
  - Good contrast and sharpness of organs
  - Clinical representation of organs
- Physical Image Quality
  - Contrast
  - Spatial resolution
  - Noise
- Patient Safety

DR Users Guidelines

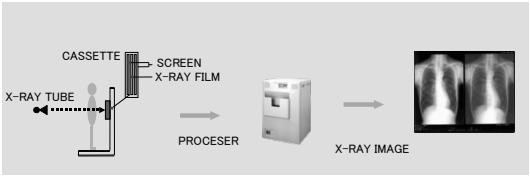
- Technologist professional guidelines
  - Know about workflow change
  - Technical adjustments for best image quality
  - Artifacts evaluation
- Acceptance Test and Quality Control
  - Quality control program to assure optimal image quality

Technologist professional guidelines

1. Workflow changes

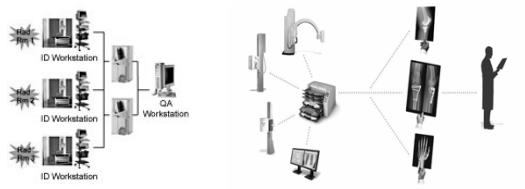
Workflow: DR vs. Conventional

CONVENTIONAL X-RAY IMAGING SYSTEM

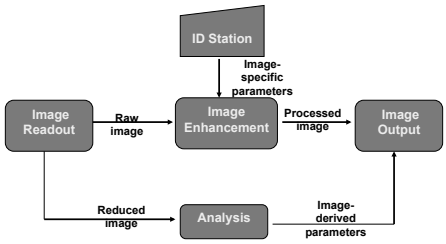


Workflow: DR vs. Conventional

DIGITAL X-RAY IMAGING SYSTEM



DR IMAGE PROCESSING FLOW DIAGRAM



2. Technical Settings

- Positioning
- Collimation
- Exposure factors
- Image processing selection

Positioning

- Good positioning = good anatomical delineation
- This applies to both conventional and digital radiographic exams
- Keep in mind! : No image processing can create anatomical views that are not properly set by you.

Collimation

- Conventional Radiography
  - Adequate collimation – good image quality with less radiation dose
- Digital Radiography
  - Proper collimation – contrast optimization
  - Matching collimation with image processing parameter (exposure area recognition process) – acceptable image quality for each technique

Why collimation is necessary in DR?

- Most DR image processing needs proper collimation
- Improper collimation will result in poor image quality
- Need to refer to what has been set by Manufacturer

Grids

- Grids help reject scattered radiation and optimize image contrast
- In DR, do we need grids?
- The answer is YES!

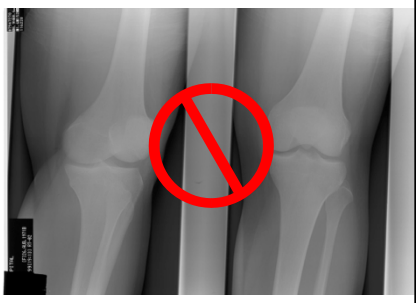
Proper Grid Use

- Any part over 10 cm thickness
- 5:1 or 6:1 for portable chest
- Thicker portables require 8:1 or higher
- 150 LPI recommended
- Good positioning and centering

Grid Recommended

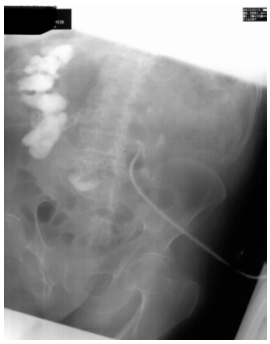
Knees
Shoulders
C-Spines

Subjects
>10 cm



Grid Cut-Off

Lowers Image Contrast
-
Grid Lines Visible
-
Image appears "blurry"

