Physics Education to Enhance CT Image Quality Optimization and Dose Management. A model, Method, and Materials

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Handouts and Resources at

http://www.sprawls.org/ipad
Computed Tomography

Image Characteristics and Quality

Radiation Dose

Imaging Protocols

Technology

Physics
Who needs a knowledge of Physics applied to clinical imaging?

Radiologists, Residents and Fellows

Technologists

Medical Physicists

Each provides unique challenges and opportunities.
Clinically Focused Physics Education

Classroom
Clinical Conference
Small Group
“Flying Solo”

Learning Facilitator “Teacher”
Individual and Peer Interactive Learning

Each type of learning activity has a unique value.
Clinically Focused Physics Education

Classroom  Clinical Conference  Small Group  “Flying Solo”

Learning Facilitator “Teacher”  Individual and Peer Interactive Learning

The Goal..

Increase the EFFECTIVENESS of each type of learning activity with the necessary resources and understanding of the process by the Learning Facilitators.

Sprawls
Capability & Complexity
(Computed Tomography)

The Three Phases of CT Image Formation
- Scan and Data Acquisition
- Image Reconstruction
- Digital/Analog Conversion and Display Control

Major Protocol Factors
- KV
- MA
- Beam Width
- Slice Th.
- FOV
- Matrix
- Filter
- Zoom

CT Dose Quantities
- Effective Dose
- CTDI

Sprawls
Digital Resources to Enrich Learning Activities

The Web
Connecting and Sharing

Textbooks, Modules
Visuals
Clinical Images
Reference Teaching Files

Classroom
Clinical Conference
Small Group
"Flying Solo"
Physics Education to Enhance CT Image Quality Optimization and Dose Management

Physicists With Experience in Clinical CT

Open Access Educational Resources
- Visuals
- Modules

Global Impact

Teach, Collaborate, Consult Physicists in Local Institutions (with Limited Clinical CT Experience)

A resource to enhance the performance of medical physicists in every country of the world.
Technology Enhanced Learning

Learning Guide

Learner

COMPTON SCATTER INTERACTIONS

X-RAY PHOTON

ENERGY

WEAK

NUCLEUS

Visuals for Classroom

Online Resources

Notes and Text
Computed Tomography Image Quality Optimization and Dose Management

Companion Module
http://www.sprawls.org/resources/CTIQDM/

Visuals for Classroom, Conference, and Collaborative Learning

RIGHT CLICK on each visual to download and use in PowerPoint or other display programs.
The Imaging Process

The Three Phases of CT Image Formation:

- Scan and Data Acquisition
  - Scan Data
  - KV
  - Pitch
  - MA
  - Beam Wid.
  - Time

- Image Reconstruction
  - Filtered Back Projection
  - Slice Th.
  - FOV
  - Matrix
  - Filter

- Digital/Analog Conversion and Display Control
  - Digital Image
  - Window
  - Width
  - Window Level
  - Zoom

Clinical Images
The Three Phases of CT Image Formation

Scan and Data Acquisition

Image Reconstruction

Digital/Analog Conversion and Display Control

Major Protocol Factors

KV
Pitch
Slice Th.
Window Width

MA
Beam Wid.
FOV
Window Level

Time
Matrix
Filter
Zoom
CT Image Characteristics

Spatial

Detail

Artifacts

Noise

Contrast Sensitivity

Major Protocol Factors

KV

Pitch

Slice Th.

Window Width

MA

Beam Wid.

FOV

Window Level

Time

Filter

Matrix

Zoom
SPIRAL SCAN

CONTINUOUS

Distance per Revolution

PITCH = \( \frac{D}{W} \)  
Beam Width
CT Slice Divided into Matrix of Voxels

Field Of View (mm)

Matrix Size (voxels/pixels)

Slice Thickness (mm)

Voxel Size Controlled By

FOV ÷ Matrix = Slice Th.
Reconstruction Filter Kernels

Filtered Back Projection

Noise Reduction
Filter
- Standard
  - Increased Blurring
  - Reference Image

Enhance Detail
- Increased Noise

(Effects exaggerated for illustration here)
Factors That Determine Image Detail
(Sources of Blurring)

- Focal Spot
- Pitch
- Beam Wid.

