

Digital Radiography & Fluoroscopic Radiation Safety for the Certified Radiologic Technologist

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Introduction

Cassette-based (CR)
Cassette-less (DR)

Digital Radiography – Cassette & Cassetteless

- Linear response between transmitted x-rays & image optical density
 - ↑ 10,000 shades of gray
 - F/S ~ 30 shades of gray response between transmitted x-rays & image optical density
- Post-processing image manipulation
 - Contrast
 - Brightness
 - ...and much, much more!

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3

Digital – Cassette-based (CR)

- Standard x-ray room
- Image sensitive plate
- Electrons are trapped in response to an x-ray interaction
- Latent image formation
- CR reader dry laser processing
- Softcopy or hardcopy viewing

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4

Digital – Cassette-less

- Image receptor (IR)
 - Matrix (arrangement) of discrete (separate or distinct) imaging elements
 - Electronic signal produced in response to transmitted x-rays
 - Electronic signal digitized & stored
- Softcopy or hardcopy viewing

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5

Digital – Cassette-less

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6

Image Processing Tools

- Image processing has a number of beneficial aspects
- There are also potential deleterious consequences of using certain image processing tools with digital radiography

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7

Un-sharp Masking

- **Upside**
 - Can enhance the sharpness of mass lesion borders
- **Downside**
 - Can make indistinct masses appear more circumscribed

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8

Histogram-based Intensity Windowing

- **Upside**
 - Can improve the conspicuity of edges
- **Downside**
 - Possible loss of detail outside of the denser parts of the image

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9

Contrast-limited Adaptive Histogram Equalization

- **Upside**
 - Brings out edge information of lesions

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10

Contrast-limited Adaptive Histogram Equalization

- **Downside**
 - Enhances the visibility of distracting non-lesion features, potentially leading to false positive reports

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11

Peripheral Equalization

- **Upside**
 - Brings out lesion detail while preserving peripheral information in the surrounding structures

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12

Peripheral Equalization

- **Downside**
 - Possible flattening of image contrast in non-peripheral areas

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13

Window Width & Window Level

- **Window width**
 - ↑ or ↓ the relative differences in grayscale values
 - Creates an image that has ↑ or ↓ contrast (black or white)

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Radiation Protection in Digital Radiology L02 Exposure indicators & patient dose estimation in CR & DR 14

Window Width & Window Level

- Changing the ratio of density difference ↓ or ↑ the total number of intensities

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Radiation Protection in Digital Radiology L02 Exposure indicators & patient dose estimation in CR & DR 15

Window Width & Window Level

- **Window level**
 - Brings different tissues into visible range based on attenuation values
 - Represents the digital brightness of the image

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Radiation Protection in Digital Radiology L02 Exposure indicators & patient dose estimation in CR & DR 16

Disadvantages of Digital Radiography

- Documented tendency of overexposure using CR/DR
 - Exposure indicators are critical in the oversight of exposure factor selection
- Digital imaging artifacts

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17

Lumbar Spine Radiography — Poor Collimation Practices After Implementation of Digital Technology

- Involved two hospitals
 - Norwegian
 - Danish

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18

Lumbar Spine Radiography — Poor Collimation Practices After Implementation of Digital Technology

- Mean total field size was 46% larger in digital than in analog images (791 cm² vs 541 cm²)

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19

Lumbar Spine Radiography — Poor Collimation Practices After Implementation of Digital Technology

- 46% ↑ in irradiated field size = ↑ radiation dose to patients
- ↑ may go unnoticed due to cropping of the final images

Zetterberg & Espeland Brit J Radiol , 84 (2011), 566 – 569

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20

Disadvantages of Digital Radiography

- Substitute cropping &/or black masking for appropriate collimation
- An ALARA violation!

