

UFL Health

CT Dosimetry in the Clinical Environment: Methods and Analysis

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Outline

- Basic concepts
- AAPM Report 96
- AAPM Report 208
- AAPM Report 220
- AAPM Report 111
- An approach to measured organ doses in CT

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CT Dose Measurement and Determination

- Never in dispute, but much less now...
- 2006: The NCRP Report on Dose to Population of the US
- 2009: The high dose incidents in California
- 2015: TJC new Standards for Advanced Imaging Modalities
- Overall increased use of CT...

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Where Do We Stand Now?

National Council on Radiation Protection and Measurements, "Ionizing Radiation Exposure of the Population of the United States," Report 160 (2009).

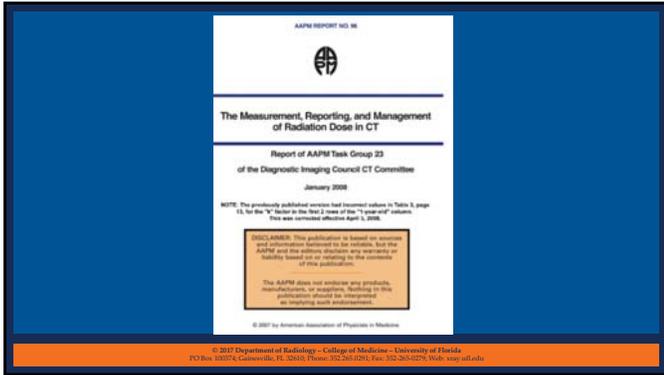
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MDCT...but especially Broad Beam scanners

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Clinical Impact of MDCT Technology

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Computed Tomography Dose Index (CTDI)

- The geometry of CT requires a special way to define and measure dose
- The *Computed Tomography Dose Index (CTDI)* is defined as the equivalent of the dose value inside the nominal irradiated slice (beam) that would result if the absorbed radiation dose profile were entirely concentrated to a rectangular profile of width equal to the nominal beam width
- Tails extend to quite long distances beyond scanned region

Bahti, Vitek, Primak, Bruesewitz, McCollough, RadioGraphics 2008; 28: 245-253

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Computed Tomography Dose Index (CTDI)

- The profile is actually a typical spread function
- CTDI theoretically estimates the average dose within the central region of the scanned volume consisting of multiple contiguous slices
- This is also known as the Multiple Scan Average Dose (MSAD)
- The MSAD represents the average dose over a small interval about the center of the scanned length
- It requires multiple measurements

Bahti, Vitek, Primak, Bruesewitz, McCollough, RadioGraphics 2008; 28: 245-253

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CTDI - Definitions

$$CTDI = \frac{1}{NT} \int_{-NT}^{+NT} D(z) dz$$

- $D(z)$ Dose profile in the z-direction
- N = Number of slices acquired in one scan (or number of active channels during acquisition)
 - Note that N is less or equal to N_{max} (the maximum number of channels)
- T = Width of tomographic section of ONE acquisition channel in mm
 - Note that in SDCT, T corresponds to the collimated slice width
- Limits of integral intend to include all contributions to the dose
- NT = Collimated beam width (mm)

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SDCT vs MDCT detector configurations

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CTDI - Definitions

$$CTDI = \frac{1}{NT} \int_{-NT}^{+NT} D(z) dz$$

- CTDI represents the average absorbed dose along the z-axis for a series of contiguous rotations
- It is measured from an axial, single-rotation acquisition

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CTDI_{FDA}

- The original incarnation of the CTDI
- Used and applicable to SDCT scanners of the 1980s
- The +/- 7T integration limits were defined in an attempt to standardize the determination of the CTDI
- At the time for all scanners: N=1

$$CTDI = \frac{1}{T} \int_{-7T}^{+7T} D(z) dz$$

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Measuring CTDI

- CTDI is measured using two cylindrical PMMA phantoms
- A small (16cm diameter) and a large (32 cm diameter) phantoms are used
- A 100 mm, 3 cc pencil ion chamber with acrylic cap is inserted into each hole in the phantoms to measure the CTDI
- Meter reading in either R or mGy



