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AAPM Report 220: Quantifying Patient Size in Terms of Water Equivalent Diameter

Cynthia H. McCollough, PhD, DABR, FAAPM, FACR
Director, CT Clinical Innovation Center
Professor of Medical Physics and Biomedical Engineering
Mayo Clinic, Rochester, MN

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DISCLOSURES

Research Support:

NIH	Other
EB 017095	Mayo Discovery Translation Award
EB 017185	Mayo Center for Individualized Medicine Award
EB 016966	Thrasher Foundation
DK 100227	Siemens Healthcare
HR 046158	
RR 018898	

Off Label Usage

None

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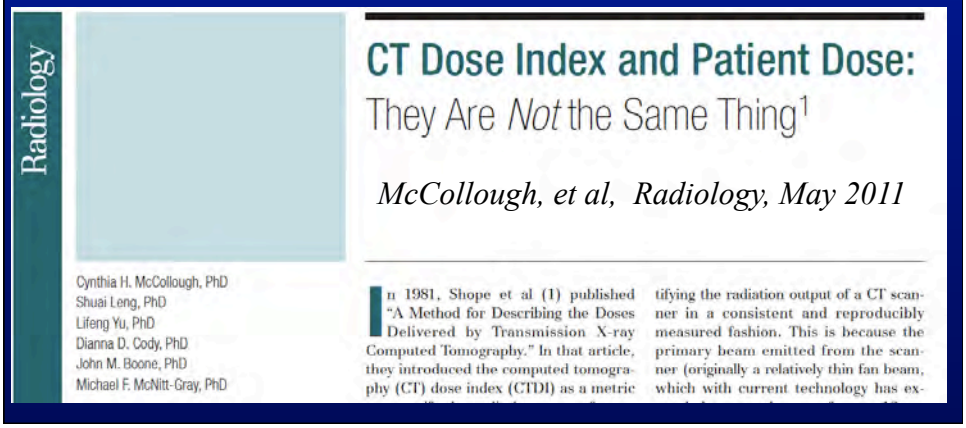
CTDIvol is NOT patient dose

- CTDI quantifies scanner radiation output
- Patient size must be considered to estimate patient dose



Radiology

CT Dose Index and Patient Dose:
They Are *Not* the Same Thing[1]

McCollough, et al, Radiology, May 2011

Cynthia H. McCollough, PhD
Shuai Leng, PhD
Lifeng Yu, PhD
Dianna D. Cody, PhD
John M. Boone, PhD
Michael F. McNitt-Gray, PhD

In 1981, Shope et al (1) published "A Method for Describing the Doses Delivered by Transmission X-ray Computed Tomography." In that article, they introduced the computed tomography (CT) dose index (CTDI) as a metric

tifying the radiation output of a CT scanner in a consistent and reproducibly measured fashion. This is because the primary beam emitted from the scanner (originally a relatively thin fan beam, which with current technology has ex-

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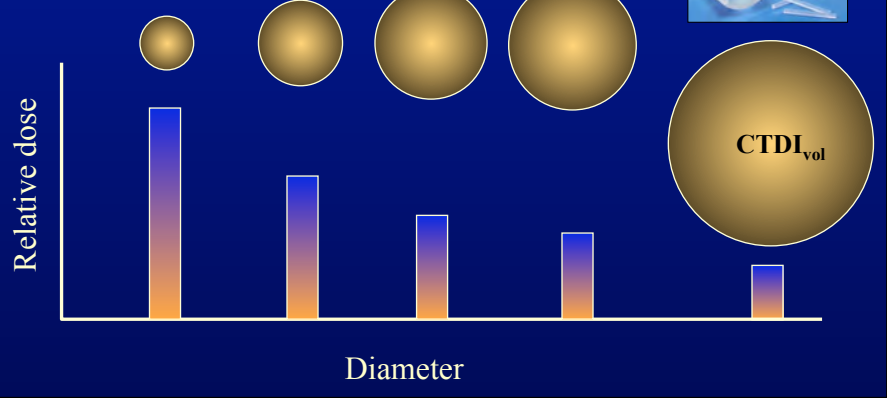
DIFFERENT patient doses for different size patients