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21

Image Gently – Primary Objective

- To raise awareness in the imaging community of the need to adjust radiation dose when imaging children
- **The ultimate goal of the Alliance is to change practice**

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22

Signal

- That portion of the image-forming x-rays that represent anatomy
- Represents the difference between those x-rays transmitted to the IR & those absorbed photoelectrically

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23

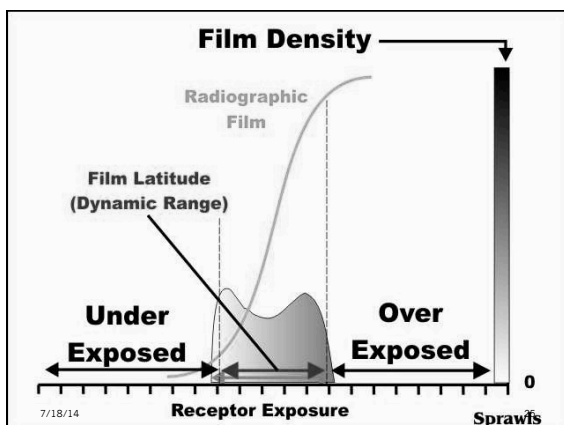
Dynamic range

- The number of gray shades that an imaging system can reproduce

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24



Pixel Bit Depth

- Number of shades of gray that can be displayed in the image
- The more gray levels = ↑ range when adjusting window width & level (contrast & brightness)

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26

Noise (Quantum Mottle)

- Grainy or uneven appearance of an image caused by an insufficient number of primary x-rays

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27

Image noise

- Deterioration of the radiographic image; limits contrast resolution
- Caused by:
 - Scatter
 - Mechanical, optical & computer defects

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28

Signal-to-Noise Ratio (SNR)

- A method of describing the strength of the radiation exposure compared with the amount of noise apparent in a digital image

(Fauber 154) Fauber. *Radiographic Imaging and Exposure, 4th Edition*. Mosby, 2013.
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29

AMA TFT/TFT FPD

- Active Matrix Array Thin Film Transistor
- Thin Film Transistor Flat Panel Detector

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30

Detector Element (DEL)

- The TFT array is divided into square detector elements (DELs)

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31

Detector Element (DEL)

- Each DEL has a:
 - Capacitor to store electrical charges
 - Switching transistor for readout
 - Picture element (pixel)

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32

Pixel

- Picture element
 - The active area of the DEL in a FPD IR
 - The smallest component of the display monitor matrix

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33

Pixel

- Pitch
 - The pixel spacing or distance measured from the center of a pixel to an adjacent pixel
- Density
 - The number of pixels/unit area

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Felder. Radiographic Imaging and Exposure, 4th Edition. Mosby, 2013.

34

DQE: Detective Quantum Efficiency

- A measure of information transfer efficiency dependent on:
 - Efficient absorption of X-rays
 - Conversion into a useful signal with minimum corruption by other detector noise sources (such as electronic & artifact noise)

* Seibert JA, Morin RL. The standardized exposure index for digital radiography: an opportunity for optimization of radiation dose to the pediatric population. *Pediatr Radiol*. 2011 May;41(5):573-581. doi:10.1007/s00261-011-1411-4. Apr 14.

35

EI – Exposure Indicator

- Expresses the amount of light given off by the IR
- Indicates the amount of radiation exposure to the patient & IR

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36

Histogram

- A graphic representation of a data set
- Includes all the pixel values that represent the image before edge detection and rescaling

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37

Histogram Analysis

- The computer analyzes the histogram using processing algorithms
- Compares it with a pre-established histogram specific to the anatomic part being imaged

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38

Histogram Analysis

- The computer software has stored histogram models, each having:
 - A shape characteristic of the selected anatomic region
 - A shape characteristic of the selected projection

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39

Automatic Rescaling

- Occurs during histogram analysis
- Employed to maintain consistent image brightness even in the presence of over- or under-exposure

(Fauber 309) Fauber. *Radiographic Imaging and Exposure, 4th Edition*. Mosby, 2013.

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40

LUT

- Look Up Table
 - Histogram of the brightness values of the ideal image
 - Used as a reference to evaluate the raw data of similar images & automatically rescales their values to match those in the LUT

(Martensen 574) Martensen, McQuillen. *Radiographic Image Analysis, 3rd Edition*. WB Saunders Company, 2011.

