New ICRU* Report on CT Dosimetry

*International Commission on Radiation Units *(and Measurement)*

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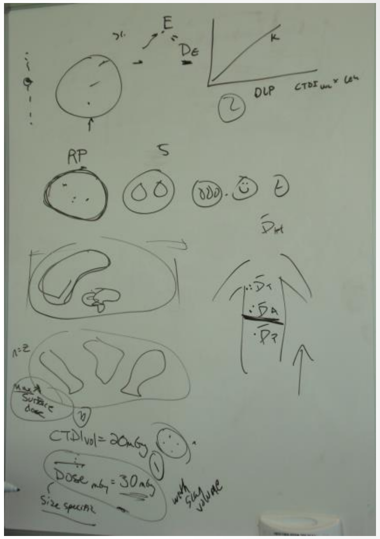
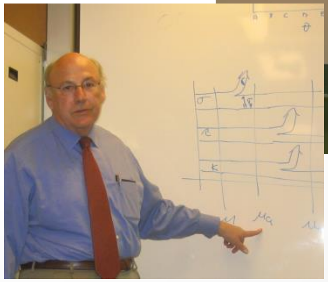
ICRU Report 87: Radiation Dose and Image Quality Assessment in CT





Disclosures

Paid Consultant to:

Varian Imaging Systems

Alston and Bird LLC

CardioInsight

DXray

Royalty Income from:

Lippincott Williams and Wilkins

Samsung Corporation

Research Funding from:

Stanford Research Institute

University of Pittsburgh

Siemens Medical Systems

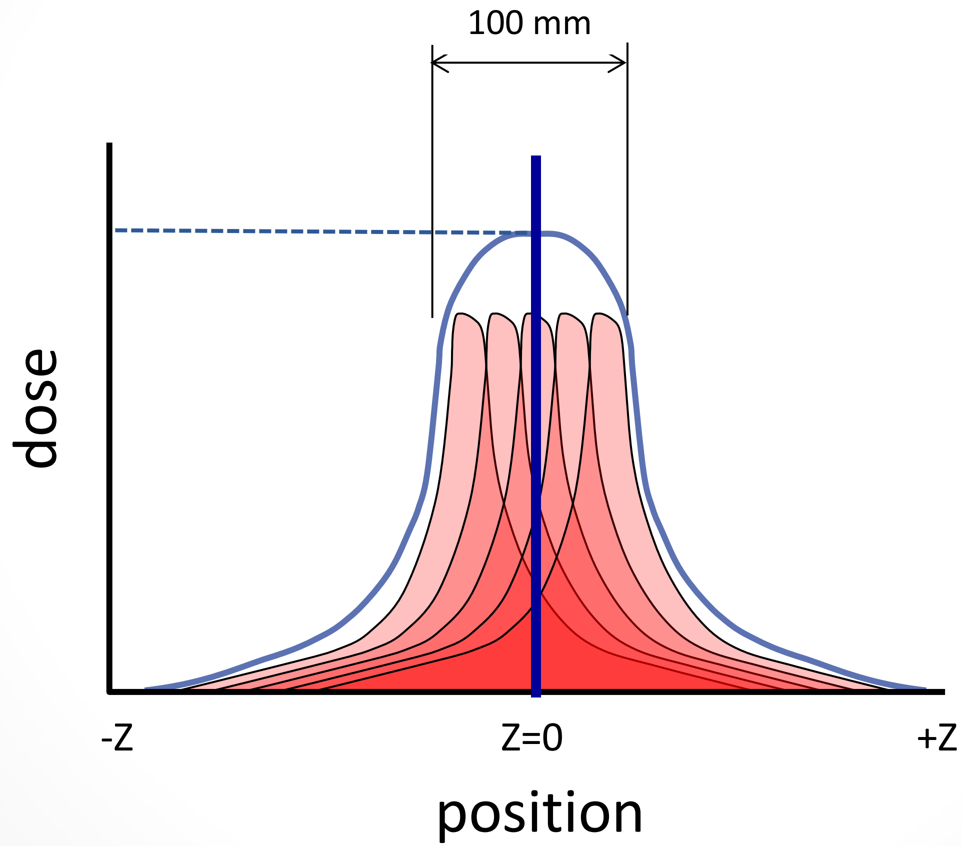
Hologic Corporation

National Institutes of Health (NIBIB)

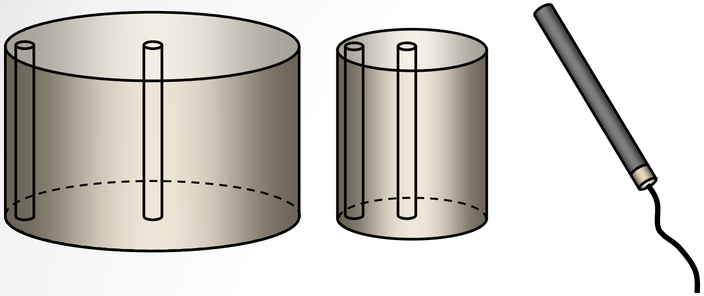
ICRU Report on CT Dosimetry

- Introduction & Historical CT Dose Metrics
- Dose dependency on patient size
- Dose and CT scan length
- Phantoms and radiation meters
- ICRU extension to AAPM Report 111
- Summary

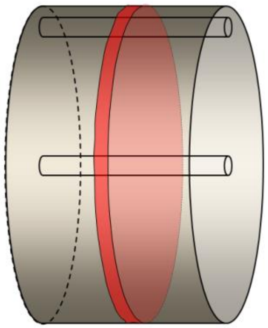
$$CTDI_{100} = \frac{1}{nT} \int_{-50mm}^{+50mm} D(z) \quad dz$$



CTDI - based Dose Metrics



The Tools



The Methods

The Metrics

$CTDI_{100}$ (center & peripheral)

$CTDI_w$

$CTDI_{vol}$

DLP

CTDI is a good measure of CT dose to a large plastic phantom, but is not a stand-alone metric for patient dose

A new look at CT dose measurement: Beyond CTDI

Robert L. Dixon

Med Phys 2003

The trouble with $CTDI_{100}$

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Departments of Radiology and Biomedical Engineering, University of California Davis Medical Center, Ellison Building, 4860 Y Street, Suite 3100, Sacramento, California 95817

(Received 1 September 2005; revised 26 October 2006; accepted for publication 6 November 2006; published 20 March 2007)

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

Robert L. Dixon

Med. Phys. **33**, 3973 (2006)

Radiology

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

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

Experimental validation of a versatile system of CT dosimetry using a conventional ion chamber: Beyond CTDI100

Robert L. Dixon and Adam C. Ballard

Med. Phys. **34**, 3399 (2007)

