TU-SAMS-L100J-01

Determination of Dose from CT Examinations

John M. Boone, Ph.D.
Professor and Vice Chairman of Radiology
Professor of Biomedical Engineering
University of California, Davis

Chairman, AAPM Science Council
Chairman, ICRU CT* Committee

*Image Quality and Patient Dose in Computed Tomography, ICRU Report 93

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- CT “dosimetry” in the real world
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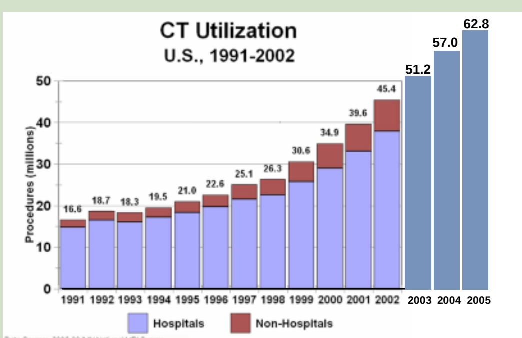
- Summary



www:myhealthfinder.com/hcac/CTreport04.pdf

UCDAVIS UNIVERSITY OF CALIFORNIA

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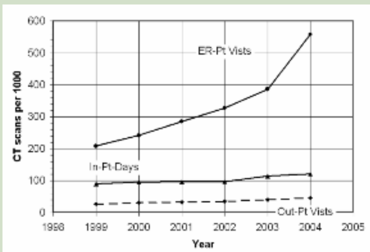
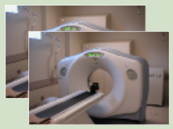
emergency room CT scans





in press, Journal of the American College of Radiology

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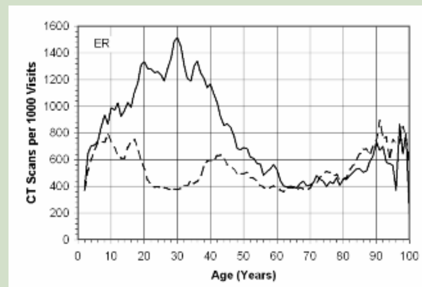
emergency room CT use rate



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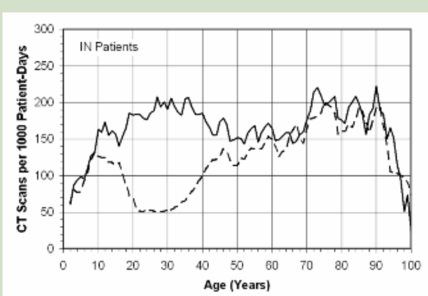
in-patient CT use rate



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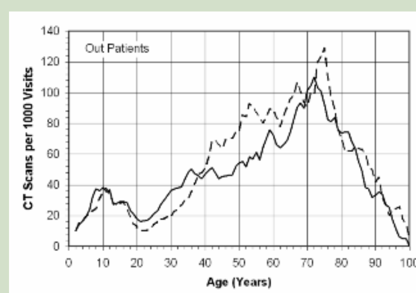
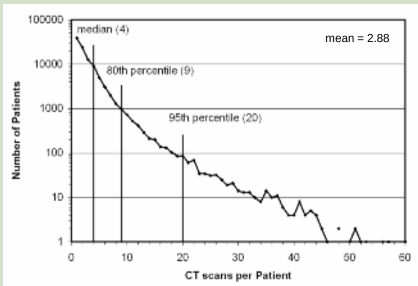
out-patient CT use rate



CT scans *per patient*



The radiation levels from CT has caught the eye of the public

FDA Public Health Notification:
Reducing Radiation Risk from Computed Tomography for Pediatric and Small Adult Patients

CT scans in children linked to cancer

By Steve Sternberg, USA TODAY

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.

What's more, CT or computed tomography scans given to kids are typically calibrated for adults, so children absorb two to six times the radiation needed to produce clear images, a second study shows. These doses are "way bigger than the sorts of doses that people at Three Mile Island were getting," David Brenner of Columbia University says. "Most people got a tenth or a hundredth of the dose of a CT."