SAME
scanner output



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AAPM Report No. 204

Size-Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations

Report of AAPM Task Group 204, developed in collaboration with the International Commission on Radiation Units and Measurements (ICRU) and the Image Gently campaign of the Alliance for Radiation Safety in Pediatric Imaging

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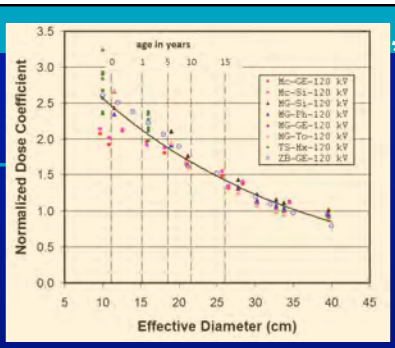
AAPM Report 204



- Dose as a function of size
- 4 Research groups
  - Physical measurements:
    - Anthropomorphic, torso shaped phantoms
    - Cylinders of polymethyl-methacrylate
  - Monte Carlo calculations:
    - Patient models from voxelized CT images
    - Cylinders of water, polymethyl-methacrylate and polyethelene
- Data for absorbed dose, normalized to CTDIvol had an exponential relationship to size

*AAPM Report 204. 2011

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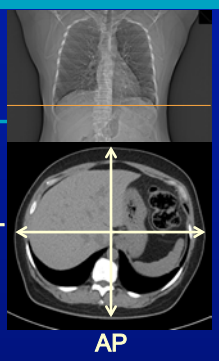
How to Determine SSDE



- Patient dimension such as
  - anterioposterior thickness (AP)
  - lateral width (LAT)
  - AP+LAT
- Tabulated* conversion factors, f_{size}

SSDE = f_{size} x CTDIvol

*** AAPM TG Report 204. 2011**

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CT radiograph

Lateral Dim (cm)	Effective Dia (cm)	Correction Factor
8	9.2	2.65
9	9.7	2.60
10	10.2	2.55
11	10.7	2.50
12	11.3	2.45
13	11.8	2.40
14	12.4	2.35
15	13.1	2.29
16	13.7	2.24
17	14.3	2.19
18	15.0	2.13
19	15.7	2.08
20	16.4	2.03
...	...	...
38	32.7	1.11
39	33.8	1.07
40	34.9	1.03

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SSDE estimates

- Mean dose
- Center of scan range
- Specific size
- IF an organ is reasonably large and fully contained within a scan region, then SSDE is a reasonable estimate of organ dose

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What "size" to use?

- Weight
- BMI
- Lateral or AP dimensions
  - From CT radiograph or CT image
- Cross sectional area
- Perimeter (circumference)
- Scan volume (cross sectional area ×scan length)
- ???

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AAPM TG220

Task Group on

Determination of a Patient Size Metric

for Calculation of

Size Specific Dose Estimates (SSDE)

Official Charge:

Develop a robust and scientifically sound metric for automatically estimating patient size in CT that allows determination of size specific dose estimates (SSDE – as described in Report 204)

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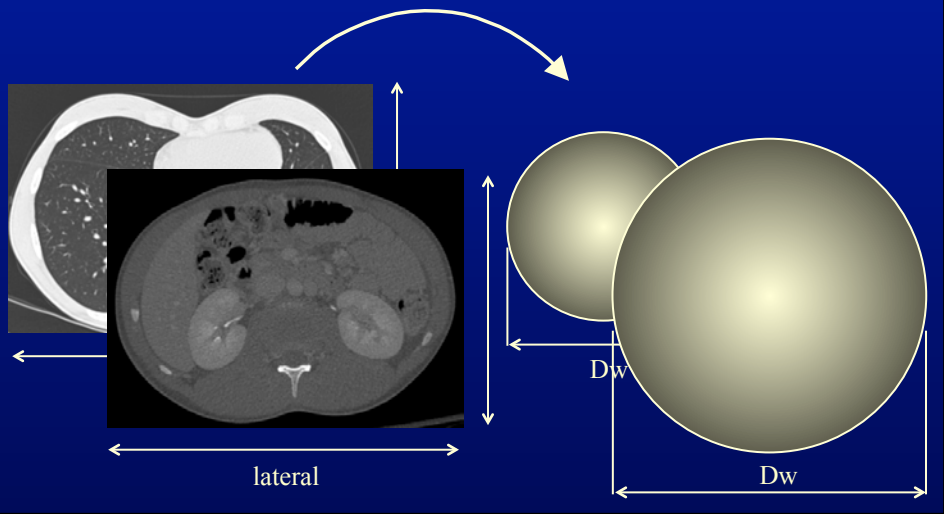
Water-equivalent diameter (Dw)