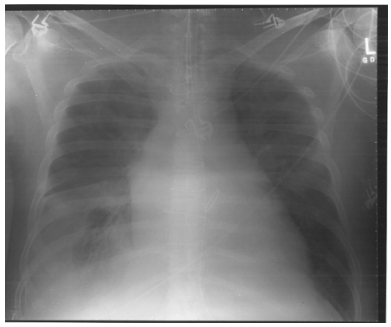


Portable Chest - No Grid

>10 cm

80 kVp

Day 1

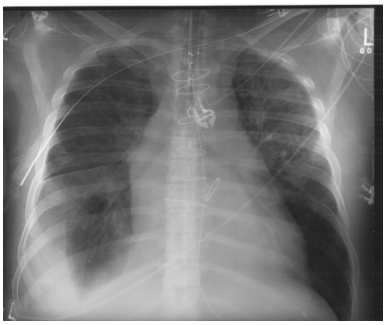


Portable Chest – 6:1 Grid

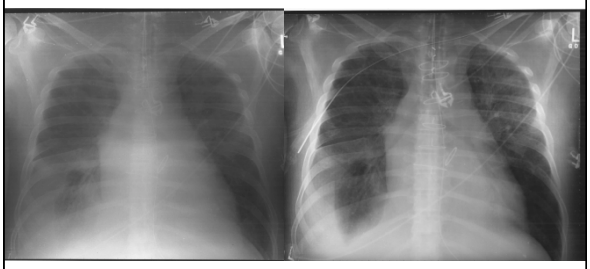
Same Pt.

85 kVp

Day 2



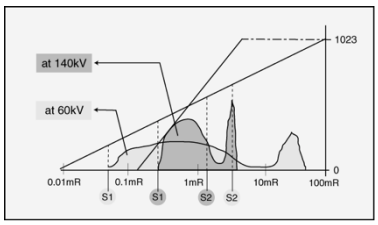
You be the Judge



Exposure factors

- Exposure factors, i.e., kVp and mAs are VERY important in DR
- Keep in mind that image processing were pre-adjust to receive proper information from you to produce optimal quality images.
- Mismatch exposure factors with image processing will result in poor image quality

Histogram obtained from different kVp but same mAs



Histogram obtained from different mAs but same kVp

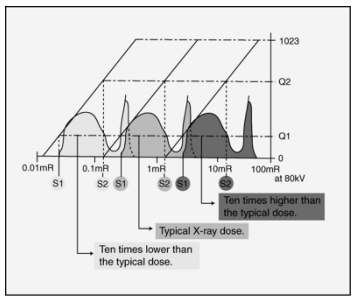


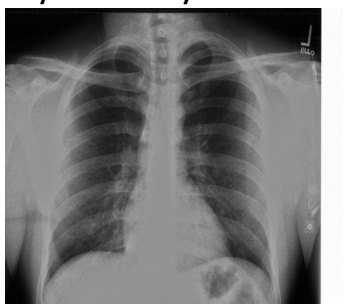
Image quality vs. dose in DR

- Signal to Noise Ratio (SNR) is important in digital imaging
- Poor SNR results in poor low contrast detectability
- Low radiation dose gives poor SNR
- SNR can be improved by increasing the dose (mAs) but patient dose will be high.

Why So Noisy?

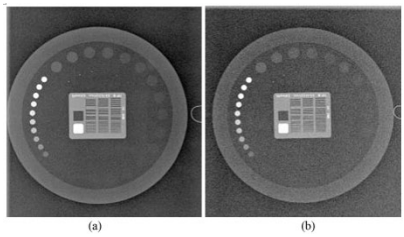
"S" Number 5200

"I Used the Photo-timer"



Then something is wrong with your AEC

Effect of SNR



(a) 70 kVp, 2 mAs; (b) 70 kVp, 0.5 mA

Understand Exposure Index

PHILIPS

The Exposure Index and Its Standardization

Ulrich Neitzel
Philips Medical Systems – Clinical Science
Hamburg, Germany

ulrich.neitzel@philips.com

PHILIPS

Content

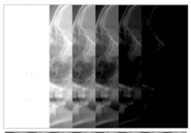
- The Exposure Index (EI)
  - What is it?
  - What is it good for?
  - What are its limitations?
  - How can it be improved?