ICRU Report on CT Dosimetry

Introduction & Historical CT Dose Metrics

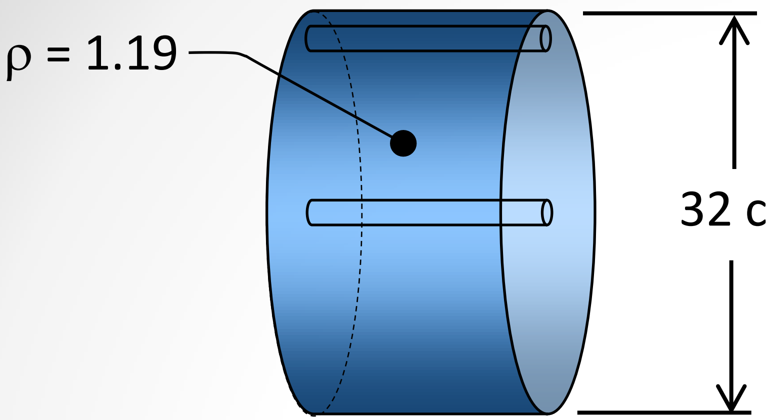
Dose dependency on patient size

Dose and CT scan length

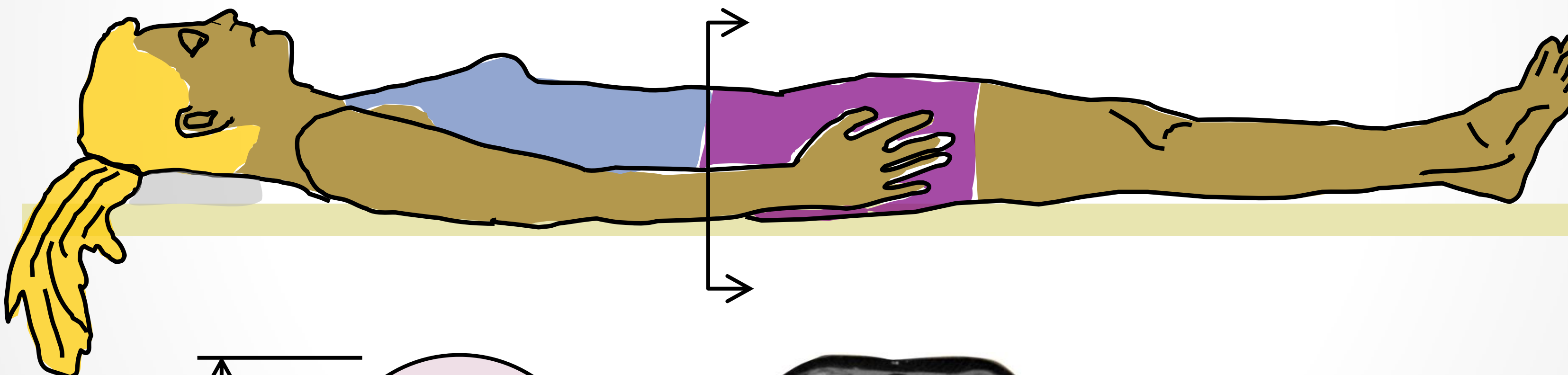
Phantoms and radiation meters

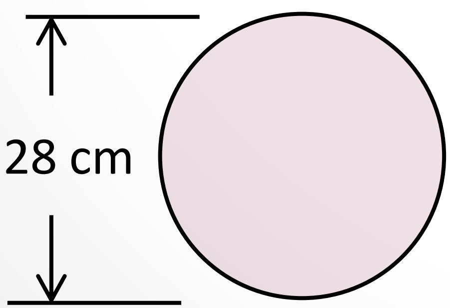
ICRU extension to AAPM Report 111

Summary



47”
120 cm
waistline



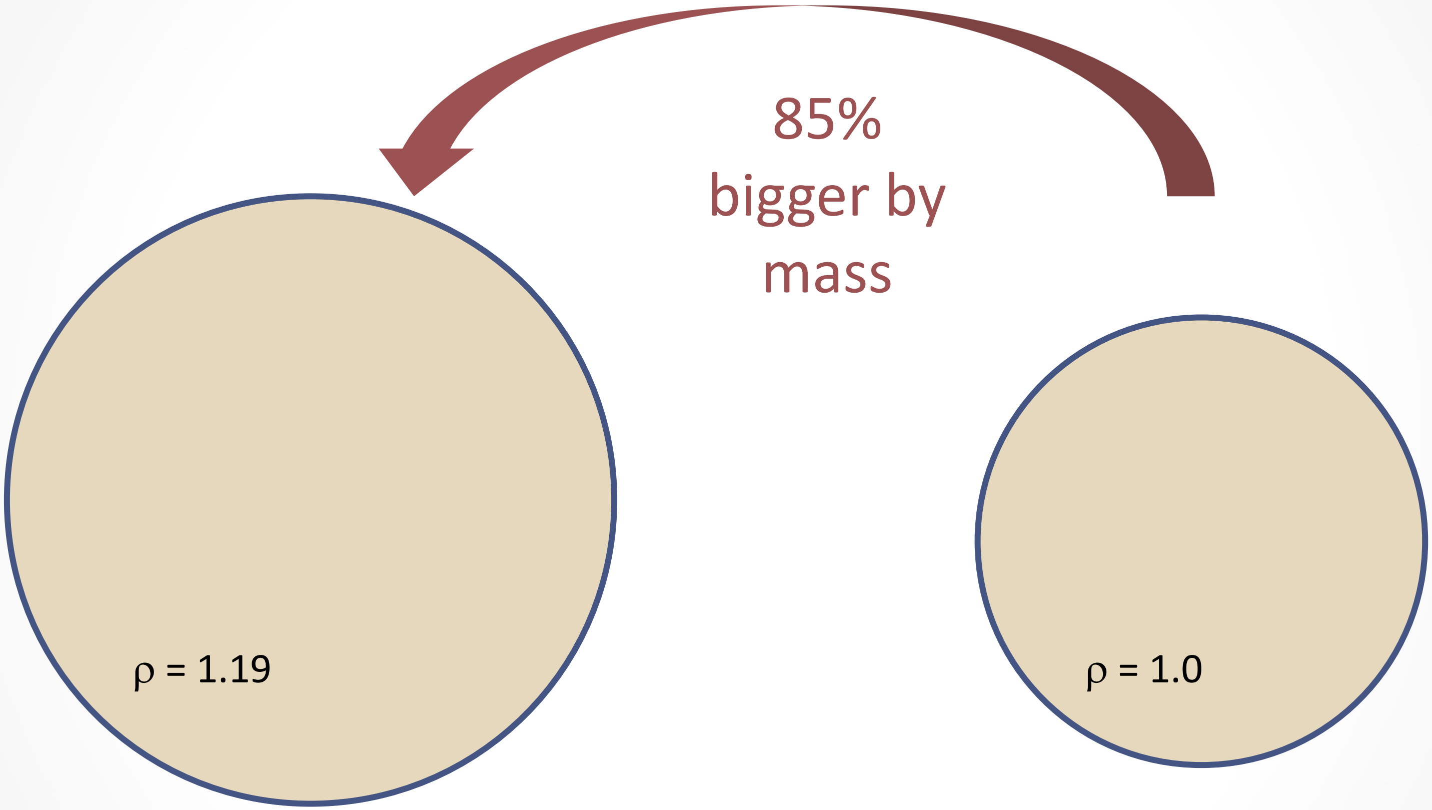


≈

35”
88 cm
waistline

UC Davis Data

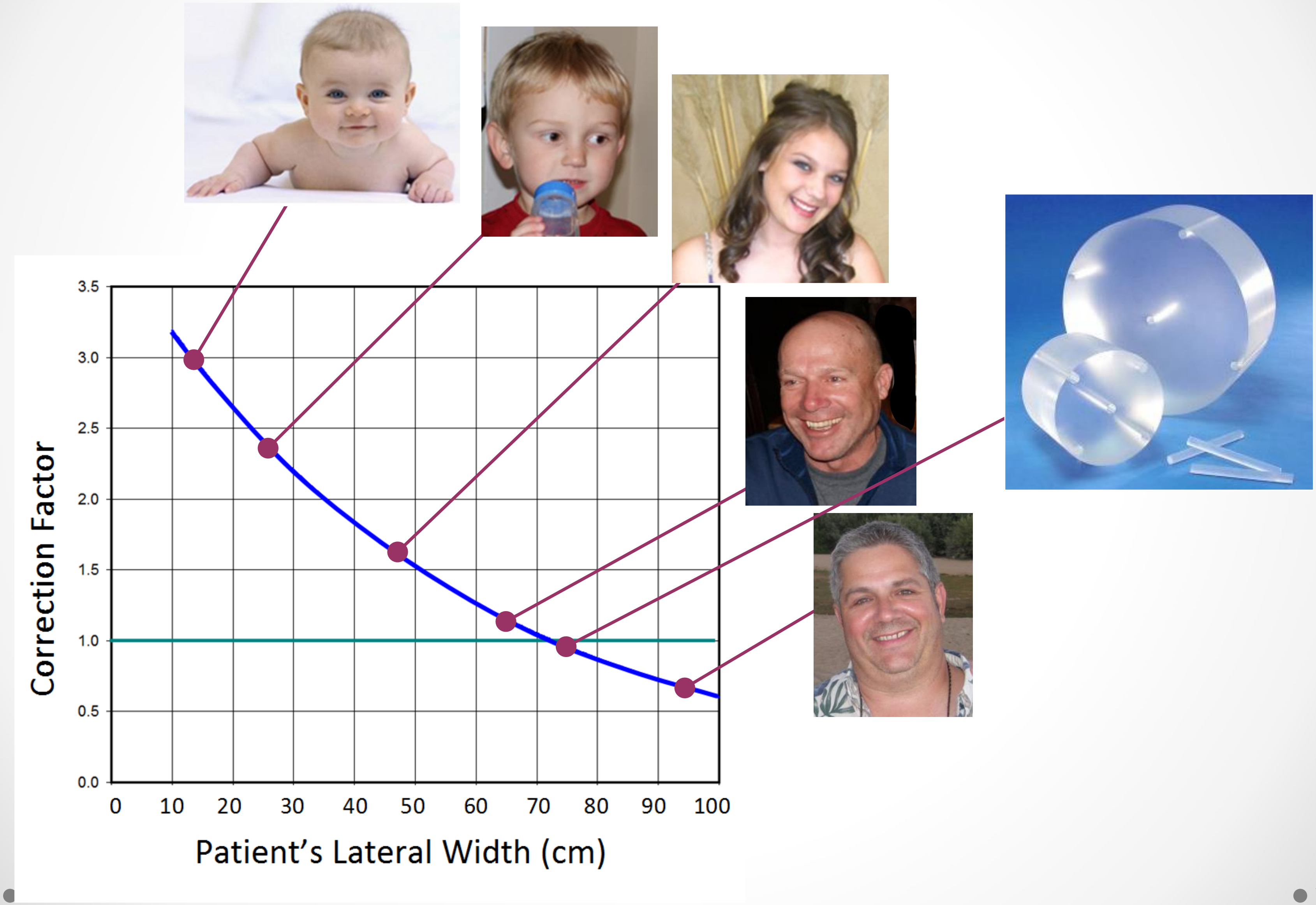
Dose Dependency on patient size



32 cm PMMA phantom
1138 cm^2

average patient
615 cm^2

practical methods to correct dosimetry estimates for patient size



AAPM Report No. 204

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

Default Protocol

CT Dose Summit:

100% Dose, 120 kV

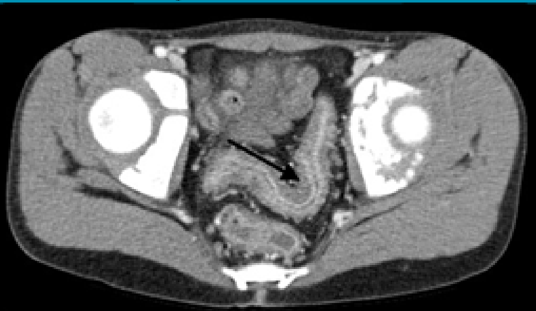
Scan Parameter Optimization

April 29-30, 2010

The Renaissance Concourse Atlanta Airport Hotel

Atlanta, GA

Improved Protocol



75% Dose, 100 kV

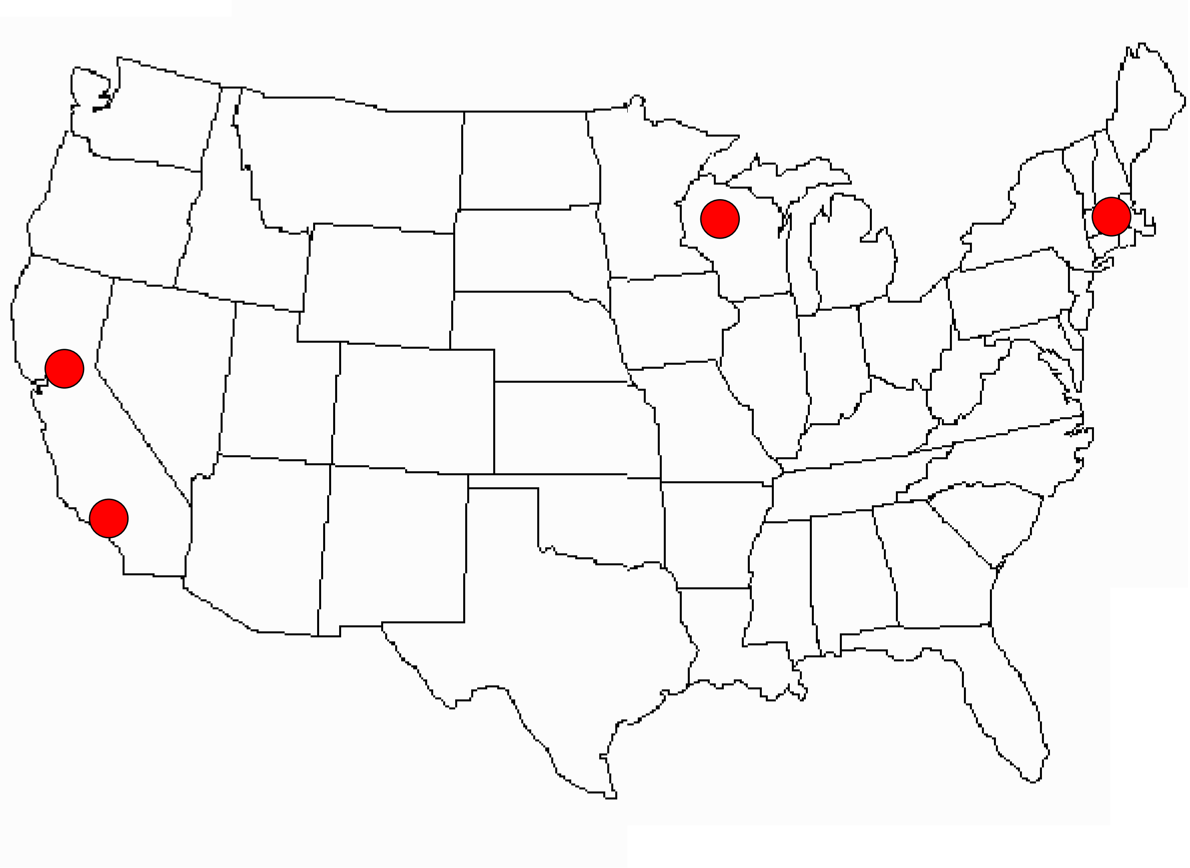
Lower Dose & Brighter Iodine

AAPM Report No. 204

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

TG-204 Approach

- Four Independent Research Groups
- Studied Size-dependent CT Dose

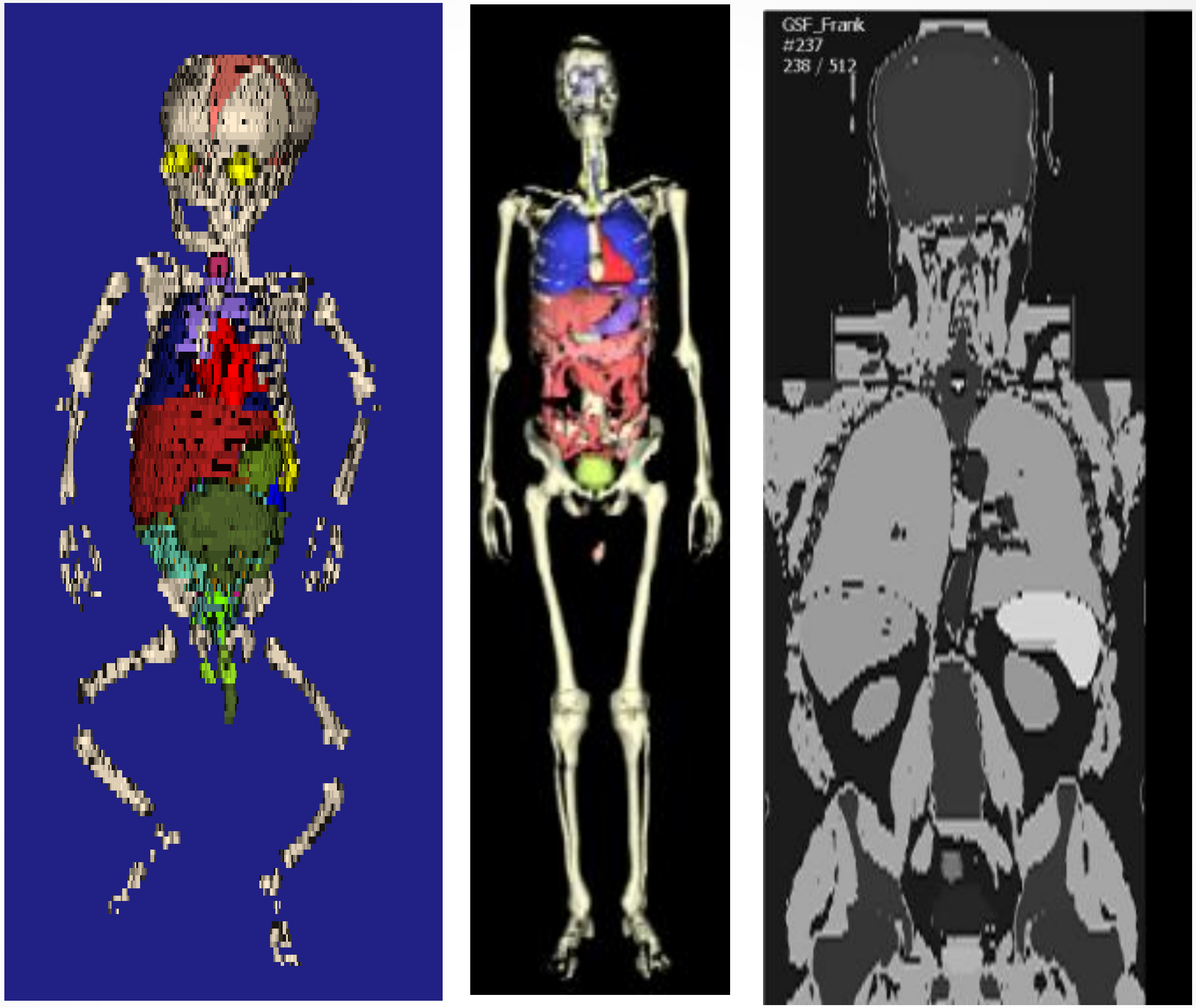


Family of physical phantoms
Cynthia McCollough, Mayo Clinic

TOTH DATA		
Pediatric Body		
Diameter	A32	a16
5	2.93	1.45
10	2.63	1.31
15	2.33	1.16
20	2.04	1.02
25	1.74	0.87
30	1.44	0.73
35	1.14	0.58
40	0.85	0.44

standard phantoms

Tom Toth & Keith Strauss



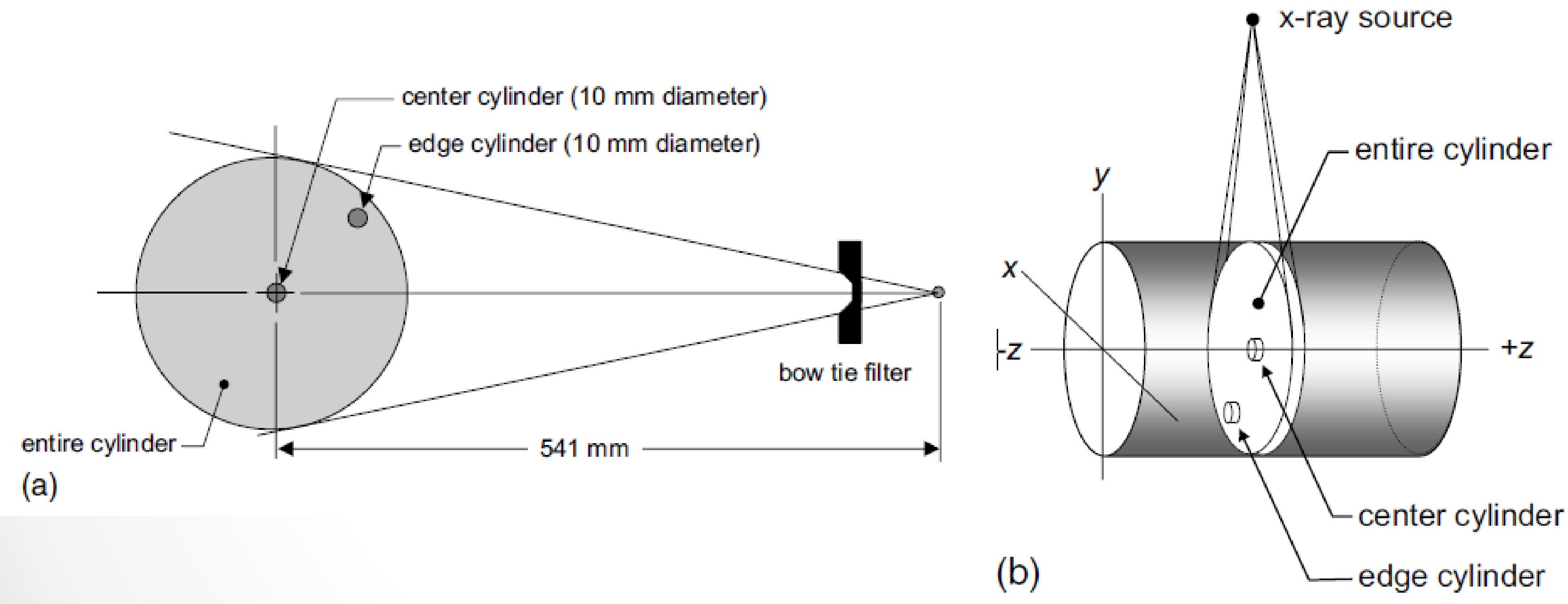
Anthropomorphic Monte Carlo phantoms

Mike McNitt-Gray, UCLA

Monte Carlo evaluation of $CTDI_\infty$ in infinitely long cylinders of water, polyethylene and PMMA with diameters from 10 mm to 500 mm

Hong Zhou
Department of Radiology and Department of Radiation Oncology, University of California, Davis, Sacramento, California 95817

John M. Boone[a)]
Department of Radiology and Department of Biomedical Engineering, University of California, Davis, Sacramento, California 95817



Monte Carlo phantoms (1 – 50 cm)

John M. Boone, UC Davis

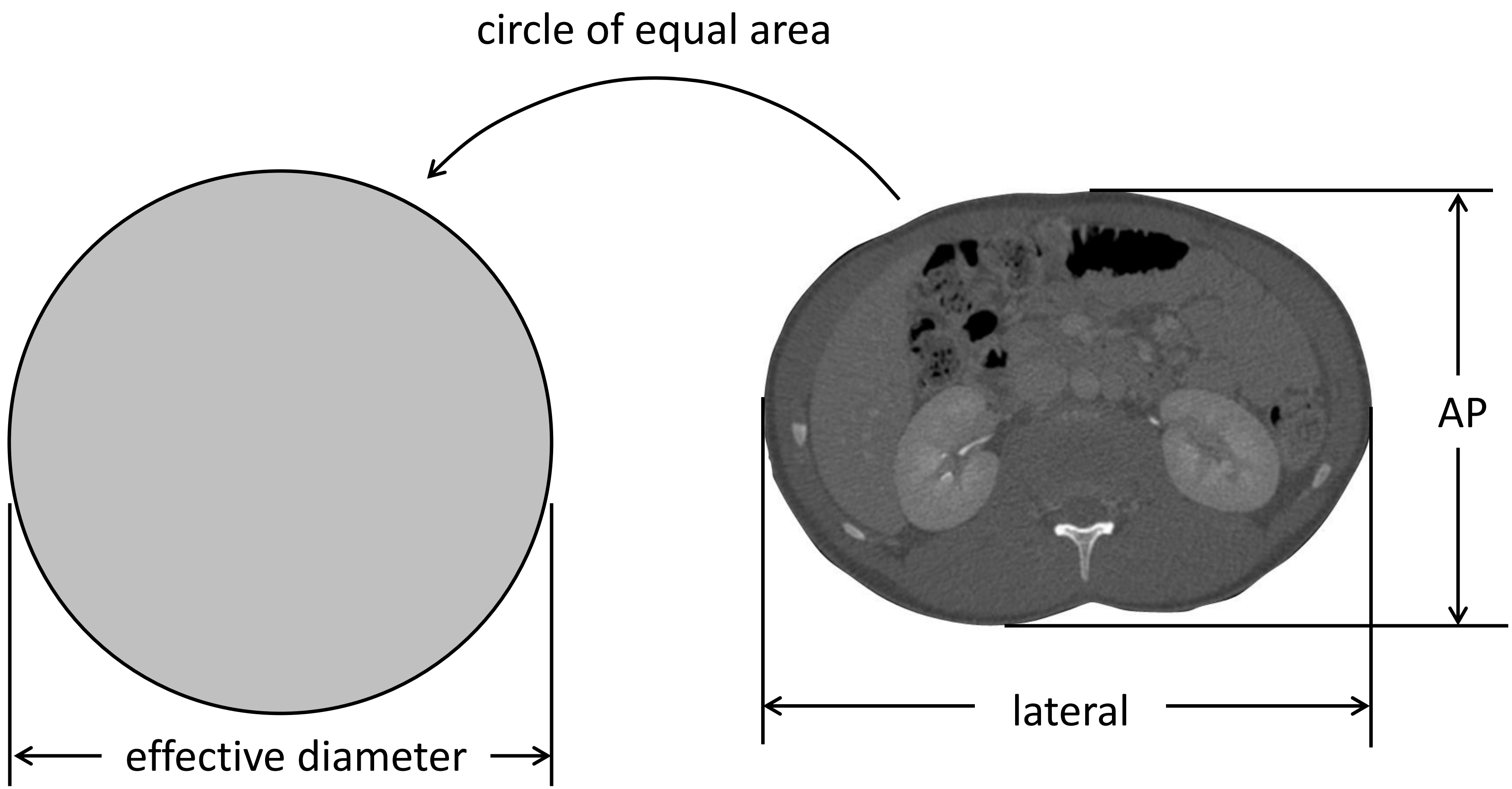
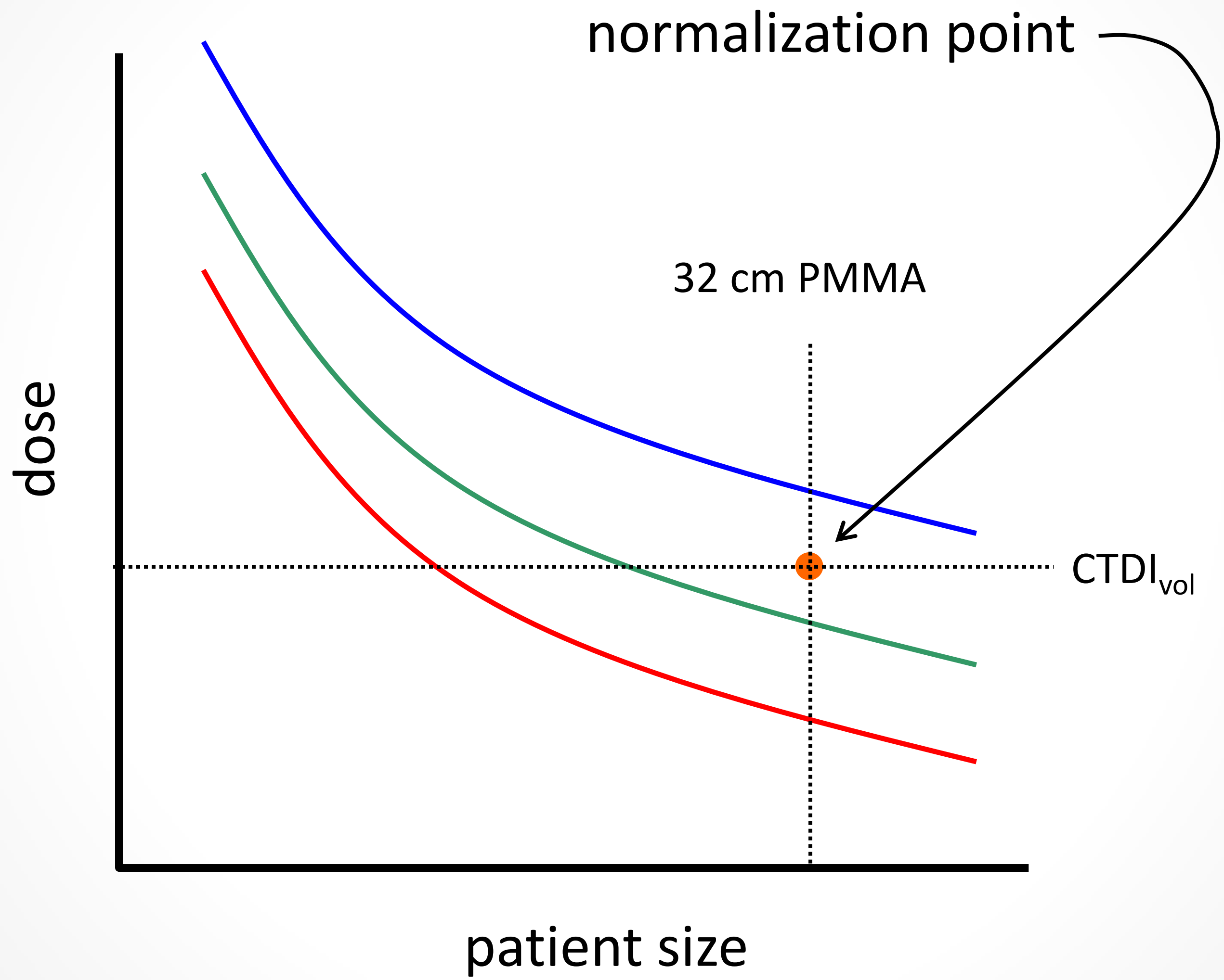
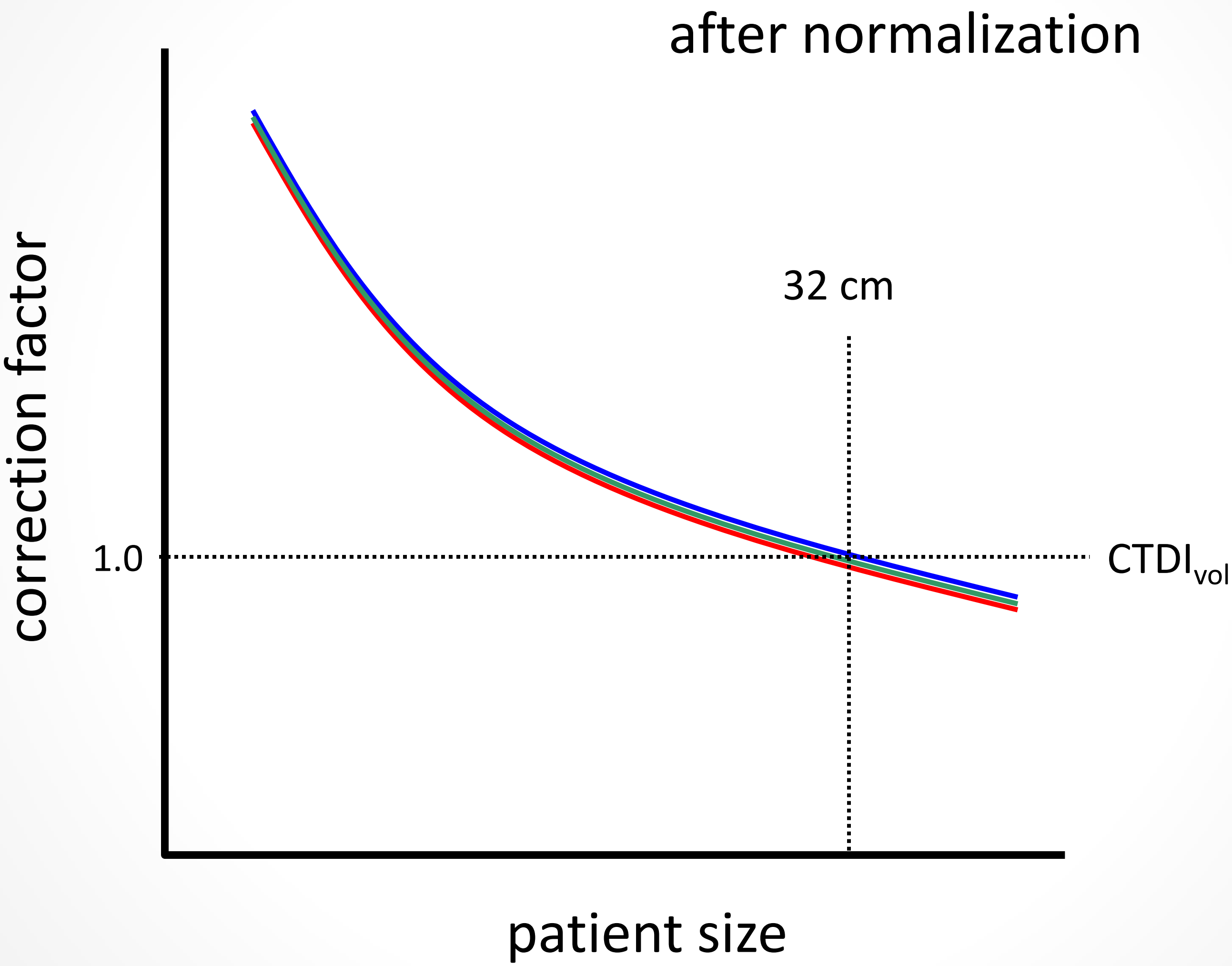