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Measuring CTDI

- The pencil ion chamber measures the integral dose of D(z) over a single rotation
- The "meter reading" represents the average exposure (in R) or air kerma (in mGy) over the chamber length

$$CTDI = \frac{f(\text{rad/R}) \cdot (\text{mm}) \cdot \text{meter reading (R)}}{N \cdot T(\text{mm})}$$

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Measuring CTDI

- Where C is the chamber temperature and pressure correction factor
- f takes the following values:
 - 0.78 rad/R for calculation to dose to acrylic (e.g., CTDI_{FDA}).
 - 0.94 rad/R for tissue dose estimates.
 - 0.87 rad/R for dose to air and calculation of or comparison to CTDI₁₀₀ or CTDI_w
 - These values correspond to the typical CT kVp value of 120 kVp, which corresponds to an effective energy of approximately 70 keV.
 - For scans at other tube voltage settings, the f-factors must be chosen accordingly.
- 1.06 mGy/mGy for dose to tissue
- 0.90 mGy/mGy for dose to Lucite
- 1.00 mGy/mGy for dose to air.

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CTDI₁₀₀

- With the standardization of the CTDI phantoms and pencil ion chamber, the CTDI was defined based on the 100 mm active length of the chamber

$$CTDI_{100} = \frac{1}{NT} \int_{-50}^{+50} D(z) dz$$

- The CTDI₁₀₀ underestimates the equilibrium dose and the MSAD
- It prevents overestimation of dose over narrow slice widths (< 3 mm)

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CTDI₁₀₀

- With the standardization of the CTDI phantoms and pencil ion chamber, the CTDI was defined based on the 100 mm active length of the chamber

$$CTDI_{100} = \frac{1}{NT} \int_{-50}^{+50} D(z) dz$$

- It underestimates the MSAD and equilibrium dose for scanning lengths longer than 100 mm
- Broad-beam MDCT scanners have collimated beams which extend beyond the 100 mm length

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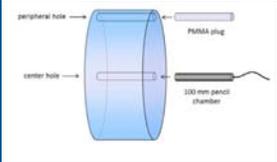
AAPM Report 111



- Contains the formalism for measurement and determination of equilibrium dose for broad-beam MDCT scanners
- However, it indicates the lack of consensus regarding a standard phantom
- Stay tuned...

Back to Measuring CTDI

- Pencil ion chamber inserted into center hole and at least one of the peripheral holes
- CTDI is defined to be measured using an axial, single-rotation acquisition
- Strictly not defined for helical acquisition



AAPM Report 204 (2011)

CTDI_w

- To account for the variations of the CTDI across the FOV, measurements at the periphery and the center of the phantom are performed in practice, and a weighed CTDI is defined as

$$CTDI_{100,w} = \frac{1}{3}(CTDI_{100,c} + 2 CTDI_{100,p})$$

- Where CTDI_{100,c} and CTDI_{100,p} are the meter readings obtained in the center and the average of the measurements in the peripheral holes of the phantoms, respectively
- The Weighted CTDI is a measure of the relative dose output

CTDI_{vol}

- Finally, to account for helical scanning, the pitch-corrected dose index can be calculated as follows:

$$CTDI_{vol,w} = \frac{CTDI_{100,w}}{pitch}$$

- Where

$$pitch = \frac{d}{NT}$$

- And d is the table increment distance per tube rotation
- It represents the average absorbed dose along the x, y and z axes

Dose-Length Product (DLP)

- CTDI is not to be used to specify patient doses!!
- Another useful quantity is the Dose-Length Product (DLP)
 - Defined as the product of CTDI_{vol} and scanned length
 - It provides a measure of the absorbed dose taking into account the scanned length

$$DLP = CTDI_{vol,w} \times l \text{ (mGy} \cdot \text{cm)}$$

- DLP represents the energy absorbed (and therefore the potential biological effect)

Dose-Length Product (DLP)

- The DLP can be used to estimate an effective dose (E) by using published conversion factors

$$E \text{ (mSv)} = k(\text{mSv/mGy cm}) \times \text{DLP}(\text{mGy cm})$$

Table 3. Normalized effective dose per dose-length product (DLP) for adults (standard physique) and pediatric patients of various ages over various body regions. Conversion factor for adult head and neck and pediatric patients assume use of the head CT dose phantom (16 cm). All other conversion factors assume use of the 32-cm diameter CT body phantom^{16,19}.