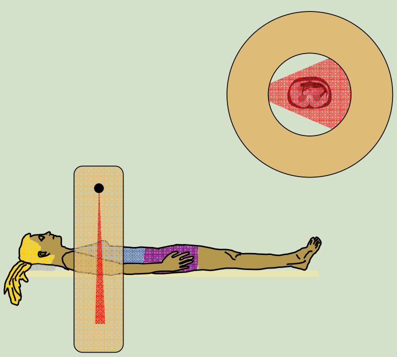
Radiation-induced temporary hair loss as a radiation damage only occurring in patients who had the combination of MDCT and DSA

Eur Radiol (2005) 15:41–46

BEIR VII: Health Risks from Exposure to Low Levels of Ionizing Radiation

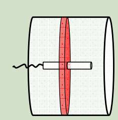
Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries

Amy Berrington de González, Sarah Darby



let's go measure the

$CTDI_{100}$



A new look at CT dose measurement: Beyond CTDI

Robert L. Dixon[a)]
Department of Radiology, Wake Forest University School of Medicine, Winston-Salem, North Carolina 27157-1088

(Received 9 January 2003; accepted for publication 2 April 2003; published 30 May 2003)

Letter to the Editor — Bob Dixon

Restructuring CT dosimetry—A realistic strategy for the future Requiem for the pencil chamber

(Received 30 October 2005; revised 21 July 2006; accepted for publication 21 July 2006; published 27 September 2006)

It is time to retire the computed tomography dose index (CTDI) for CT quality assurance and dose optimization

POINT/COUNTERPOINT

David J. Brenner, Ph.D., DSc
Center for Radiological Research, Columbia University Medical Center, New York, New York 10032

Cynthia H. McCollough, Ph.D., DABR
Mayo Clinic College of Medicine, Department of Radiology, Rochester, Minnesota 55905

Letter to the Editor — David Brenner

Is it time to retire the CTDI for CT quality assurance and dose optimization?

(Received 8 April 2005; revised 21 July 2005; accepted for publication 23 July 2005; published 29 September 2005)

The trouble with $CTDI_{100}$

John M. Boone[*]
Department of Radiology and Biomedical Engineering, University of California Davis Medical Center, Ellison Building, 4860 Y Street, Suite 3100, Sacramento, California 95817

(Received 1 September 2006; revised 26 October 2006; accepted for publication 6 November 2006; published 20 March 2007)

So what's wrong with the $CTDI_{100}$?

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where it all began…….

A method for describing the doses delivered by transmission x-ray computed tomography[a)]

Thomas B. Shope, Robert M. Gagne, and Gordon C. Johnson
Bureau of Radiological Health, Food and Drug Administration, 5600 Fishers Lane, Rockville, Maryland 20857

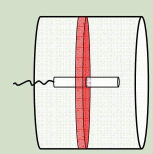
(Received 23 September 1980; accepted for publication 3 October 1980)

II. SUGGESTED DOSE DESCRIPTOR FOR COMPUTED TOMOGRAPHY

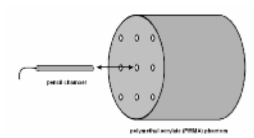
The dose descriptor we propose is the computed tomography dose index (CTDI) denoted as C and defined by

$$C = (1/T)\int_{-\infty}^{\infty} D_1(z)dz. \qquad (1)$$

where $D_1(z)$ is the dose as a function of position along the z axis coordinate for a single scan dose profile at a given point (x,y). T is the slice thickness as stated by the manufacturer or selected by the CT system operator. The CTDI will be shown below to be equal to the average dose along the z direction at the point (x,y) over the central scan of a series of scans when the series consists of a large number of scans separated by the slice thickness.