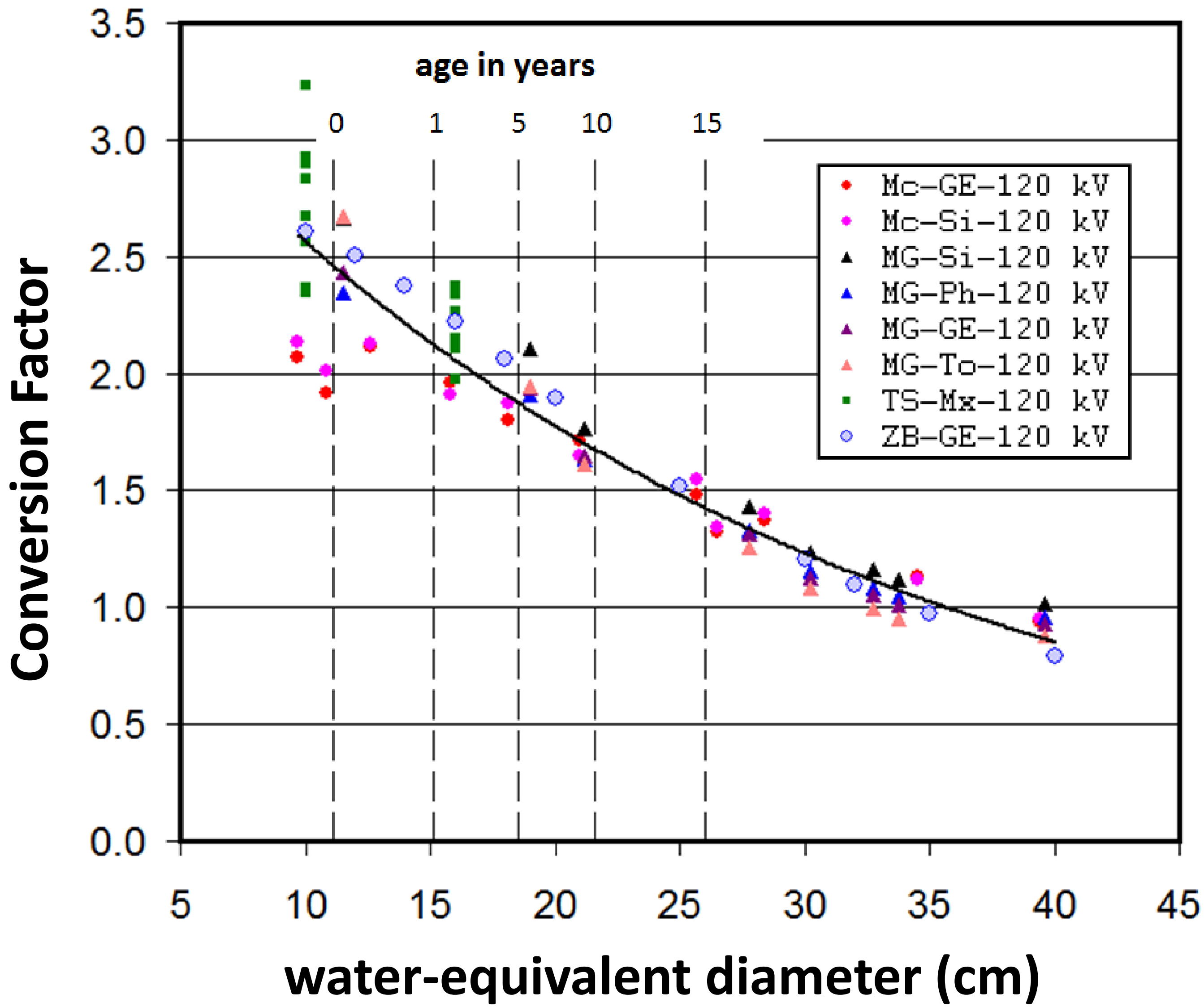
Figure 2



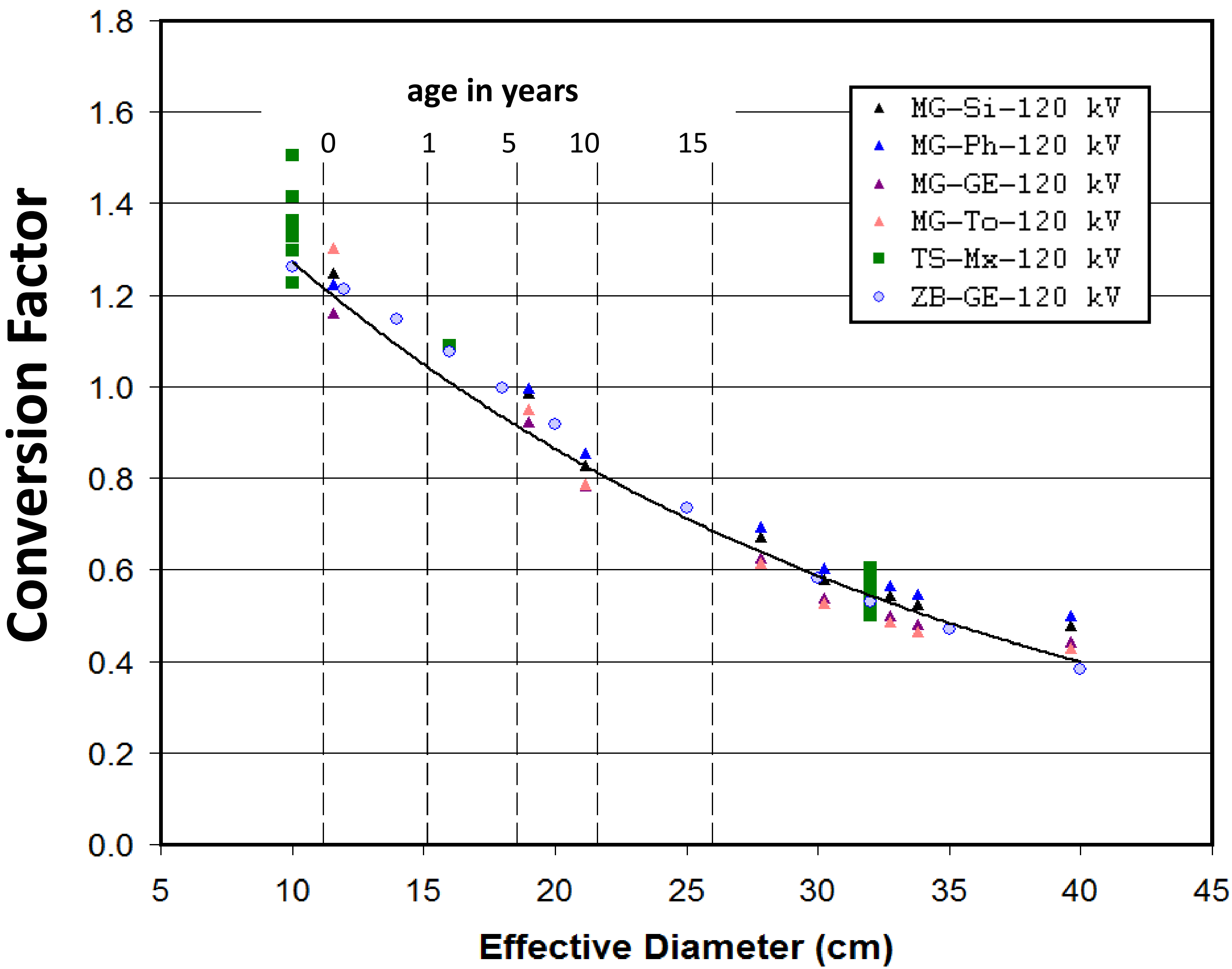
normalization point
32 cm PMMA
CTDIvol
dose
patient size