PHILIPS

Conventional and Digital X-ray

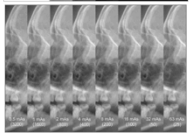
- Conventional X-ray:

  Fixed dose requirement due to fixed film speed



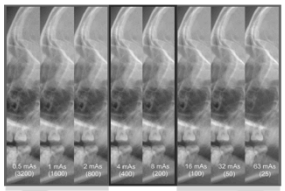
- Digital X-ray:

  Wide dynamic range
  = variable speed
  = wide range of possible doses



PHILIPS

Wide Dynamic Range: A Two-Edged Sword



Potential for dose reduction | How to control the dose? | Risk of overexposure

PHILIPS

Dose Monitoring

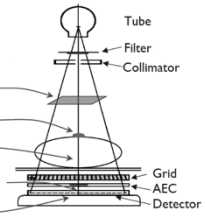
- ALARA Principle
  Dose „As low As Reasonably Achievable“
- EU-Directive 97/43/EURATOM
  - Justification, Optimization
  - Patient Dose Monitoring
  - Diagnostic Reference Values

PHILIPS

Dose-Related Quantities

Philips DigitalDiagnost:

- Kerma-area product (KAP)
- Entrance skin exposure (ESE)
- Effective dose
- Detector exposure (air kerma)
- Exposure index (EI)



PHILIPS

Why is the KAP not enough?

- The KAP does not indicate approriateness of exposure level in the individual case.
- Under- and overexposed images (in sense of noise level) cannot be identified from the KAP value.
- In radiography, KAP gives only an upper limit of dose in a statistical (average) sense.
  ⇒ comparison to DRL

PHILIPS

What is the EI good for?

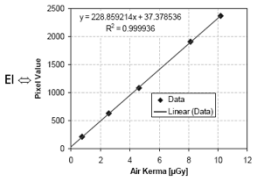
- Feedback to radiographer about appropriate exposure level in clinical routine („speedometer“)
- Comparison with prescribed „speed classes“ for radiographic examinations
  - e.g. in Germany most examinations should be done with „400 speed“
- Quality control tool for medical physicist (e.g. for dose check @ constancy test)

PHILIPS

EI as Dosemeter

- If properly calibrated, digital detectors can be used as „dosemeters“
- Flat-field exposure
- Known (calibrated) beam quality

⇒ Exposure in µGy can be calculated from the Exposure Index



PHILIPS

Be aware!!

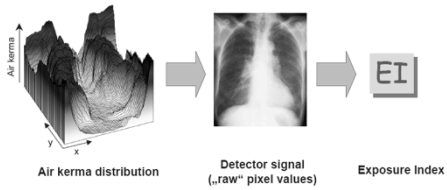
The Exposure Index

- is related to **detector exposure**, NOT to patient exposure
- does not replace **patient dose** related parameters (like dose-area-product, entrance skin exposure)

Both are necessary for dose-conscious work

PHILIPS

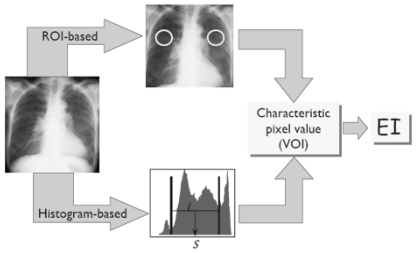
Determination of Exposure Index



Air kerma distribution | Detector signal („raw" pixel values) | Exposure Index

PHILIPS

Determination of Exposure Index



PHILIPS

Determination of "Value of Interest (VOI)"

Different concepts:

- ROI based
  - e.g. mean value of center 25% area
- Histogram based
  - e.g. mean of relevant pixel value range
- Combination
  - Histogam evaluation of subarea

PHILIPS

Now to the Practice....

- Using the EI for monitoring the exposure levels in routine clinical work
- Example Philips DigitalDiagnost

PHILIPS

Digital Diagnost Exposure Index (EI)

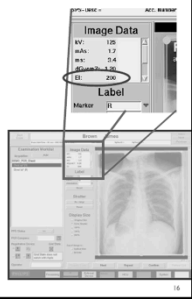
- Monitors exposure incident on detector
- Derived from pixel values of the actual image
- Scaled identically to film speed

Exposure Index EI	Detector Exposure [µGy]
160	6.3
200	5.0
250	4.0
320	3.1
400	2.5
500	2.0
630	1.6
800	1.3
1000	1.0
1250	0.8
1600	0.63
2000	0.5

PHILIPS

Clinical Dose Monitoring

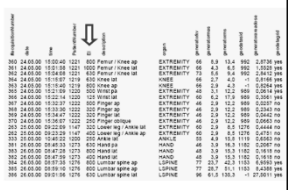
- Feedback about dose-relevant parameters
  - Examination settings (kV, mAs, ms, filter, ...)
  - **Exposure Index (EI)** and Kerma-Area Product (KAP)
- Displayed at acquisition workstation
- Included in the DICOM image header



PHILIPS

Exposure Log

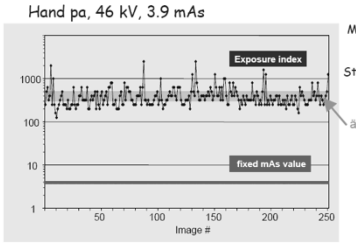
- Philips Digital Diagnost:
  Log file contains all relevant parameters for each exposure:
  - date, time
  - pat ID, image #
  - exam type
  - kV, mAs, ms, SID
  - grid, filter
  - field size
  - EI, DAP
  - processing type
  - ....