circle of water with equal ATTENUATION



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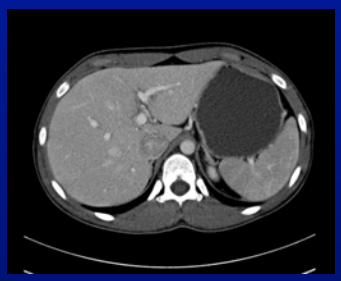
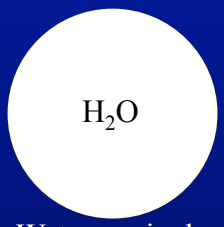
Water Equivalent Diameter (Dw)



Absorbs equal dose



Water equivalent diameter (D_w)

Wang et al, Med. Phys.2012 39(11)/6764

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Estimating Dw

CT radiograph

Can obtain before the scan,
requires proper centering,
requires manufacturer calibrations

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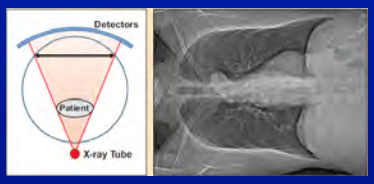
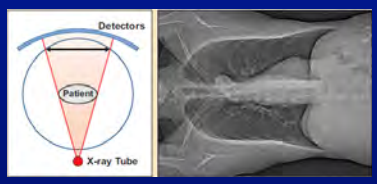
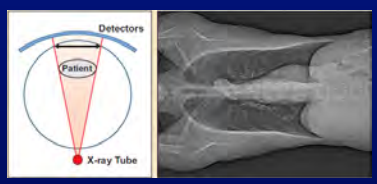
Patient too low: Dw too large



Patient centered: Dw accurate



Patient too high: Dw too small



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Estimating Dw

CT image

Requires waiting till after scan
and full FOV reconstruction,
user can calculate

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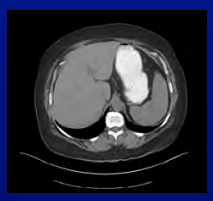
Water equivalent diameter (D_w)

- Calculation methodology



Input image

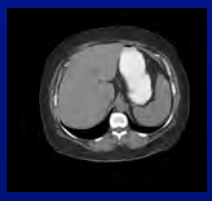
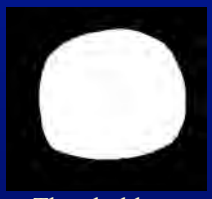