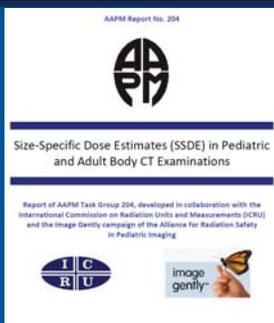
Region of Body	k (mSv/mGy ² cm ³)				
	0 year old	1 year old	5 year old	10 year old	Adult
Head and neck	0.013	0.0095	0.0067	0.0042	0.0031
Head	0.011	0.008	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.026	0.026	0.018	0.013	0.014
Abdomen & pelvis	0.049	0.030	0.020	0.015	0.015
Thigh	0.044	0.028	0.019	0.014	0.015

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Dose-Length Product (DLP)

- Remember
- The reported CTDI_{vol} and DLP values are retrieved from lookup tables in the scanner based on
 - kV, mA, pitch, rotation time used, detector configuration, bowtie filter and length scanned
 - Pre-programmed radiation output tables generated at the factory
- No service technician measures CTDI or calibrates the DLP calculation for your scanner
- Use for monitoring and comparing, as intended...

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- CTDI_{vol} defined as a relative radiation output to do inter- and intra-scanner comparisons
- DLP represents the total energy imparted to the reference phantom
- Both quantities are reported pre and post scan based on the phantom (head or body) used by the manufacturer to determine its own values
- Adult head study values based on 16-cm phantom
- Adult body study values based on 32-cm phantom
- For pediatric studies, some manufacturers use the 16 cm and others the 32 cm phantoms

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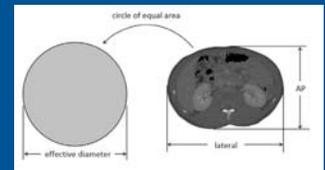
AAPM Report 204

- Accounting for patient size is a key factor to understand and estimate patient dose in a better, more realistic manner
- Two basic parameters are required for this estimation:
 - A scanner-based output parameter (The volume CTDI)
 - A patient size parameter, based on two measurable dimensions
 - AP dimension: measured from the lateral topogram (scout)
 - LAT dimension: measured from the frontal topogram (scout)

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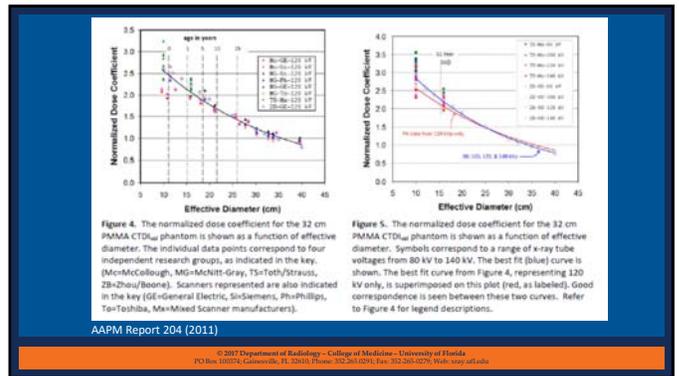
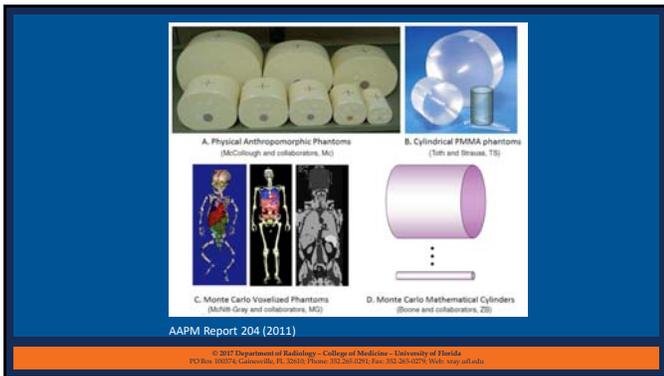
Effective diameter

$$\text{effective diameter} = \sqrt{AP \times LAT}$$



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Size-Specific Dose Estimate (SSDE)

- An estimate of absorbed dose to the region scanned which takes into account both the scanner radiation output and the size of the patient
- For the 16 cm phantom

$$\text{size specific dose estimate} = \text{SSDE} = f_{\text{size}}^{16X} \times \text{CTDI}_{\text{ref}}^{16}$$