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



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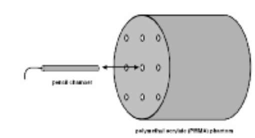
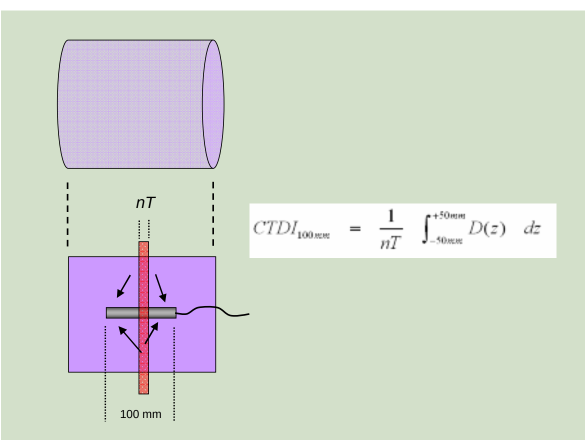


$$CTDI_{100mm} = \frac{1}{nT} \int_{-50mm}^{+50mm} D(z) \quad dz$$



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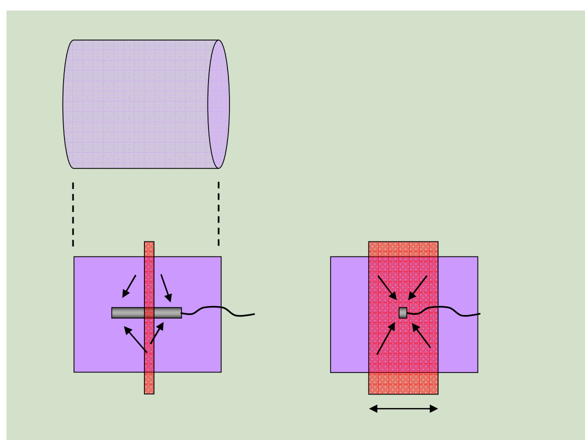
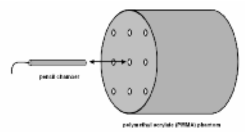


$$CTDI = \frac{1}{nT} \int_{-7T}^{+7T} D(z) \, dz$$



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

$$CTDI_{w} = \frac{1}{3} CTDI_{center} + \frac{2}{3} CTDI_{peripheral}$$

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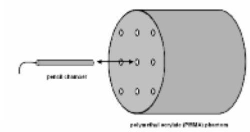

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$$CTDI_{vol} = \frac{CTDI_{w}}{pitch} \qquad pitch = \frac{s}{nT}$$

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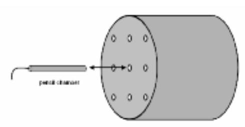

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$$DLP = CTDI_{vol} \times scan\_length$$

So what’s wrong with the $CTDI_{100}$?

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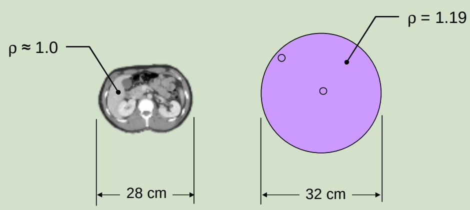

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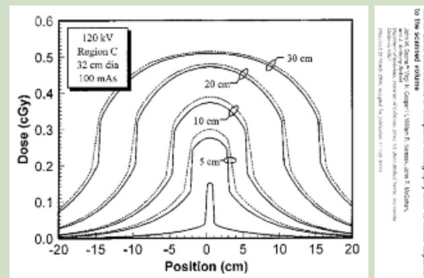

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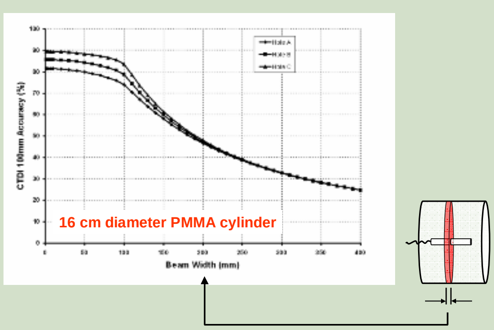

