Computed Tomography
Image Quality and Dose Optimization

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2008 Fall Meeting, Charlotte, NC

PowerPoint of the Presentation
CLICK HERE

Resources, Online Modules
Computed Tomography Image Formation
http://www.sprawls.org/resources/CTIMG/module.htm
Computed Tomography Image Quality and Dose Management
http://www.sprawls.org/resources/CTIQ/module.htm

References

How to Develop CT Protocols for Children
http://www.pedrad.org/associations/5364/ig/

impactscan.org
We are the UK’s CT scanner evaluation centre. We provide a wide range of CT scanner related services to the UK’s National Health Service. On our site, we try to give you an idea of our work, as well as providing resources for people involved in CT scanning.
http://www.impactscan.org/
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Radiation Risks and Pediatric Computed Tomography (CT):
A Guide for Health Care Providers
http://www.cancer.gov/cancertopics/causes/radiation-risks-pediatric-CT

http://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/1_Radiology/index.htm
COMPUTED TOMOGRAPHY QUALITY CHARACTERISTICS

- Spatial
- Spatial
- Spatial

- Artifacts

- Detail (Blurring)
- Contrast
- Sensitivity
- Noise

DEVELOPMENT and DESIGN PERFORMANCE OPERATION
COMPUTED TOMOGRAPHY QUALITY CHARACTERISTICS

Spatial
Spatial
Spatial

Detail (blurring)

Contrast Sensitivity

Artifacts

Noise

Development and Design

30 Years
COMPUTED TOMOGRAPHY
QUALITY CHARACTERISTICS

- Spatial
- Artifacts
- Detail (blurring)
- Contrast sensitivity
- Noise

PERFORMANCE
Evaluation (Testing) and Maintenance
Quality Assurance
COMPUTED TOMOGRAPHY QUALITY CHARACTERISTICS

PROTOCOL FACTORS

OPERATION
SLICE ACQUISITION

DATA
Spiral Scan

Continuous

Distance per Revolution

Pitch = \frac{D}{W}

Beam Width
VOLUME ACQUISITION HELICAL/SPIRAL SCAN

DATA SET
RECONSTRUCTION from VOLUME DATA SET
RECONSTRUCTION from VOLUME DATA SET

DATA SET

3D IMAGE
SPIRAL SCAN
SPIRAL SCAN

PITCH = 1

PITCH = 2
Single Row Detectors → Multiple Row Detectors
IMAGE RECONSTRUCTION

SCAN DATA

FILTERED BACK PROJECTION

DIGITAL IMAGE
CT Voxel Size

Tissue Slice

Tissue Voxel

Slice Thickness

Thickness 2-5 mm

FOV 250 mm

Matrix 512
CT NUMBER

\[
\frac{U_{\text{Tissue}} - U_{\text{H}_2\text{O}}}{U_{\text{H}_2\text{O}}} \times 1000 = \text{CT NUMBER}
\]
DIGITAL to ANALOG CONVERSION

DIGITAL IMAGE

LEVEL

WIDTH

ZOOM
COMPUTED TOMOGRAPHY
QUALITY CHARACTERISTICS

SPATIAL

DETAIL (BLURRING)

CONTRAST SENSITIVITY

NOISE

PROTOCOL FACTORS

SLICE TH.

MAS

Matrix

OPERATION

ARTIFACTS
COMPUTED TOMOGRAPHY
IMAGE DETAIL (BLURRING)

LOW DETAIL

HIGH DETAIL

FOCAL SPOT
RAY SIZE

VOXEL SIZE
FILTER ALGORITHM

PITCH
SLICE TH.
Matrix
FOV

PROTOCOL FACTORS

Sprawls
CT Voxel Size

Tissue Slice

Tissue Voxel

Slice Thickness

Thickness 2-5 mm

FOV

Matrix

250 mm

512

Sprawls
COMPUTED TOMOGRAPHY

IMAGE NOISE

VOXEL SIZE

SLICE TH.
Matrix
FOV

NOISE

TISSUE DOSE

WIDTH
FILTER ALGORITHM

MAS

PROTOCOL FACTORS
CT NOISE MEASUREMENT

STANDARD DEVIATION
CT NOISE MEASUREMENT

-2 -2 -3 0 -6 -6 1 0
4 1 2 5 -1 1 5 3
2 -1 0 5 0 0 2 1
-1 -1 -2 0 0 1 0 0
1 1 -2 -1 1 -1 -4 -2
-2 2 -1 0 1 -1 -3 0
6 -3 2 1 -4 3 1 4
3 4 2 -4 -3 -1 -2 -5

Attenuation Coefficient

1 SD = 0.5%
CT NUMBER

\[ \frac{U_{\text{Tissue}} - U_{\text{H}_2\text{O}}}{U_{\text{H}_2\text{O}}} \times 1000 = \text{CT NUMBER} \]