- For the 32 cm phantom

$$\text{size specific dose estimate} = \text{SSDE} = f_{\text{size}}^{32X} \times \text{CTDI}_{\text{ref}}^{32}$$

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f factors for the 32 cm phantom

Table 1. This table provides conversion factors based on the use of the 32 cm diameter PMMA phantom for CTD₁₀₀. Table 1a shows the conversion factor as a function of the sum of the lateral and AP dimensions. Table 1b shows conversion factors as a function of the lateral dimension, and Table 1c is for the AP dimension. Table 1d provides conversion factors as a function of effective diameter. It is essential that these data be used when the CTD₁₀₀ reported is known to be based on the 32 cm diameter body diameter phantom.

Table 1a				Table 1b				Table 1c				Table 1d			
Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	
10	10	1.00	10	10	1.00	10	10	1.00	10	10	1.00	10	10	1.00	
11	11	1.00	11	11	1.00	11	11	1.00	11	11	1.00	11	11	1.00	
12	12	1.00	12	12	1.00	12	12	1.00	12	12	1.00	12	12	1.00	
13	13	1.00	13	13	1.00	13	13	1.00	13	13	1.00	13	13	1.00	
14	14	1.00	14	14	1.00	14	14	1.00	14	14	1.00	14	14	1.00	
15	15	1.00	15	15	1.00	15	15	1.00	15	15	1.00	15	15	1.00	
16	16	1.00	16	16	1.00	16	16	1.00	16	16	1.00	16	16	1.00	
17	17	1.00	17	17	1.00	17	17	1.00	17	17	1.00	17	17	1.00	
18	18	1.00	18	18	1.00	18	18	1.00	18	18	1.00	18	18	1.00	
19	19	1.00	19	19	1.00	19	19	1.00	19	19	1.00	19	19	1.00	
20	20	1.00	20	20	1.00	20	20	1.00	20	20	1.00	20	20	1.00	
22	22	1.00	22	22	1.00	22	22	1.00	22	22	1.00	22	22	1.00	
24	24	1.00	24	24	1.00	24	24	1.00	24	24	1.00	24	24	1.00	
26	26	1.00	26	26	1.00	26	26	1.00	26	26	1.00	26	26	1.00	
28	28	1.00	28	28	1.00	28	28	1.00	28	28	1.00	28	28	1.00	
30	30	1.00	30	30	1.00	30	30	1.00	30	30	1.00	30	30	1.00	
32	32	1.00	32	32	1.00	32	32	1.00	32	32	1.00	32	32	1.00	
34	34	1.00	34	34	1.00	34	34	1.00	34	34	1.00	34	34	1.00	
36	36	1.00	36	36	1.00	36	36	1.00	36	36	1.00	36	36	1.00	
38	38	1.00	38	38	1.00	38	38	1.00	38	38	1.00	38	38	1.00	
40	40	1.00	40	40	1.00	40	40	1.00	40	40	1.00	40	40	1.00	

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f factors for the 32 cm phantom

Table 2. This table provides conversion factors based on the use of the 16 cm diameter PMMA phantom for CTD₁₀₀. Table 2a shows the conversion factor as a function of the sum of the lateral and AP dimensions. Table 2b shows conversion factors as a function of the lateral dimension, and Table 2c is for the AP dimension. Table 2d provides conversion factors as a function of effective diameter. It is essential that these data be used when the CTD₁₀₀ reported is known to be based on the 16 cm diameter body diameter phantom.