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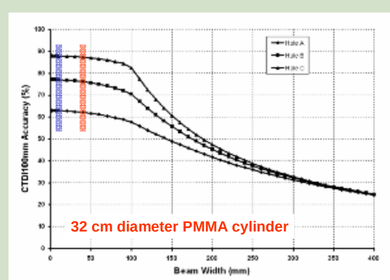

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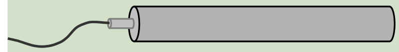
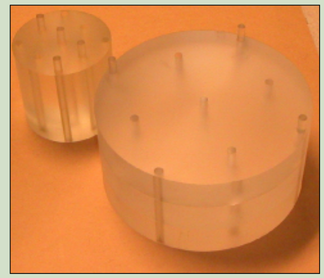


100 mm pencil chamber



GE-16 CT Scanner
UC Davis Medical Center
Scanner 2
June 8, 2006
Reference Log Book 1 page 121

Measurements made by John M. Boone, Ph.D. and Alex LC Kwan, Ph.D.

BODY (32 cm PMMA) — **20 mm collimation, 100 mAs**

RAW DATA (mR)				0.043668 Corrected** mGy / 100 mAs			
kVp	**in air**	**center**	**edge**	**kVp**	**in air**	**center**	**edge**
80	180.2	33.4	85.3	80	7.9	1.5	3.7
100	326.9	72.7	162.8	100	14.4	3.2	7.1
120	507.2	123.7	256.0	120	22.1	5.4	11.2
140	718.0	185.0	364.7	140	31.4	8.1	15.9

-8.8% *Differences from IMPACT (%)*				IMPACT RESULTS* mGy/100 mAs			
kVp	**in air**	**center**	**edge**	**kVp**	**in air**	**center**	**edge**
80	-14.9%	-1.2%	13.2%	80	9.2	1.5	3.3
100	-16.0%	-11.8%	1.9%	100	17.1	3.6	7.0
120	-12.2%	-12.6%	-5.6%	120	25.2	6.2	11.8
140	-8.9%	-13.0%	-0.5%	140	34.4	9.3	16.0

*Impact results are reported for 10 mm collimation, but were corrected to 20 mm by a factor 0.86
**correction of raw data includes multiplication by 100mm/20mm and division by 114.5 (cell E11)

GE-16 CT Scanner
UC Davis Medical Center
Scanner 2
June 8, 2006
Reference Log Book 1 page 121

Measurements made by John M. Boone, Ph.D. and Alex LC Kwan, Ph.D.

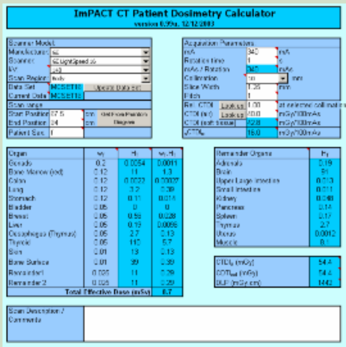
HEAD (16 cm PMMA) — **20 mm collimation, 100 mAs**

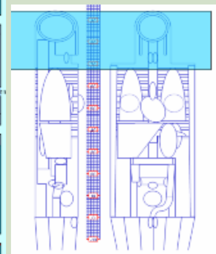
RAW DATA (mR)				0.043668 Corrected** mGy / 100 mAs			
kVp	**in air**	**center**	**edge**	**kVp**	**in air**	**center**	**edge**
80	230.6	134.9	141.9	80	10.1	5.9	6.2
100	393.9	255.0	254.4	100	17.2	11.1	11.1
120	585.9	397.7	392.0	120	25.6	17.4	17.1
140	804.8	560.2	550.7	140	35.1	24.5	24.0

-5.8% *Differences from IMPACT (%)*				*IMPACT RESULTS* mGy/100 mAs*			
kVp	**in air**	**center**	**edge**	**kVp**	**in air**	**center**	**edge**
80	-10.1%	-3.4%	-5.0%	80	11.2	6.1	6.5
100	-8.8%	-3.7%	-5.4%	100	18.9	11.6	11.7
120	-7.5%	-4.1%	-4.5%	120	27.7	18.1	17.9
140	-6.8%	-4.3%	-3.5%	140	37.7	25.5	24.9

*Impact results are reported for 10 mm collimation, but were corrected to 20 mm by a factor 0.86
**correction of raw data includes multiplication by 100mm/20mm and division by 114.5 (cell E11)

Computation of effective dose (ImPACT of UK) based on Standard patient geometry and Monte Carlo derived tables





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International Commission on Radiation Units and Measurements, Inc.