after normalization
correction factor
32 cm
1.0
CTDI$_{vol}$
patient size

32 cm 120 kV

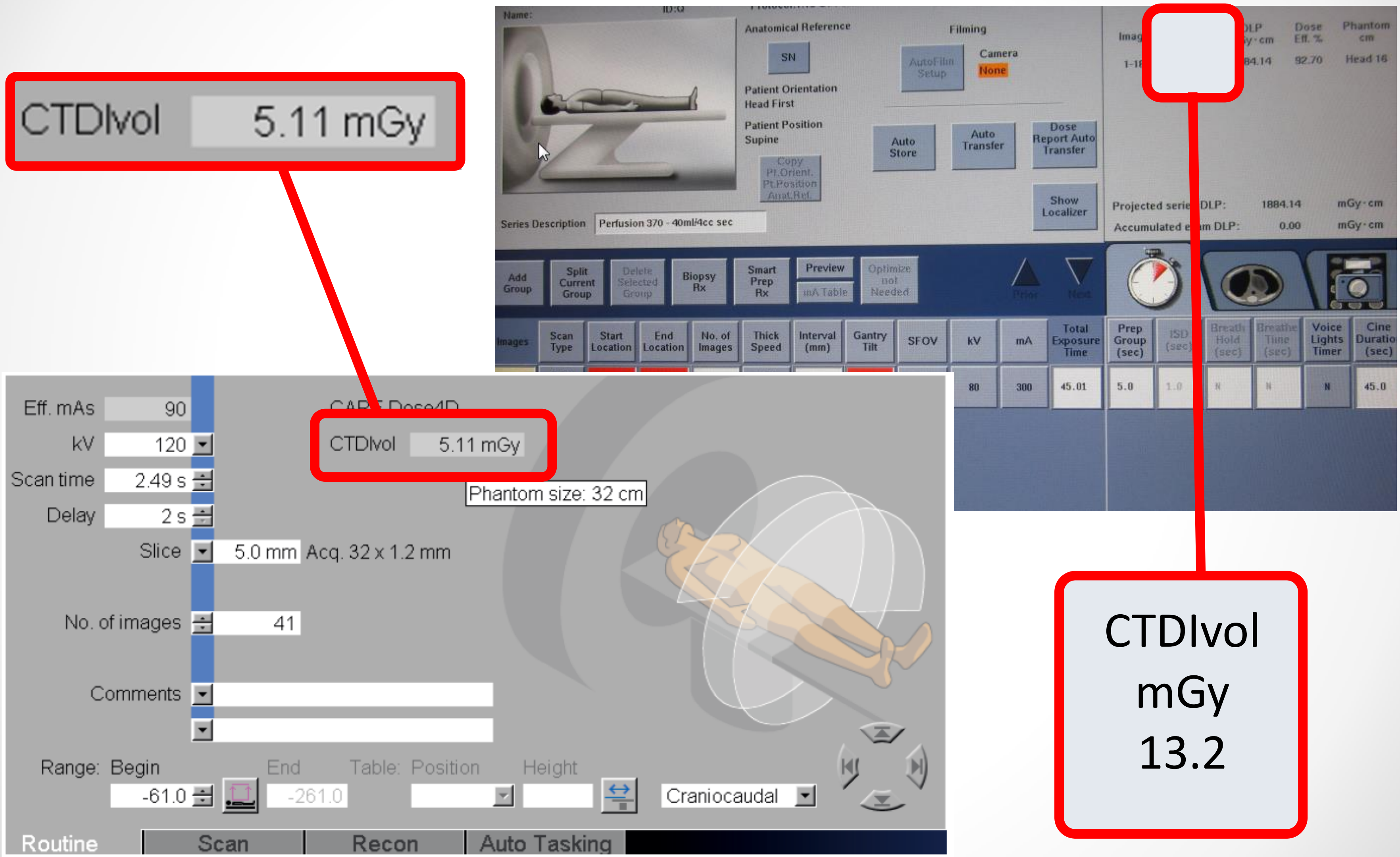

age in years
0
1
5
10
15
Mc–GE–120 kV
Mc–Si–120 kV
MG–Si–120 kV
MG–Ph–120 kV
MG–GE–120 kV
MG–To–120 kV
TS–Mx–120 kV
ZB–GE–120 kV
Conversion Factor
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
5
10
15
20
25
30
35
40
45
water-equivalent diameter (cm)

16 cm 120 kV



Conversion Factor
Effective Diameter (cm)
age in years
0
1
5
10
15
MG-Si-120 kV
MG-Ph-120 kV
MG-GE-120 kV
MG-To-120 kV
TS-Mx-120 kV
ZB-GE-120 kV
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
25
30
35
40
45

CTDI$_{vol}$ is indicated on most scanners.....



UC DAVIS MEDICAL CENTER
LightSpeed16 cti1
Dose Report
Ser: 999 Img: 1 / 1
Table Pos

Patient Name:

Accession Number:

Exam no:

Apr 2009

LightSpeed16

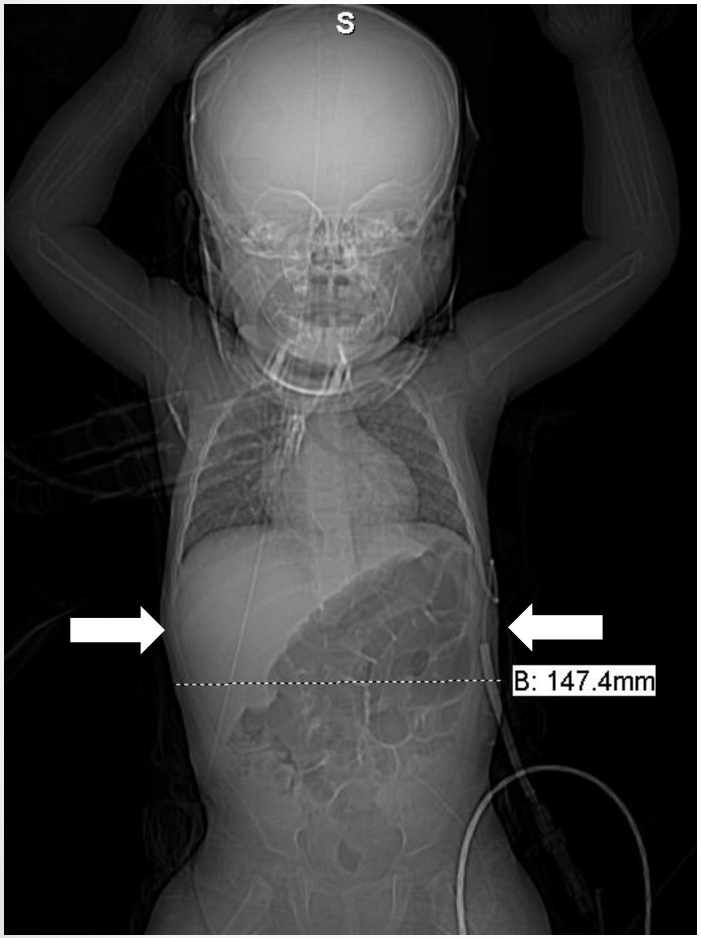
Exam Description: CT CHEST WITH CONTRAST

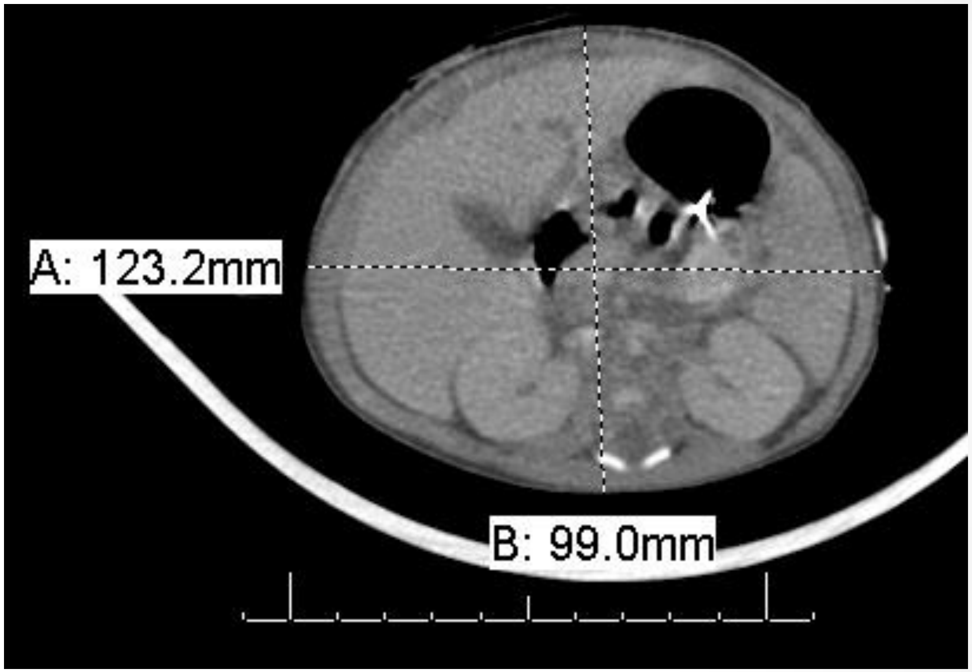
Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	I510.250-I700.250	15.55	349.79	Body 32
4	Helical	I50.000-I395.000	17.48	661.77	Body 32
4	Helical	I230.750-I715.750	16.09	834.64	Body 32
4	Helical	I230.750-I725.750	7.98	421.68	Body 32
			Total Exam DLP:	2267.88	