Table 2a				Table 2b				Table 2c				Table 2d			
Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	Effective Diameter (cm)	Sum of Lateral and AP Dimensions (cm)	Conversion Factor	
10	10	1.00	10	10	1.00	10	10	1.00	10	10	1.00	10	10	1.00	
11	11	1.00	11	11	1.00	11	11	1.00	11	11	1.00	11	11	1.00	
12	12	1.00	12	12	1.00	12	12	1.00	12	12	1.00	12	12	1.00	
13	13	1.00	13	13	1.00	13	13	1.00	13	13	1.00	13	13	1.00	
14	14	1.00	14	14	1.00	14	14	1.00	14	14	1.00	14	14	1.00	
15	15	1.00	15	15	1.00	15	15	1.00	15	15	1.00	15	15	1.00	
16	16	1.00	16	16	1.00	16	16	1.00	16	16	1.00	16	16	1.00	
17	17	1.00	17	17	1.00	17	17	1.00	17	17	1.00	17	17	1.00	
18	18	1.00	18	18	1.00	18	18	1.00	18	18	1.00	18	18	1.00	
19	19	1.00	19	19	1.00	19	19	1.00	19	19	1.00	19	19	1.00	
20	20	1.00	20	20	1.00	20	20	1.00	20	20	1.00	20	20	1.00	
22	22	1.00	22	22	1.00	22	22	1.00	22	22	1.00	22	22	1.00	
24	24	1.00	24	24	1.00	24	24	1.00	24	24	1.00	24	24	1.00	
26	26	1.00	26	26	1.00	26	26	1.00	26	26	1.00	26	26	1.00	
28	28	1.00	28	28	1.00	28	28	1.00	28	28	1.00	28	28	1.00	
30	30	1.00	30	30	1.00	30	30	1.00	30	30	1.00	30	30	1.00	
32	32	1.00	32	32	1.00	32	32	1.00	32	32	1.00	32	32	1.00	
34	34	1.00	34	34	1.00	34	34	1.00	34	34	1.00	34	34	1.00	
36	36	1.00	36	36	1.00	36	36	1.00	36	36	1.00	36	36	1.00	
38	38	1.00	38	38	1.00	38	38	1.00	38	38	1.00	38	38	1.00	
40	40	1.00	40	40	1.00	40	40	1.00	40	40	1.00	40	40	1.00	

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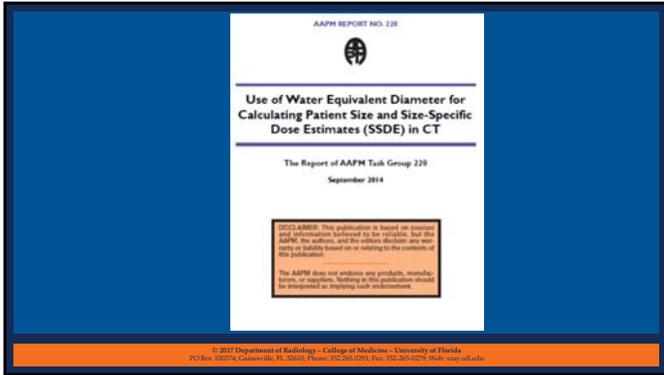
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SSDE

- SSDE provide an estimate of absorbed dose at the center of the scanned region (a “peak” dose value over the scanned region)
- Actual dose will be lower at both ends of the scanned region
- However, it does not take into account the differences in attenuation from different organs and tissues, only the overall patient dimensions
- So, for a better estimate of the dose to all organs in the scanned region....

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AAPM Report 220

- Improves on the concept of SSDE from Report 204 to account for attenuation differences
- Defines a methodology to determine a water-equivalent effective diameter, which can be estimated from the reconstructed images
- This methodology has been implemented by CT manufacturers
- The "corrected" effective diameter can then be used with the Tables of Report 204

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AAPM Report 220

- A single SSDE value can be obtained from a D_w determined from a central location in the scanned range and the scanner-reported mean $CTDI_{vol}$
- The report describes the process to be followed by CT manufacturers for the scanner-based determination of the water-equivalent effective diameter
- So, how do we approach organ dose determination

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Empirical CT Organ Dose Determination at the University of Florida

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Are cadavers valid surrogates for living patients?

CADAVER

PATIENT

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Are cadavers valid surrogates for living patients?

Seven post-mortem adult female subjects

- Anatomically intact, embalmed individuals
- All voluntarily donated their bodies to science
- Obtained from Anatomical Board of Florida
- Range of BMIs: 17 to 44
- No Patient Identifying Information for subjects

Body Mass Index	
CADAVERS	PATIENTS
16.6	20.89
17.4	23.89
21.7	27.31
26.6	28.29
27.1	31.46
33.5	34.31
43.8	37.36

Seven patient adult female subjects

- IRB Approval granted to search patient records
- For patients selected, BMI ranged from 21 to 37
- Age at time of scan was between 61 to 78 years

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Are cadavers valid surrogates for living patients?