ICRU: Image Quality and Patient Dose in CT

John M. Boone (US)
James Brink (US)
Sue Edyvean (UK)
Jacob Geleijns (Netherlends)
Walter Huda (US)
Wolfram Leitz (Sweden)
Cynthia McCollough (US)
Michael McNitt-Gray (US)

ICRU Sponsors:
Willi Kalender (Germany)
Kunio Doi (US)
Peter Dawson (UK)

ICRU: Image Quality and **Patient Dose** in CT

A. CT scanner radiation output measurement

B. Dose to the Reference Patient - D_{RP}

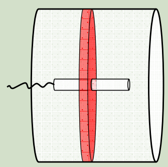
C. Dose to the Individual Patient

A. CT scanner radiation output measurement

A-1 $CTDI_{100}$

A-2 D(z) of CT beam

A-3 D(x, z) of CT beam



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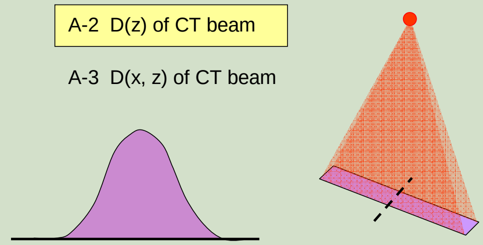

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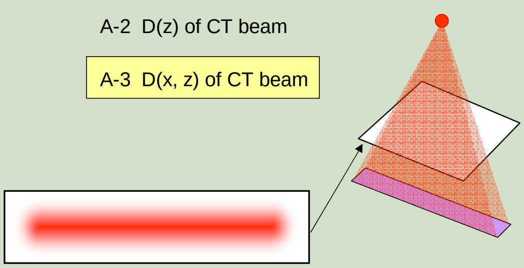


B. Dose to the Reference Patient - D_{RP}

B-1 Definition of the Reference Patient

B-1.1 Size Range

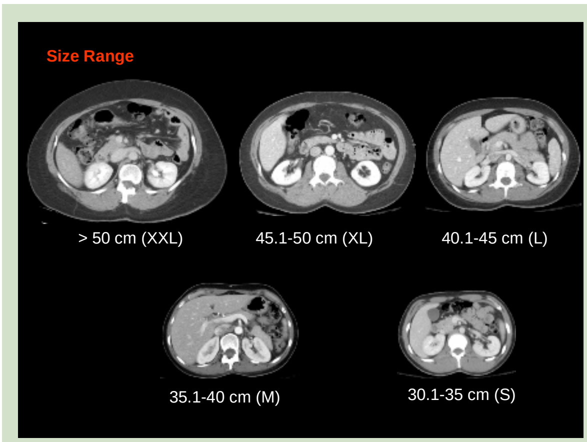
B-1.2 Standard Scans (D_{RP-X})

