Clinically Embedded Physics Education
A major Factor in
Image Quality Assurance
and Radiation Dose Management

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www.sprawls.org

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This presentation available at:
www.sprawls.org/ipad
Effective Medical Imaging Physics Education

Goals & Objectives

Medical imaging professionals with a knowledge of physics that will enable them to perform clinically effective imaging procedures with managed risk to both patients and staff.
Our Learning Objectives

Clinical Radiology

Effective Knowledge Structures

DO

LEARN PHYSICS

Levels of Learning

Learning Activities

Effectiveness and Efficiency

RESOURCES

Sprawls
The inverse square law is......

Twice the Distance

Photon Concentration (Exposure) decreased to 1/4th

X-ray beam now covers four times the area

The Inverse Square Law

\[
\frac{I_1}{I_2} = \left( \frac{d_2}{d_1} \right)^2
\]

- \( I_1 \) is the initial intensity of radiation.
- \( d_1 \) is the initial distance.
- \( I_2 \) is the final intensity.
- \( d_2 \) is the final distance.
Who needs a knowledge of Physics applied to clinical imaging?

Radiologists, Residents and Fellows

Technologists

Medical Physicists

Each provides unique challenges and opportunities.
Physics Learning Objectives for Radiologists

Image Physical Characteristics

- Identify
- Relationship to Visibility
- Evaluate
- Control and Optimize
- Anatomy and Pathology
- Risk

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The Physicist as an Educator and Teacher

Our Objectives

Provide more EFFECTIVE learning activities.

Be EFFICIENT in our teaching

Challenges  Opportunities

Sprawls
IMAGE QUALITY

Conducting Clinical Procedures

Analyze & Evaluate Image Quality
Selection of Imaging Parameters
Procedure Protocol Optimization
"The Human Factor"

Quality Assurance Procedures
Image Analysis & Evaluation
Verifying Equipment Performance
Calibration

Design of Equipment
Physics Limitations

Research

Sprawls
Image Quality
Visibility of Anatomical Structures and Signs of Pathology or Trauma

spatial

Contrast

Artifacts

Detail

Noise

KV 120 MA 100 Pitch 1 FOV 20 XYZ XYZ XYZ XYZ XYZ XYZ XYZ XYZ XYZ XYZ XYZ XYZ XYZ XYZ

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Capability & Complexity

(Computed Tomography)

The Three Phases of CT Image Formation

1. Scan and Data Acquisition
2. Image Reconstruction
3. Digital/Analog Conversion and Display Control

Major Protocol Factors

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CT Dose Quantities

Effective Dose

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Sprawls

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Years
Digital Resources to Enrich Learning Activities

The Web
Connecting and Sharing

Textbooks
Modules
Visuals
Clinical Images
Modules
References
Teaching Files

Classroom
Clinical Conference
Small Group
“Flying Solo”
LEARNING is..............
Building a knowledge structure in the brain.
LEARNING PHYSICS is......
Building a knowledge structure in the brain
by Encounter and Experience

Physical Universe
Learning is a Natural Human Process

We Learn by Experience

Learner

Observe

Physical Universe

Interact
Teaching is helping someone
Building a Knowledge Structure in the Brain

Physical Universe

A mental representation of physical reality

Connect  Organize  Guide

Sprawls
The Elements of a Highly Effective Educational Session

The Brain

Connection

Observe

The Physical Universe
(Physics of Medical Imaging)

Interact

Teacher/Guide

“Window”
Physics Learning Objectives for Radiologists

Image Physical Characteristics

- Identify
- Relationship to Visibility
- Evaluate
- Control and Optimize
- Risk
- Anatomy and Pathology

Sprawls
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

Sprawls
Analyze and Make Decisions

Image

Clinical Characteristics

Radiologist

Physical Characteristics

Physics

KV 120  MA 100  Pitch 1  FOV 20  XYZ  XYZ  XYZ

XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ

XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ

XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ
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.