- CT scans of the head and body were reviewed
 - Hospital standardized CAP and head protocols
 - Conducted on the Toshiba Aquilion One
- Scan settings
 - All scans performed at 120 kVp
 - Detector configuration: 64 x 0.5 mm
 - Helical acquisitions
 - Pitch value at 0.87
 - All scans used tube current modulation (SUREExposure 3D)
 - Images reconstructed to 5.00 mm slices



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Are cadavers valid surrogates for living patients?

Organ	Mean HU		Attenuation μ (cm ⁻¹)			Difference
	CADAVERS	PATIENTS	Organ	CADAVERS	PATIENTS	
Liver	49.34	54.08	Liver	0.2427	0.2438	0.45%
Lungs (fluid)	-547.30	-715.98	Lungs (fluid)	0.3511	0.3894	9.83%
Lungs (clear)	-680.97	-715.98	Lungs (clear)	0.3814	0.3894	2.04%
Breast	-69.23	-90.32	Breast	0.2426	0.2474	1.93%
Kidney	44.02	33.10	Kidney	0.2369	0.2344	-1.06%
Bone (lumbar)	224.80	233.87	Bone (lumbar)	0.2779	0.2800	0.73%
Brain	40.87	33.27	Brain	0.2362	0.2344	-0.73%

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Optically-Stimulated Luminescent Dosimetry (OSLD)

- Major advantages: high sensitivity, small size, ease of readout, reusability
- Material: Al₂O₃:C
- Manufacturer: Landauer Microstar InLight System
- Calibrated to an 80 kVp, 2.9 mm Al HVL beam,

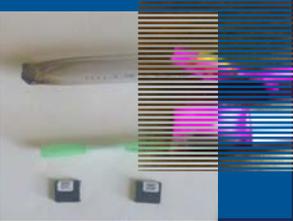


CHARACTERIZATION OF A COMMERCIALY-AVAILABLE, OPTICALLY-STIMULATED LUMINESCENT DOSIMETRY SYSTEM FOR USE IN COMPUTED TOMOGRAPHY
Lindsay Lavic,* Monica Glitz,[†] Libby Brateman,[‡] and Manuel Arreola[§]

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Tube and Dosimeter Placement System

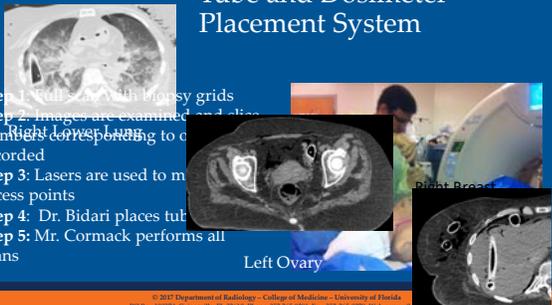
- Provides consistent and reproducible EXTERNAL access to INTERNAL organs
- Sets of tubes:
 - Outer - clear PVC tube
 - OD 19 mm & ID 16 mm
 - Inner - Dosimeter Holder & Re-enforcer tube
- Most organs require single or double dosimeter holders
 - Exceptions: Breast and Liver



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Tube and Dosimeter Placement System

- Step 1: XUL's are with biopsy grids
- Step 2: Images are examined and alignment points corresponding to organs are recorded
- Step 3: Lasers are used to mark access points
- Step 4: Dr. Bidari places tube
- Step 5: Mr. Cormack performs all scans



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Dosimeter Distribution

Organ	# of Dosimeters
Lens	2
Thyroid	2
Brain	5
Head Surface	3
Breasts	10
Lungs	8
Liver	5
Stomach	2
Small Intestine	2
Colon	2
Ovary	2
Uterus	1
Surface	15
TOTAL	59

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Head Protocol Measurements

- 3 protocols: Head, CTA Head, Brain Perfusion
- International fellows of neurosurgery performed tube placement via craniotomy

Tube 1: Frontal lobe insertion at the midpupillary line

- 2 dosimeters

Tube 2: Inserted on the Parieto-occipital fissure

- 3 dosimeters

- Additional Dosimeters: Lens, Thyroid, 3 surface



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Determining Organ Doses from CT with Direct Measurements in Postmortem Subjects: Part 1—Methodology and Validation¹

Thomas M. Gajack, PhD¹
Lindsay Garcia, PhD¹
Anna Marsh, PhD¹
Brian Carmona, RT¹
CharlesWesley Hines, MD¹
Lynn Hill, PhD¹
Manuel Arevalo, PhD¹

Purpose: To develop a methodology that allows direct measurement of organ doses from computed tomographic (CT) exams of postmortem subjects.