Table removal



Threshold segmentation

Total attenuation normalized to water → $Dw=2\times\sqrt{Aw/\pi}$

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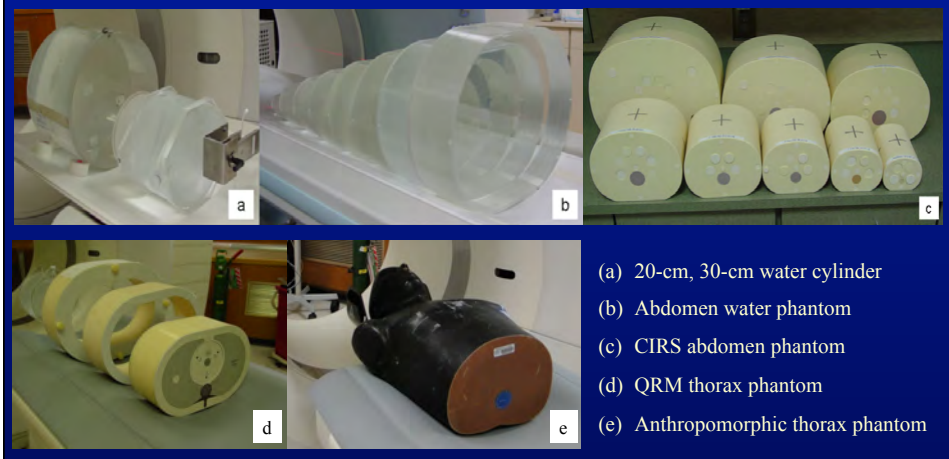
Phantoms used to assess Dw



(a) 20-cm, 30-cm water cylinder
(b) Abdomen water phantom
(c) CIRS abdomen phantom
(d) QRM thorax phantom
(e) Anthropomorphic thorax phantom

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ABDOMEN (water) phantoms

	AP (cm)	LAT (cm)	CT radiograph Dw (cm)	CT image Dw (cm)
Water cylinder	**20**	**20**	**20.6**	**20.4**
	30	**30**	**31.2**	**30.6**
Water torso phantom				Acrylic shell
	7.4	**10**	**9.8**	**9.1**
	11.2	**15**	**14**	**13.5**
	14.9	**20**	**18.4**	**18**
	18.6	**25**	**22.9**	**22.7**
	22.4	**30**	**27.4**	**27.2**
	26.1	**35**	**32.1**	**31.6**
	29.8	**40**	**36.7**	**36.1**
	33.6	**45**	**41.5**	**40.5**

Absolute error in Dw from CT radiograph relative to CT image < 1 cm

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ABDOMEN (water) phantoms

	AP (% error)	LAT (% error)	CT radiograph Dw (% error)	CT image Dw
Water cylinder	-2.0%	-2.0%	**1.0%**	-
	-2.0%	-2.0%	**2.0%**	-
Water torso phantom				-
	-18.7%	9.9%	**7.7%**	-
	-17.0%	11.1%	**3.7%**	-
	-17.2%	11.1%	**2.2%**	-
	-18.1%	10.1%	**0.9%**	-
	-17.6%	10.3%	**0.7%**	-
	-17.4%	10.8%	**1.6%**	-
	-17.5%	10.8%	**1.7%**	-
	-17.0%	11.1%	**2.5%**	-

Newborn

% error in Dw from CT radiograph relative to CT image < 4%

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THORAX phantoms

	AP (cm)	LAT (cm)	CT radiograph Dw (cm)	CT image Dw (cm)
QRM 30cm	20	30	20.9	20.9
QRM 35cm	25	35	27.5	27.3
QRM 40cm	30	40	33.7	33.2
Anthropomorphic thorax	21.6	31.8	25.6	25.6
Anthropomorphic thorax + breast	21.6	31.8	29.9	30.7

Absolute error in Dw from CT radiograph relative to CT image <1 cm

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THORAX phantoms

	AP (cm)	LAT (cm)	CT radiograph Dw (cm)	CT image Dw (cm)
QRM 30cm	-4.3%	43.5%	0.0%	-
QRM 35cm	-8.4%	28.2%	0.7%	-
QRM 40cm	-9.6%	20.5%	1.5%	-
Anthropomorphic thorax	-15.6%	24.2%	0.0%	-
Anthropomorphic thorax + breast	-29.6%	3.6%	-2.6%	-

% error in Dw from CT radiograph relative to CT image <3 %

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Summary

- Water equivalent diameter measures patient attenuation
  - It can be determined from CT radiograph prior to CT scan
  - It may be updated (for higher accuracy than achieved with the CT radiograph), if needed, after the CT scan
  - It can be easily, robustly, and reproducibly calculated
  - It is minimally affected by operator choices
  - It can be implemented by manufacturers and automatically placed in a DICOM field that
  - It can be used to calculate size specific dose estimates (SSDE)