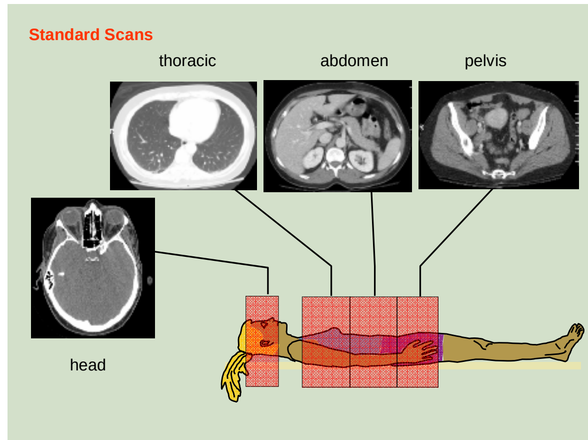
B-2 Dose assessment

B-2a Monte Carlo measurements

B-2b physical measurements

B-3 Utility of D_{RP-X}





B. Dose to the Reference Patient - D_{RP}

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- **B-2 Dose assessment**
  - B-2a Monte Carlo measurements
  - B-2b physical measurements
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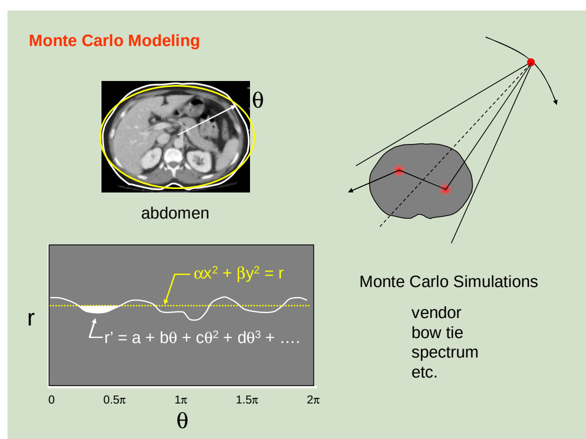
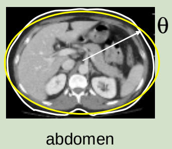
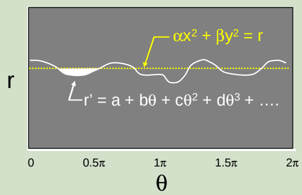
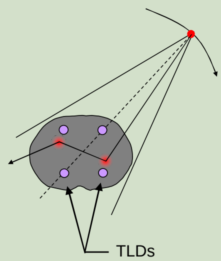


physical dose measurements







B. Dose to the Reference Patient - D_{RP}

- B-1 Definition of the Reference Patient
  - B-1.1 Size Range
  - B-1.2 Standard Scans ($D_{RP\text{-}X}$)
- B-2 Dose assessment
  - B-2a Monte Carlo measurements
  - B-2b physical measurements
- B-3 Utility of $D_{RP\text{-}X}$

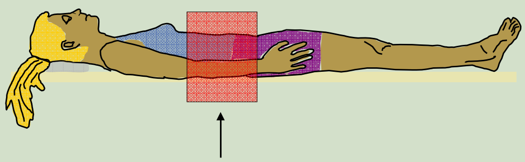
Doses from XX CT Scanner in Room 4
(mGy per 100 mAs)

		Pediatric	Female	Male
abdomen				
	Xs	xx	yy	zz
	S	xx	yy	zz
	M	xx	yy	zz
	L	xx	yy	zz
	XL	xx	yy	zz
thorax				
	Xs	xx	yy	zz
	S	xx	yy	zz
	M	xx	yy	zz
	L	xx	yy	zz
	XL	xx	yy	zz

C. Dose to the Individual Patient

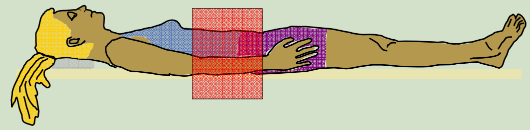
- C-1 Doses to patients measured in mGy
- C-2 Individualized deterministic dose computation

Dose metrics
Dose units



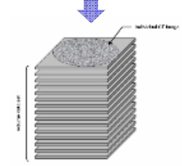
Individualized Dose Estimates

DICOM header
kVp, mAs eff., pixel size, slice thickness, etc.