PHILIPS

Exposure Index: Free Technique

Hand pa, 46 kV, 3.9 mAs



Median value: EI = 320

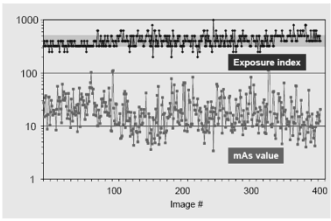
Std. Deviation: ± 70%

äquivalent „400"

PHILIPS

Exposure Index: AEC Technique

Pelvis ap, 77 kV, AEC



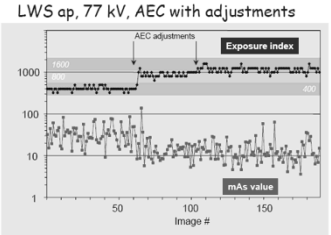
Mean value: EI = 400

Mean deviation : ± 25%

PHILIPS

Exposure Index: AEC Technique

LWS ap, 77 kV, AEC with adjustments



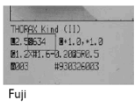
Even small adjustments/ changes can be detected

PHILIPS

Exposure Index Today

.... like European currencies before the EURO

Kodak



Fuji

Agfa

Philips

???

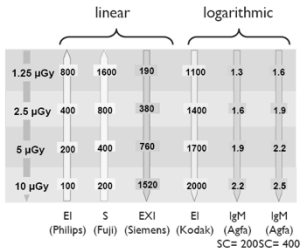
PHILIPS

The EI "Currencies"

	Name	Symbol	Range (typ.)	Value @2.5 µGy
Agfa (CR)	Logarithmic median	LgM	1.6 – 2.2	Depends on selected speed
Canon (DR)	Reached Exposure	REX	?	Depends on processing
Fuji (CR)	Sensitivity	S	200 – 800	200
Kodak (CR)	Exposure Index	EI	1300 – 1800	1500
Philips (DR)	Exposure Index	EI	200 – 800	400
Siemens (DR)	Exposure Index	EXI	200 – 800	380(?)

PHILIPS

Exposure Index Scales



PHILIPS

Exposure Index: Limitations

- The EI is a nice tool for dose monitoring – where is the problem?
  - Different scales
  - Different algorithms
  - Different calibrations

EI values between modalities/vendors are not directly comparable

PHILIPS

So what is necessary?

- Unification of EI of DR and CR
- Unification of EI of different vendors
- Unification of calibration conditions

Introduce the Exposure Index € or $!

PHILIPS

Standardization Activities

- AAPM (American Association of Physicists)
  - Task Group 116 "DR Exposure Index"
- DIN NAR (NormenAusschuss Radiologie)
  - AK Dosisindikator

IEC New Work Item Proposal (2006)

PHILIPS

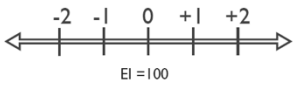
Standardized EI: Concept (WIP)

- Shall reflect detector exposure
- Derived from pixel value (VOI)
- Lin scale proportional to detector signal / dose
- Still open: radiation quality for calibration
- Still open: scale
  - AAPM: directly in µGy
  - DIN: proportional, but not directly µGy
- Still open: scale resolution / precision

PHILIPS

Relative EI

- Additional "relative" or "deviation" index
- Indicates EI deviation from an established optimal value
- Optimal value can be dependent on
  - Examination type
  - Detector type
  - Hospital



PHILIPS

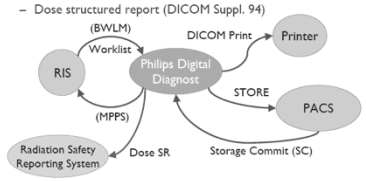
Precision and Nominal Values

- Which precision is appropriate for stating EIs ?