Scan Data → Filtered Back Projection → Digital Image

- Filter
- Voxel Size
- Slice Th.
- FOV
- Matrix

Detector
Relationship of Radiation Dose to Image Detail

**Lower Dose**

- When detail is increased by
  - Decreasing Slice Th.
  - Increasing Matrix
  - Decreasing FOV

**Higher Dose**

- Noise Increases
  - Because of decreased voxel size

- Dose must be increased to reduce noise.
Two Major Image Quality Goals

High Detail

Low Noise

Voxel Size

Small

Large

Protocol Factors

FOV

Matrix

Slice Th.
Factors That Determine Image Noise

- KV
- MA
- Time
- Pitch

Concentration of Absorbed Photons and Energy at Each Location In the Body Tissue

Filtered Back Projection

Filter

Voxel Size Determines Number of Photons

Slice Th.
FOV
Matrix
Effect of Matrix Size on Image Noise

Small Matrix

Large Voxels
Low Noise

Large Voxels
High Noise

Large Matrix

Small Voxels

The same radiation dose for both images.
Decreasing Noise

Requires Increased Photons Absorbed Per Voxel

Produces Increasing Dose
## Computed Tomography Image Quality Optimization and Dose Management

Perry Sprawls, Ph.D.

To step through module, [CLICK HERE.](#)

To go to a specific topic click on it below.

<table>
<thead>
<tr>
<th>Introduction and Overview</th>
<th>Image Quality Characteristics</th>
<th>Contrast Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility of Detail</td>
<td>Visual Noise</td>
<td>Spatial (Geometric) Characteristics</td>
</tr>
<tr>
<td>Artifacts</td>
<td>Identifying Characteristics</td>
<td>Characteristics Identified</td>
</tr>
<tr>
<td>Image Quality and Dose</td>
<td>CT Image Formation Process</td>
<td>The Scanning Motions</td>
</tr>
<tr>
<td>Views and Rays</td>
<td>Multiple Row Detectors</td>
<td>Helical and Spiral Scanning</td>
</tr>
<tr>
<td>Image Reconstruction and Voxels</td>
<td>CT Numbers</td>
<td>Hounsfield Unit Scale</td>
</tr>
<tr>
<td>Optimizing CT Procedures</td>
<td>Absorbed Dose</td>
<td>Dose Distribution Within Patient</td>
</tr>
<tr>
<td>CT Dose Index (CTDI)</td>
<td>Weighted CTDI</td>
<td>Volume CTDI</td>
</tr>
<tr>
<td>Dose for Multiple Slices</td>
<td>Dose Length Product (DLP)</td>
<td>Effective Dose</td>
</tr>
<tr>
<td>Summary of CT Dose Quantities</td>
<td>Factors That Determine Dose</td>
<td>Factors Affecting Image Detail</td>
</tr>
<tr>
<td>Measuring CT Image Noise</td>
<td>Controlling Image Noise</td>
<td>Voxel Size Compromise</td>
</tr>
</tbody>
</table>
During the reconstruction process, mathematical filters are used to change some of the image characteristics. These might be referred to by different names such as algorithms or kernels but their effects are the same.

Each CT system has many different filters that the operator can select from for a specific clinical procedure. The filters that are appropriate for the various clinical procedures have been determined from experience and are typically included in the established protocols for a facility.

We are not going into the characteristics of all of the filters here but focusing our attention on their effects of the two image characteristics, noise and detail as illustrated here.

Some filters can be selected to reduce noise in an image. However, the reduction of noise by digital image processing usually increases the blurring in the image and reduces the visibility of detail.

Filters that are selected to increase or enhance detail typically increase the visibility of image noise.

This is all part of the compromise between image detail and image noise.

In general, noise is reduced by increased blurring (voxel size, filter, etc) but that reduces image detail.

That is all part of the process of developing an optimized imaging protocol.
Effective Medical Imaging Physics Learning...In The Clinic

The Real World Motivating Interactive Collaborative

Radiologist

Resident

The Physicist Provides: Learning Modules & Collaboration

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The Sprawls Resources
Users, April 2013

Global Impact
EFFECTIVE PHYSICS EDUCATION FOR OPTIMIZING CT IMAGE QUALITY AND DOSE MANAGEMENT WITH OPEN ACCESS RESOURCES

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References and Resources

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www.mpijournal.org

Visuals and Module

www.sprawls.org/resources

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