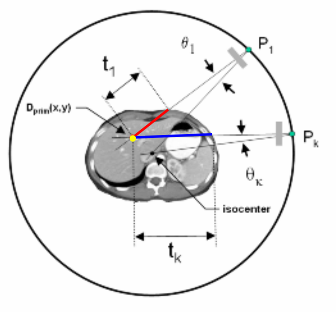


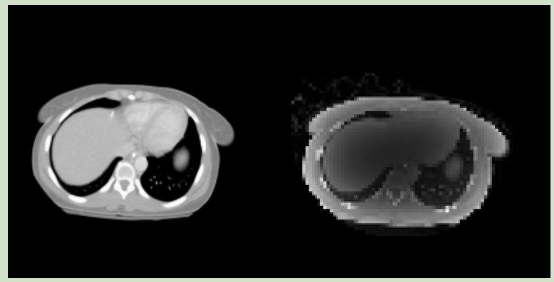
Determination of Primary Dose

$$\mu = \frac{\mu_w}{1000} HU + \mu_w$$



$$D_{prim}(x,y,z) = \sum_{k=1}^{N} P(k,\theta,z) \quad ISL(x,y,z,k) \quad F(\theta) \quad e^{-\mu t_k} \quad \left(1 - e^{-\mu \Delta}\right)$$

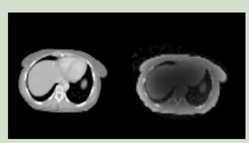




CT image

primary dose image

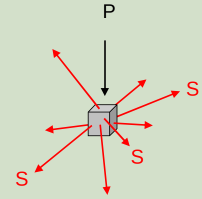
Determination of Scatter Dose



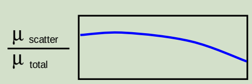
CT image

primary dose image

HU
1000 bone
0 tissue
-1000 air



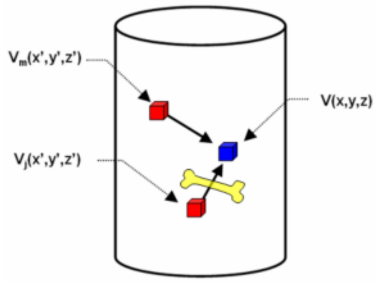
$$\frac{\mu_{scatter}}{\mu_{total}}$$



scatter to primary ratio
(per voxel) - SPR

$$D_{scat}(x,y,z) = \sum_{x'=x-d}^{x+d} \sum_{y'=y-d}^{y+d} \sum_{z'=z-d}^{z+d} D_{prim}(x',y',z')$$

$$SPR(\mu[x',y',z'])\ \ S(x,y,z,x',y',z')\ \ e^{-\mu W}\ \ \left(1 - e^{-\mu\Delta}\right)$$



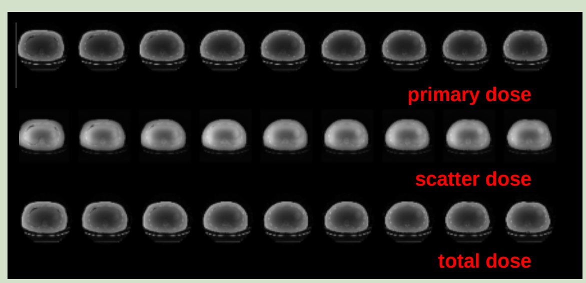
$Dose(x,y,z) = Dose_{primary}(x,y,z) + Dose_{scatter}(x,y,z)$


CT image


primary dose image


scatter dose image

three dimensional dose distribution



Determination of Dose from CT Examinations

- Why are we here?
- Definitions
- CT "dosimetry" in the real world
- Perspectives from the ICRU Committee
- Summary

Question 1:

Which of the following is NOT a good reason why measurements using a 100 mm pencil ionization chamber located in a 32 cm diameter PMMA phantom are inaccurate determinants of patient dose in body CT?

0%	1.	Most patients are not 32 cm in diameter
0%	2.	No patient has an average tissue density of 1.19 g/cm^3
0%	3.	Air ionization chambers are not as accurate as TLDs
0%	4.	Most CT scans are longer than 10 cm in length
0%	5.	The cylindrical profile of the phantom prevents realistic mA modulation schemes

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Question 2:

Upcoming ICRU recommendations for CT dosimetry will likely eliminate the use of which one of the following parameters when computing the dose to a specific patient?

0%	1.	effective dose
0%	2.	absorbed dose
0%	3.	air kerma
0%	4.	Monte Carlo-derived dose conversion coefficients
0%	5.	The dose dependency on bow tie filter and kVp

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THE END