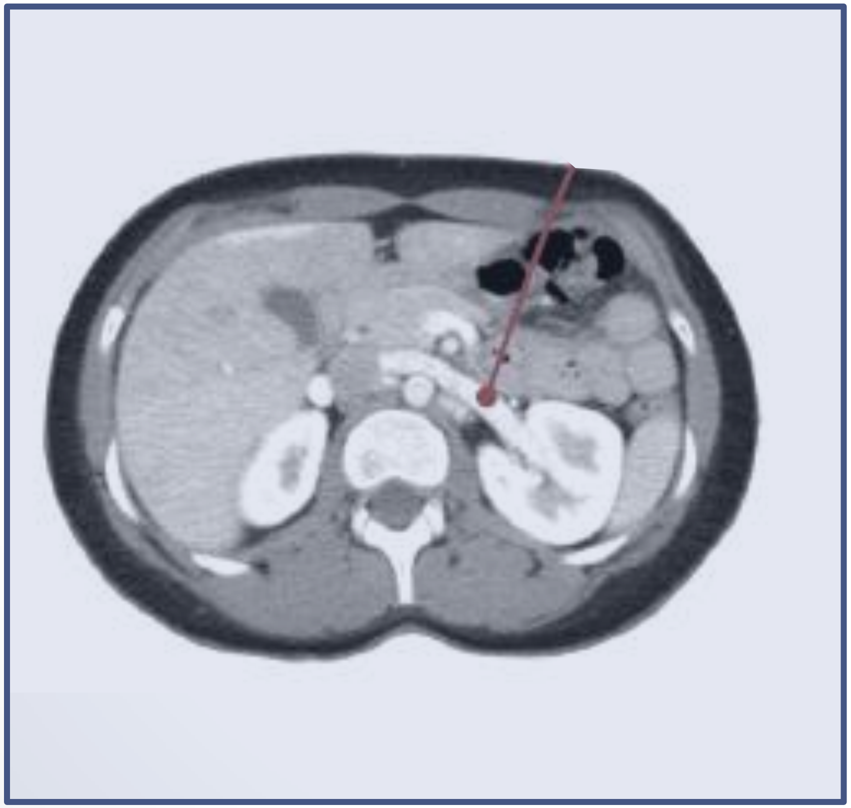
1/1

determine patient size





determine patient size



$\Rightarrow D_w$

Size-Specific Dose Estimate (SSDE)

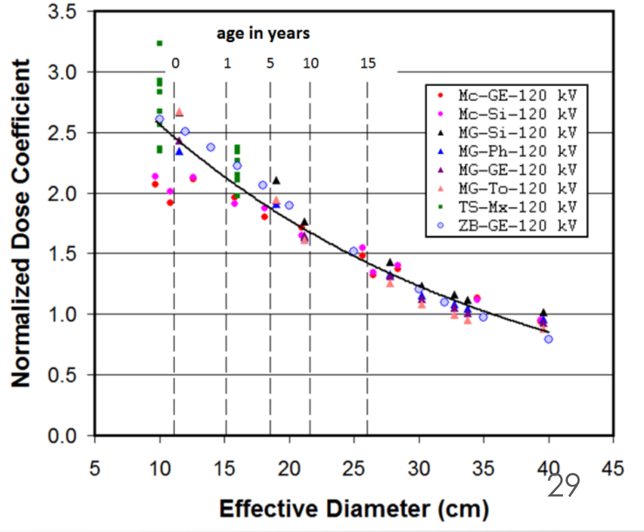
SSDE conversion factor

$$\mathrm{CTDI_{vol}}\ (\mathrm{mGy}) \times f = \mathrm{SSDE}\ (\mathrm{mGy})$$

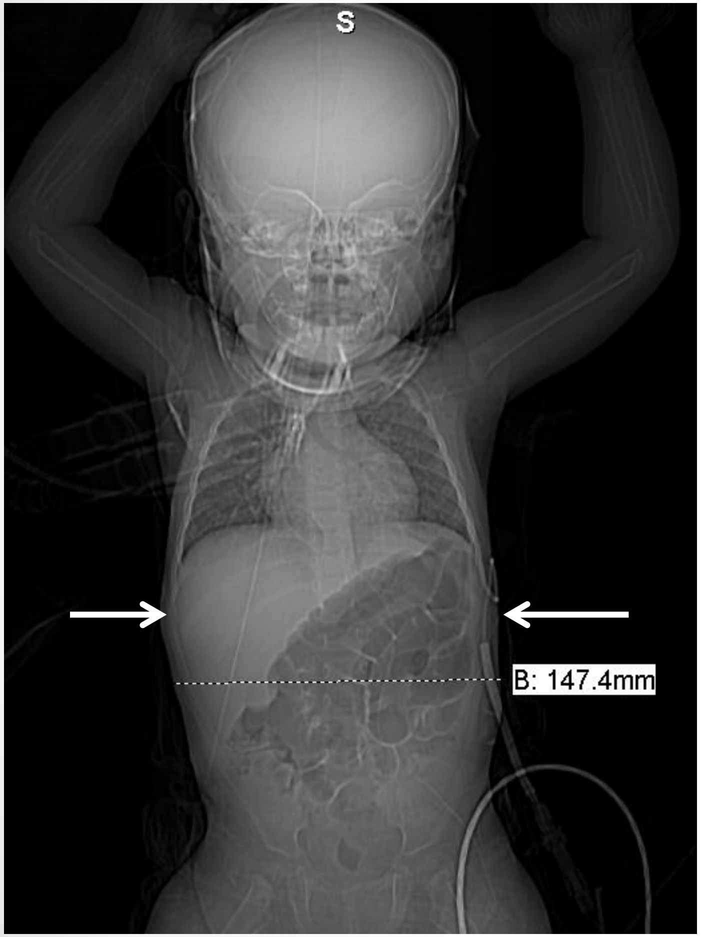
air kerma

absorbed dose

SSDE conversion factor



Example of SSDE calculation from localizer view

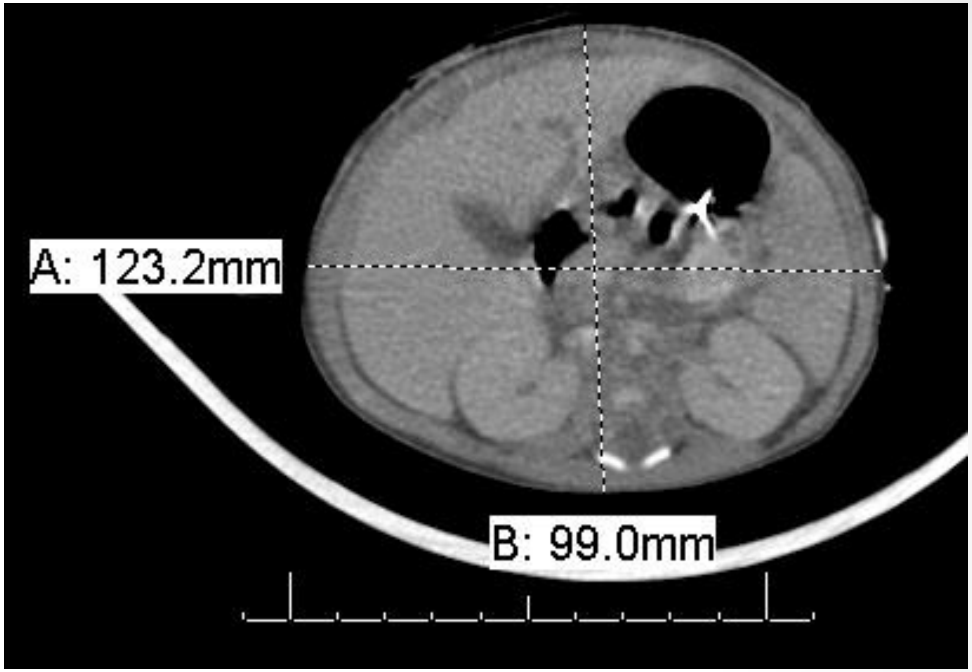


CT Radiograph

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

Example of SSDE calculation from localizer view

Lat + AP Dim (cm)	Effective Dia (cm)	Correction Factor
15	7.2	2.84
16	7.7	2.79
17	8.2	2.74
18	8.7	2.69
19	9.2	2.64
20	9.7	2.59
21	10.2	2.55
22	10.7	2.50
23	11.2	2.46
24	11.7	2.41
25	12.2	2.37
26	12.7	2.32
27	13.2	2.28
28	13.7	2.24
29	14.2	2.20
30	14.7	2.16