TISSUE VOXEL

ATTENUATION COEFFICIENT

DENSITY Z

IMAGE PIXEL

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LOW DOSE PROTOCOL

TISSUE VOXELS

IMAGE PIXELS

IMAGE NOISE
X-RAY PHOTONS

TISSUE V Voxels

IMAGE PIXELS

IMAGE NOISE
Tissue Slice

Absorbed Dose
Concentration of radiation energy absorbed in tissue
ABSORBED DOSE

1 rad = 100 ergs
100 ergs = 1 g

1 gray (G) = 1 joule
1 kg

1 gray = 100 rads
1 rad = 1 cG
COMPUTED TOMOGRAPHY
INTEGRAL DOSE

SLICE INTEGRAL DOSE = 2000 gm-rads

BODY INTEGRAL DOSE = 20,000 gm-rads
COMPUTED TOMOGRAPHY
DOSE INDEX

3 rad

DOSIMETER

$\int_{D_O S E}^{W} = C T D I$
COMPUTED TOMOGRAPHY
IMAGE NOISE

VOXEL SIZE
SLICE TH.
Matrix
FOV

NOISE
TISSUE DOSE
MAS

PROTOCOL FACTORS

WIDTH
FILTER ALGORITHM

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CT Voxel Size

Tissue Slice

Tissue Voxel

Slice Thickness

FOV
Matrix

Thickness
2-5 mm

250 mm
512

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*Determinations made using automatic mA adjustment on GE LightSpeed scanner. The scanner alters mA to keep noise levels low and constant.
Exposure* vs. Slice thickness

*Ion chamber measurements obtained in a plexiglass head phantom on the GE LightSpeed scanner (pitch 3; 5 cm scan volume).
IMAGE RECONSTRUCTION

SCAN DATA → FILTERED BACK PROJECTION → DIGITAL IMAGE

- Increases Detail
- Increases Noise
IMAGE RECONSTRUCTION

SCAN DATA

FILTERED BACK PROJECTION

FILTER
Noise

DIGITAL IMAGE

Reduces Noise

Blurs Image (Reduces Detail)
CT Imaging Goals

High Detail

Low Dose

Low Noise
CT Imaging Goals

- Digital Filter
- High Detail
- Low Noise
- Small Voxel Size
- Large Voxel Size
- Low Dose
- Pitch
- MAS

Sprawls
CT scans in children linked to cancer

By Steve Sternberg, USA TODAY

Jan. 23, 2001

Each year, about 1.6 million children in the USA get CT scans to the head and abdomen.

— and about 1,500 of those will die later in life of radiation-induced cancer, according to research out today.
CONCLUSION. The best available risk estimates suggest that pediatric CT will result in significantly increased lifetime radiation risk over adult CT, both because of the increased dose per milliampere-second, and the increased lifetime risk per unit dose. Lower milliampere-second settings can be used for children without significant loss of information. Although the risk—benefit balance is still strongly tilted toward benefit, because the frequency of pediatric CT examinations is rapidly increasing, estimates that quantitative lifetime radiation risks for children undergoing CT are not negligible may stimulate more active reduction of CT exposure settings in pediatric patients.
RESULTS. Thirty-one percent (18/58) of the CT examinations were of the chest and 69% (40/58) were of the abdomen. Sixteen percent (9/58) of the CT examinations were combined chest and abdomen. In 22% (2/9) of these combined examinations, tube current was adjusted between the chest and abdomen CT; in one (11%) of these examinations, the tube current was higher for the chest than for the abdomen portion of the CT examination. The mean tube current setting for chest was 213 mA and was 206 mA for the abdomen, with no evident adjustment in tube current based on the age of the patient. Fifty-six percent of the examinations of neonates, infants, or children 8 years old or younger were performed at a collimation of greater than 5 mm and 53% of these examinations were performed using a pitch of 1.0.

CONCLUSION. Pediatric helical CT parameters are not adjusted on the basis of the examination type or the age of the child. In particular, these results suggest that pediatric patients may be exposed to an unnecessarily high radiation dose during body CT.

AJR Feb. 2001
WHY THIS PROBLEM NOW?

- Increased Use of Helical CT.
- Pediatric Patients.
- CT is a Relatively High-Dose Procedure.
- Radiology Staffs Do Not Know What They Are Doing!
Operating CT is like driving a Porsche
FACTORS AFFECTING DOSE

- Pitch
- Voxel Size and Slice Thickness
- MA
SPIRAL SCAN

PITCH = 1

PITCH = 2
CT Voxel Size

Tissue Slice

Tissue Voxel

Slice Thickness

Thickness: 2-5 mm

FOV: 250 mm

Matrix: 512
COMPUTED TOMOGRAPHY
QUALITY CHARACTERISTICS

SPATIAL
SPATIAL
SPATIAL
SPATIAL

ARTIFACTS

DETAIL (BLURRING)

CONTRAST SENSITIVITY

NOISE

PERFORMANCE

OPERATION

Medical Physicist

Teaching
Evaluation
Consultation
http://www.sprawls.org/resources/CTIQ/module.htm

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