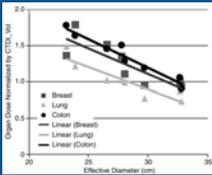
Materials and Methods: In this institutional review board approved study, the x-ray linear attenuation coefficients of various tissues were calculated from the mean CT numbers of images that were obtained in eight embalmed adult female cadavers and

- Large database of directly-measured organ doses generated
- Actual doses can be given to physicians and patients
- New and modified protocols can be dosimetrically assessed before clinical approval and implementation

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Empirical Organ Dose Equations

- CTDI_{vol} normalized organ doses from 8 postmortem subjects for lungs, breast, liver, stomach, small intestine, colon, uterus, ovary, and skin
- Measurements made for 320-slice MDCT scanner:
 - 120kV
 - 0.5mm x 64 detector rows
 - Filter back projection algorithm
- Conversion factors as a function of D_{eff} which is measured at mid-section of scan range
- Directly-measured dose values as a function of patient size!
- Simple linear fit equations...



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Size-specific organ dose Estimate (SSODE) calculation

- User-friendly for technologist or physician:
- STEP 1: Scanner reports and displays D_{eff} and CTDI_{vol}
 - If necessary, D_{eff} can be measured from scouts
- STEP 2: Multiply your D_{eff} by the a factor corresponding to the organ of concern
- STEP 3: Add the corresponding b factor
- STEP 4: Multiply by the CTDI_{vol}
- STEP 5: Decide if study must be modified to protect organ of concern

$SSODE_i = \{(a_i \times D_{eff}) + b_i\} \times CTDI_{vol}$

Organ	a _i	b _i
Liver	-0.070	3.16
Spleen	-0.058	3.06
Thyroid	-0.059	2.94
Colon	-0.059	2.88
Lung	-0.059	2.67
Uterus	-0.053	2.65
Ovary	-0.049	2.59
Breast	-0.046	2.55
Small Intestine	-0.037	2.48
Stomach	-0.037	2.33

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SSODE VS. SSDE

CADAVER 4					CADAVER 5				
Organ	ED (cm)	SSDE (mGy)	Avg Organ Dose (mGy)	% Difference	Organ	ED (cm)	SSDE (mGy)	Avg Organ Dose (mGy)	% Difference
Breast	22.6	12	10.3	16.3	Thyroid	24.1	28	19.7	42.5
Lung	23.4	12	11.4	5.7	Breast	28.4	24	24.8	-3.2
Liver	21.6	13	12.2	6.2	Lung	26.5	26	18.8	38.1
Stomach	22.7	12	11.0	9.3	Liver	28.8	24	20.3	18.1
SI	23.5	12	14.6	-17.8	Stomach	29.1	23	24.6	-6.6
Colon	23.5	12	13.5	-11.0	SI	30.1	23	28.6	-19.6
Ovary	25.1	11	8.5	29.9	Colon	29.4	23	27.5	-16.5
Uterus	25.1	11	14.1	-22.2	Ovary	29.7	23	26.5	-13.3
Skin	23.2	12	17.0	-29.4	Uterus	29.3	23	22.5	2.1
Average	23.2	12	11.9	0.4	Skin	27.8	24	28.1	-14.6
					Average	27.8	24	24.2	-0.6

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Determining Organ Doses from CT with Direct Measurements in Postmortem Subjects: Part 2—Correlations with Patient-specific Parameters¹

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Lynn Hill, PhD¹
Manuel Arevalo, PhD¹

Purpose: To generate empirical sets of equations that can be used to calculate patient-specific organ doses resulting from a group of computed tomographic (CT) studies by using data from direct dose measurements performed within a human body.

Materials and Methods: Organ dose measurements were obtained in eight post-mortem female cadavers. A linear relationship between

- Simple, scanner-side determination of organ doses prior to the scan
- New proposed CT protocols can be approved or rejected based on patient doses without the need for post-mortem measurements
- Benchmark for MC calculations

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