$$5.40 \text{ mGy} = \text{CTDI}_{vol}$$

$$\text{SSDE} = 5.4 \text{ mGy} \times 2.5$$

$$\text{SSDE} = 13.5 \text{ mGy}$$

ICRU Report on CT Dosimetry

Introduction & Historical CT Dose Metrics

Dose dependency on patient size

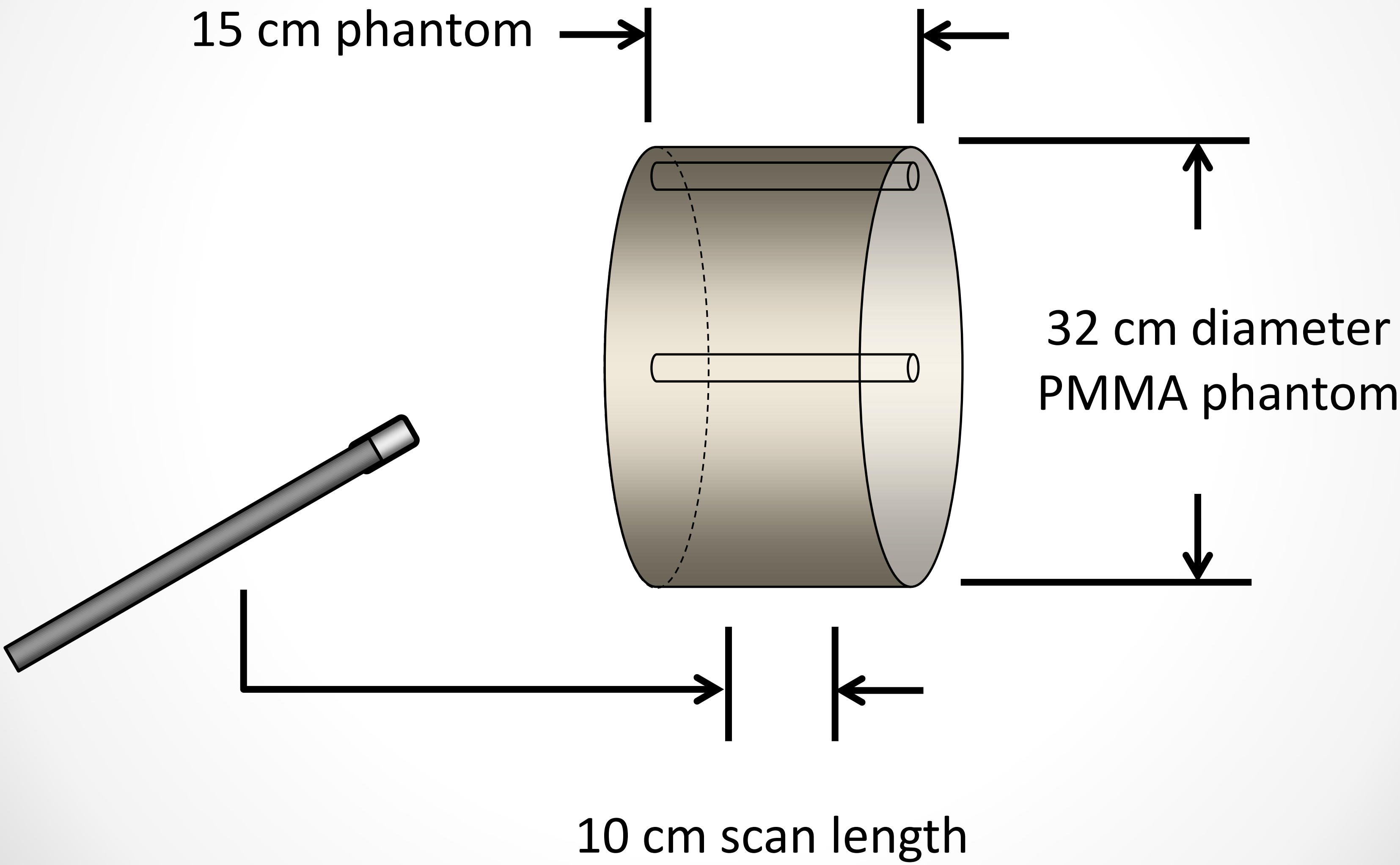
Dose and CT scan length

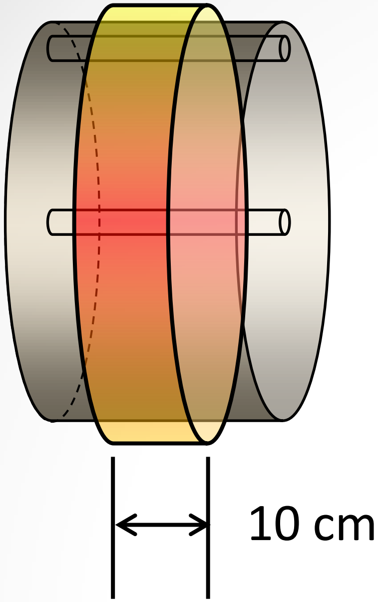
Phantoms and radiation meters

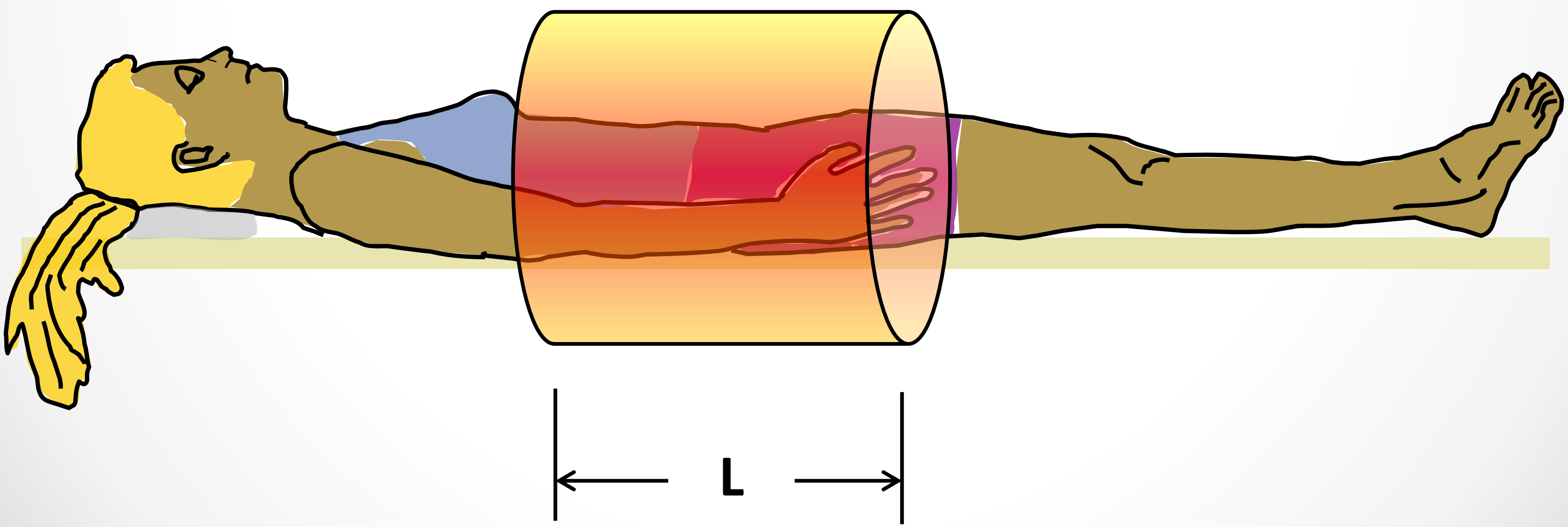
ICRU extension to AAPM Report 111

Summary

Problems with $CTDI_{vol}$




10 cm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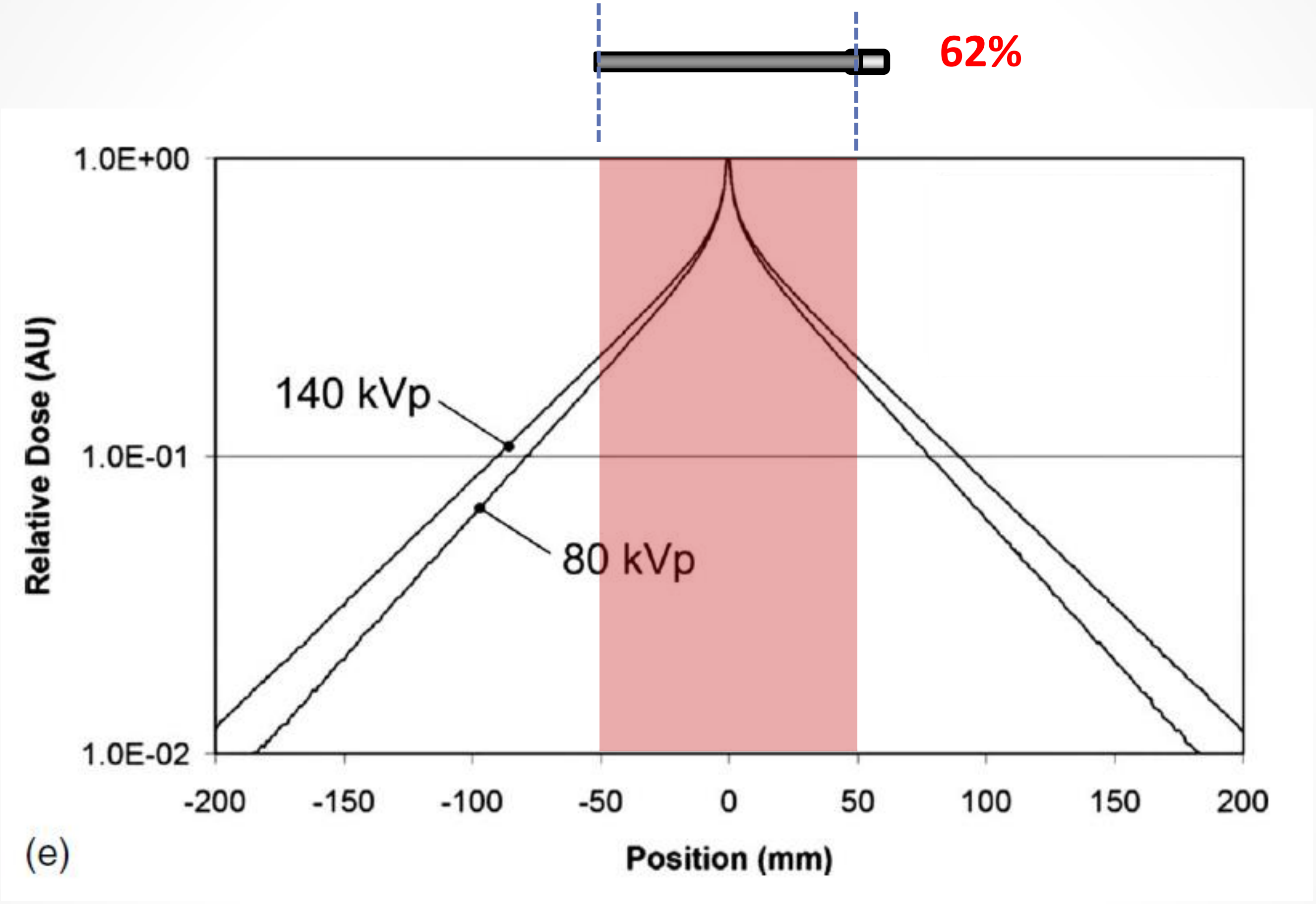
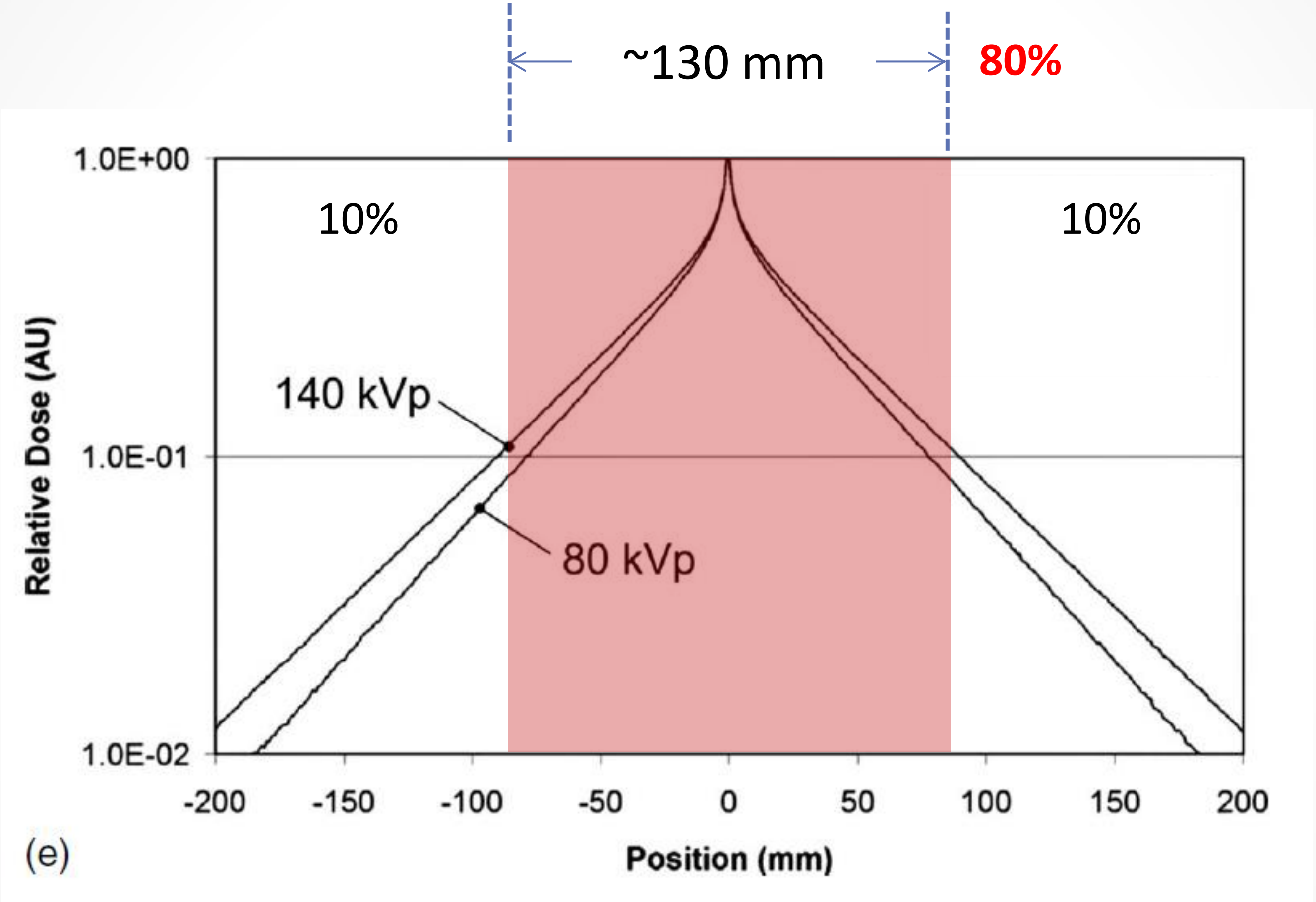
How long are the scatter tails in CT?



- JM Boone, Dose spread functions in computed tomography: A Monte Carlo study", Med Phys 36, 4547-4554 (2009)

How long are the scatter tails in CT?