Sprauls
Elements of Highly Effective Medical Physics Education

In the Clinic

Class/Conference By Physicists

Online Modules

Sprawls
Rich Classroom and Conference Learning Activities

Learning Facilitator “Teacher”
- Organize and Guide the Learning Activity
- Share Experience and Knowledge
- Explain and Interpret What is Viewed
- Motivate and Engage Learners

Visuals
- Representations of Reality
Effective Medical Imaging Physics Learning
...In The Clinic

The Real World Motivating Interactive Collaborative

The Physicist Provides:
Learning Modules & Collaboration
Visuals for Learning and Teaching

The Imaging Process

The Three Phases of CT Image Formation

Scan and Data Acquisition
Image Reconstruction
Digital/Analog Conversion and Display Control

Major Control Factors
KV
MA
Pitch
Beam Wid.
Time
Slice Th.
FOV
Matrix
Filter
Window Width
Window Level
Zoom

Clinical Images

Sprawls

Sprawls
Visuals to be used by Physicists in Classroom and Conference Discussions

Computed Tomography Image Quality Optimization and Dose Management

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

Computed Tomography
- Imaging Protocols
- Technology
- Science

CT Image Characteristics
- Contrast
- Detail
- Noise

Objects in the Body
- Imaging Procedure
- Contrast Sensitivity

Anatomical Detail
- Image
# Modules for Self Study and Collaborative Learning in the Clinic

**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.

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# Mammography Physics and Technology for effective clinical imaging

Perry Sprawls, Ph.D.

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

To go to a specific topic click on it below

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Clinically Focused Physics Education

Classroom

Clinical Conference

Small Group

“Flying Solo”

Highly Efficient
For General Physics and Related Topics

Highly Effective
Clinically Rich Learning Activities

Visuals Images Online Modules Resources and References
Analyze and Make Decisions

Image

Clinical Characteristics

Radiologist

Physical Characteristics

Physics

KV 120  MA 100  Pitch 1  FOV 20  XYZ  XYZ  XYZ  XYZ

XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ

XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ

XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ  XYZ

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The Three Phases of CT Image Formation

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

Image Reconstruction
- Pitch
- Slice Th.
- FOV
- Matrix
- Filter

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

Major Protocol Factors
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.
X-ray Photons Interact With Tissue in a Voxel

**Radiation Dose**
- Determined by concentration of absorbed energy per voxel

**Image Noise**
- Determined by number of photons per voxel

Dose is increased by increasing number of photons.

Noise is reduced by increasing number of photons.
SPIRAL SCAN

CONTINUOUS

Distance per Revolution

PITCH = \( \frac{D}{W} \)  

Beam Width
CT Dose Quantities

Effective Dose

Factors

DLP

Scan Length

Pitch

CTDI_{weighted}

CTDI_{volume}
Decreasing Noise

Requires Increased Photons Absorbed Per Voxel

Produces Increasing Dose
Effect of Matrix Size on Image Noise

Small Matrix  Large Matrix

Large Voxels  Small Voxels

Low Noise  High Noise

The same radiation dose for both images.
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

Digital Image

Filter

Voxel Size Determines Number of Photons

Slice Th.

FOV

Matrix

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Two Major Image Quality Goals

- **High Detail**
- **Low Noise**

Voxel Size

- Small
- Large

Protocol Factors

- FOV
- Matrix
- Slice Th.
Relationship of Radiation Dose to Image Detail

Lower Dose

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

Noise Increases

Because of decreased voxel size

Higher Dose

- Dose must be increased to reduce noise.
Factors That Determine Image Detail
(Sources of Blurring)

- Focal Spot
- Pitch
- Beam Width
- Detector
- Scan Data
- Filtered Back Projection
- Filter
- Digital Image
- Slice Th.
- FOV
- Matrix
- Voxel Size

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Reconstruction Filter Kernels

- Filtered Back Projection
- Noise Reduction
- Enhance Detail
- Filter
  - Standard
- Increased Blurring
- Reference Image
- Increased Noise

(Effects exaggerated for illustration here)
Scan Data Set

Focal Spot

Pitch

Revolution "Tracks"

Detector

Beam Wid.

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Classroom
Clinical Conference
Small Group
“Flying Solo”
The Sprawls Resources
Sharing the Emory Experience with the World
With Emphasis on the Developing Countries

Emory

www.sprawls.org/resources

Open Access Educational Resources

Visuals Books Modules

Global Impact

Enhancing Radiology Education in Every Country of the World
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