41

Image Lag

- Residual signals from previous exposures being superimposed on the current exposure

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42

DICOM

- DICOM (Digital Imaging & Communications in Medicine)
- A communication standard for information sharing between PACS and imaging modalities

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43

DICOM

- The standard that makes medical imaging work

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44

Standardized Exposure Indicators

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Digital Imaging

- **No direct link between the:**
 - Appearance of digital images
 - Dose needed for their creation

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Radiation Protection in Digital Radiology 102 Exposure indicators & patient dose estimation in CR & DR 45

Digital Imaging

- **Exposure Indicator** - a link between:
 - Image quality
 - Image dose

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Radiation Protection in Digital Radiology 102 Exposure indicators & patient dose estimation in CR & DR 47

Standardized Exposure Indicator

- A unified method to generate an EI value:
 - Requires users to input a target exposure index (EI_T) value for each exam
 - Indicates a deviation index (DI) value (based upon the EI_T value)
 - Gives feedback to the technologist regarding technique & image quality based on SNR

Seibert JA, Morin RL. The standardised exposure index for digital radiography: an opportunity for optimization of radiation dose to the pediatric population. *Pediatr Radiol*. 2011 May;41(5):573-581. Epub 2011 Apr 14. 48

ACR - Image Acquisition

- At the time of acquisition the system must have capabilities for acquiring demographic & imaging information such as:
 - Accession number
 - Patient name
 - ID number
 - Date & time of examination

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49

ACR - Image Acquisition

- Name of facility or institution
- Patient or anatomic part orientation (R, L, etc.)
- Data compression & display of total # of images acquired in the study

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50

Histogram Analysis Errors

- Incorrect anatomic menu selection
- Exposure field not detected
 - Collimation border recognition
 - Exposure field distribution – multiple fields

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51

Histogram Analysis Errors

- Unexpected material in data set, ie. Metal
- Inappropriate rescaling – light or dark image
- Large exposure error – plate saturation

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52

Plate Saturation

- Quantity of data on the IR is far greater than the system can provide for viewing
- Sensor is no longer able to respond linearly

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53

Scatter Control - Beam limiting

- Collimate
 - ↓ scatter production
 - ↑ contrast
 - ↓ patient dose

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54

Scatter Control - Beam limiting

- It is an ALARA violation:
 - Not to collimate
 - To 'black mask' inside collimation borders!

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55

DR - Cassette-less

- TFT FPD (Thin Film Transistor Flat Panel Detector)
- Image acquisition
 - Indirect capture or conversion
 - Direct capture or conversion

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56

DR - Cassette-less - Digital Image Matrix

- Image spatial resolution is defined by the size of the del (detector element)
- Highly linear signal response

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57

DR - Cassette-less - Indirect Capture – TFT FPD

- Csl/a-Si
- Uses an x-ray scintillator to convert x-ray to light
- Light converted to an electrical signal

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58

DR - Cassette-less Indirect Capture – TFT FPD

- Electrical signal processed by a computer
- Viewing of the image on a monitor

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59

DR - Cassette-less - Direct Capture – TFT FPD

- Amorphous selenium (a-Se) detector
- a-Se converts x-ray directly to a charge
- No scintillator = no x-ray conversion to light

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60

DR - Cassette-less

- Electrical signal processed by a computer
- Viewing of the image on a monitor

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61

Digital Image Quality

Characteristics of Digital Image Quality

- The factors used to evaluate digital image quality:
 - Brightness
 - Contrast
 - Resolution
 - Distortion
 - Exposure index
 - Noise

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63

Contrast Controlling Factors

- Radiographic contrast is affected by the:
 - Digital processing computer
 - Predetermined algorithms

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64

Because of their Limited Luminance, the Viewing Environment for Electronic Displays is Critical

- Ambient light ↓ contrast
- As ambient light ↑, display maximum luminance must ↑
- ↑ display reflection = ↓ allowable level of ambient light

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Radiation Protection in Digital Radiology LDR Optimising DR Displays

65

Because of their Limited Luminance, the Viewing Environment for Electronic Displays is Critical

- Changes in ambient illumination strongly affect contrast in the dark areas of the display; one strategy is to ↑ the minimum luminance

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Radiation Protection in Digital Radiology LDR Optimising DR Displays

66

Quantifiable Consequences of Degraded Performance

- ↓ of Contrast Sensitivity
- ↓ of Sharpness/Spatial Resolution
- ↓ of Dynamic Range
- ↑ in Noise
- ↓ in System Speed
- Geometric Distortion
- Artifacts

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Radiation Protection in Digital Radiology

LO8 Optimising DR Displays

67