PHILIPS

DICOM Integration

- Full integration into digital environment
  - Dose information included in DICOM header
  - Dose information printed on film hardcopy
  - Dose feedback to RIS via MPPS
  - Dose structured report (DICOM Suppl. 94)



PHILIPS

DICOM Radiation Dose Report

- New DICOM Supplement 94 (Nov 2005)
  - „Diagnostic X-ray radiation dose reporting (Dose SR)"
- DICOM Structured Report object
- Provides mechanism for extensive dose reporting
- Can be independent of PACS or RIS

PHILIPS

Exposure Index and DICOM

Where should the value(s) be stored?

Tag	Attribute Name	Description
~~0018,1152~~	~~Exposure~~	~~Tube current-time product in mAs~~
~~0018,1155~~	~~Image Area Dose Product~~	~~Kerma-area product in dGy · cm²~~
~~0018,1404~~	~~Exposures on plate~~	~~Number of exposures on plate~~
0018,1405	Relative X-ray Exposure	Relative exposure on plate ✓
0018,6000	Sensitivity	Detector sensitivity ✓
~~0040,0302~~	~~Entrance Dose~~	~~Entrance dose on the patient [dGy]~~

PHILIPS

EI Standardization

- Terms and definitions
- Basic concept
- Scale and calibration point
- Precision and nominal values
- Required/attainable accuracy
- DICOM documentation

} Possible standardization issues

- VOI determination
- Algorithmic details

} Probably not standardization issues

Image processing selection

- There are many image processing option available.
- Good to learn effects of different image processing algorithm
- Keep in mind that
  - Image processing cannot create anything that is not in the patient's body
  - Too much processing may cause artifacts

Image processing artifacts

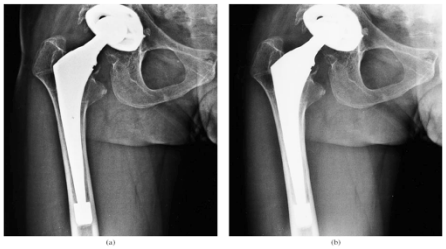


Figure 8. Image processing artefact. (a) When too large a kernel size is selected for image enhancement, artefacts like the black halo surrounding the prosthesis can create the appearance that the prosthesis is loose. (b) The same image as (a) processed with a smaller kernel size.

Image processing artifacts

Inadequate image processing

Mismatch technique/post processing

Image processing artifacts

Figure 10. Image processing artefact. Owing to lack of primary beam collimation on this lateral lumbar spine, the amount of unattenuated radiation striking the imaging plate (IP) (anterior and posterior to the patient) altered the histogram so that it was outside the normal range for that body part selection. Artefact remedy: use the smallest IP practicable and collimate the beam to the body part. This is particularly important on small or slim patients.

Image processing artifacts

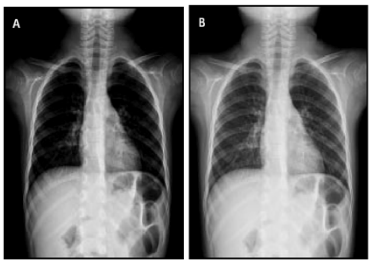


FIGURE 15. (A) Inappropriate processing of pediatric digital radiography image by vendor-supplied parameters suitable for adults. (B) Image processed by parameters modified by the customer. Images acquired on GE DR system (GE Medical Systems, Milwaukee, WI).

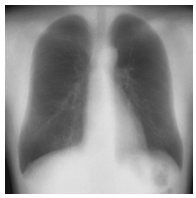
Image Quality Review

- Anatomical menu selection
- Centering
- Collimation
- Grid used (subjects > 10 cm)
- Proper kVp range selected
- Check Exposure indication numbers

Image Quality Review

Images should not be critiqued by "S" number alone.

It is very important to view the whole image



3. Artifacts Evaluation

- Good to learn about different pattern of artifacts
- Good to know how to avoid them

Acceptance Test and Quality Control

- Acceptance testing ensures proper quality of DR system
- Quality control ensures optimal standards

Effective ways to work with your DR

- Know about your system components
- Know about how it works
- Maintain your professional standards
  - Positioning and collimation
  - Exposure factors
  - Grids
  - Image processing
- Perform QC on regular basis
- Continuing Education is necessary