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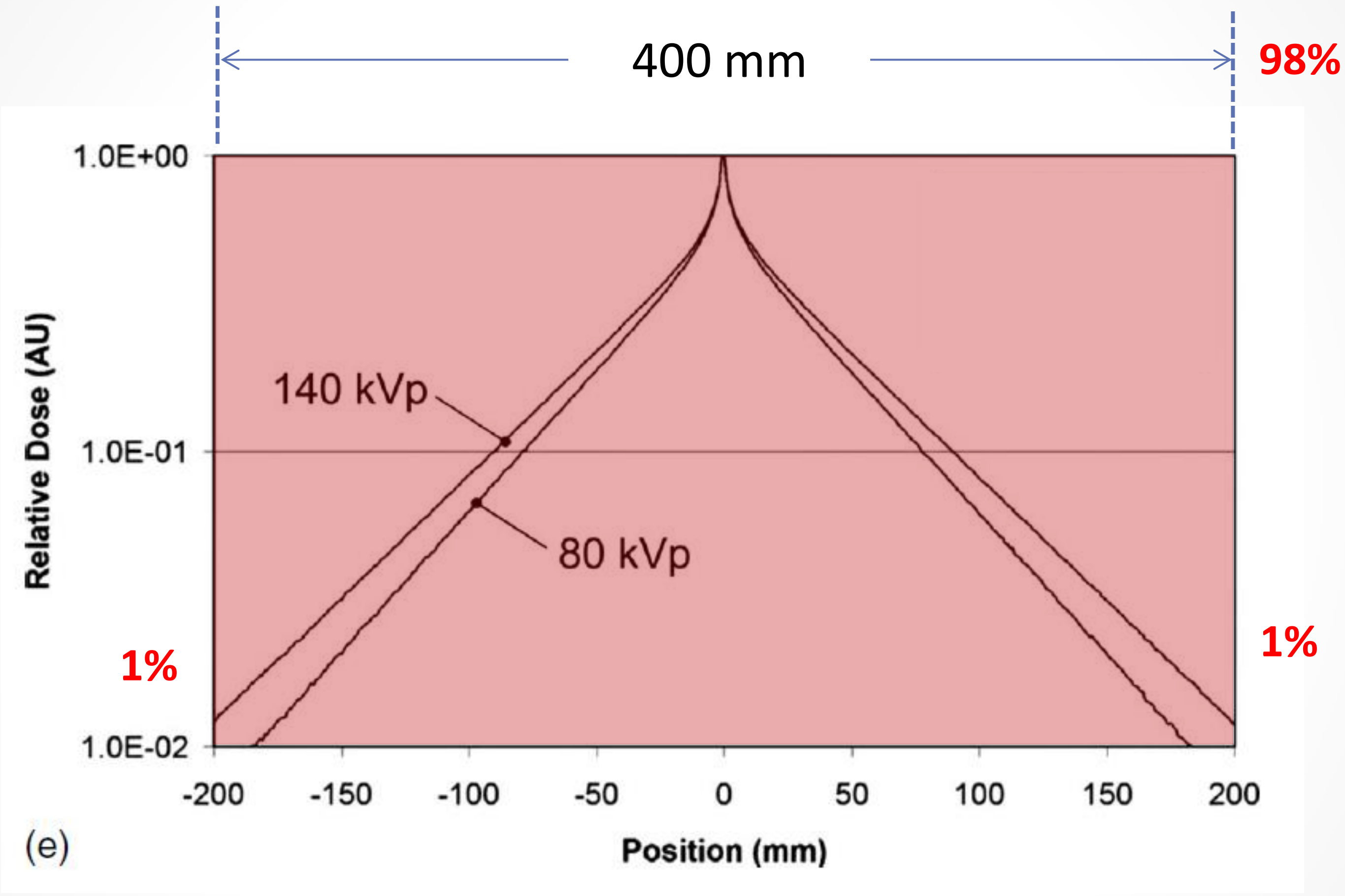
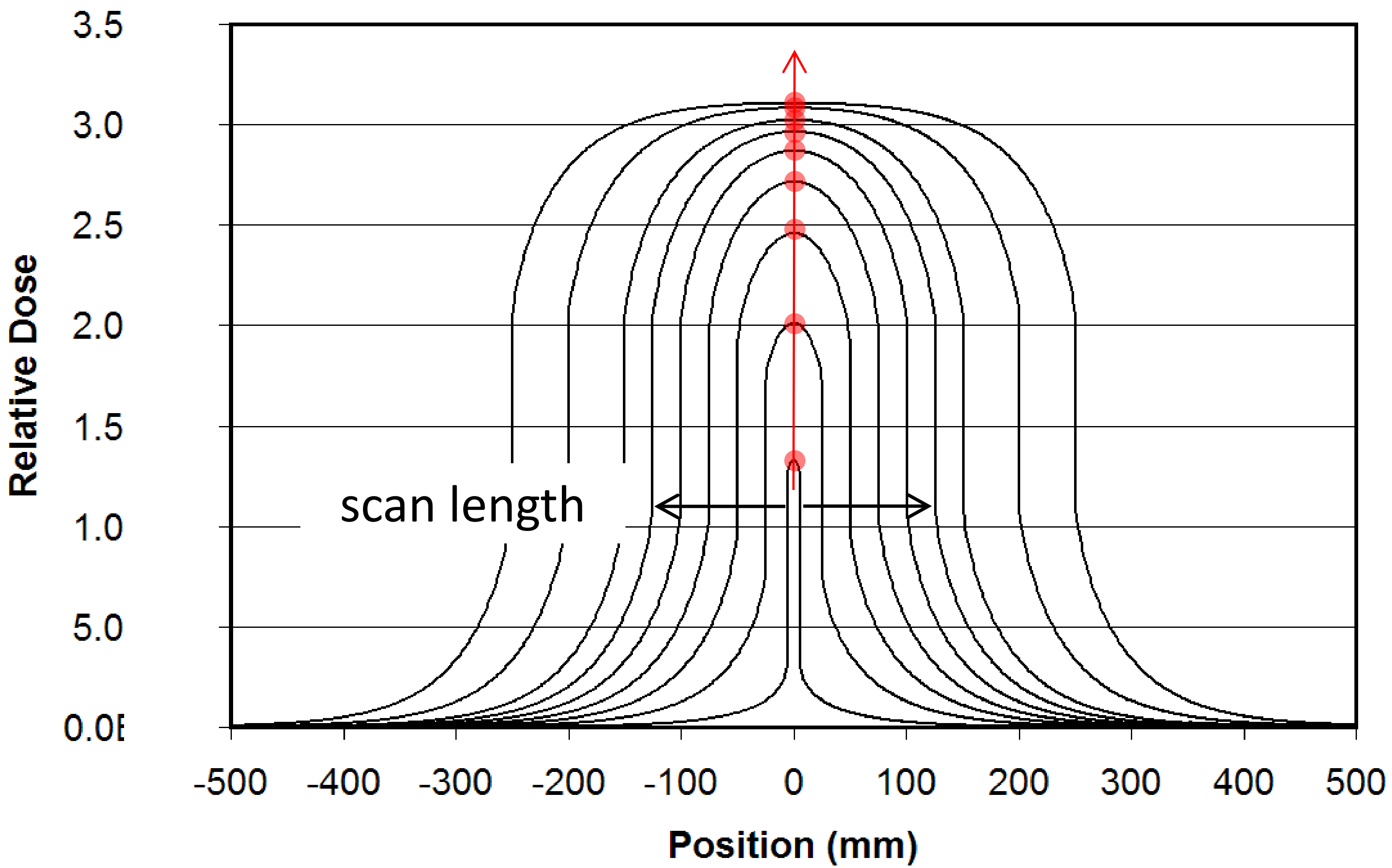
How long are the scatter tails in CT?

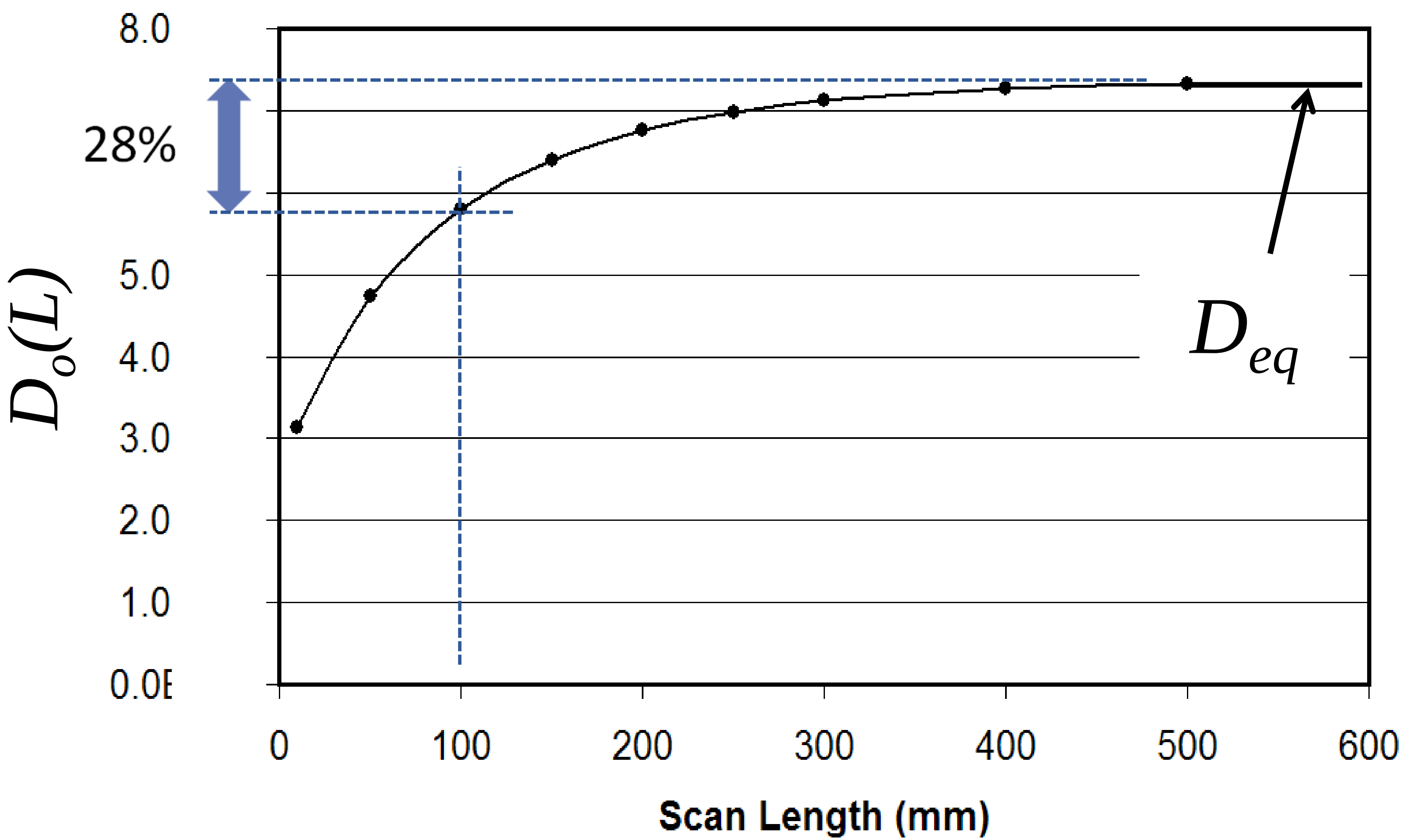


JM Boone, Dose spread functions in computed tomography: A Monte Carlo study", Med Phys 36, 4547-4554 (2009)

Dose profiles as a function of Scan Length



Equilibrium Dose as a function of Scan Length



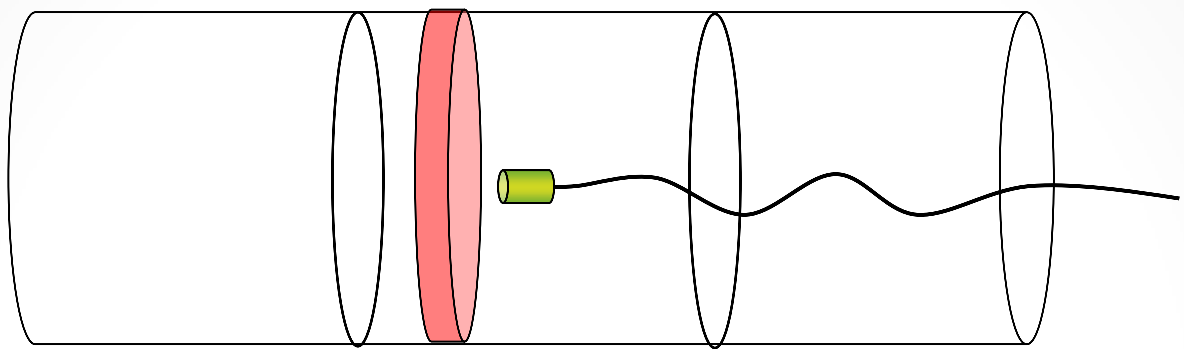
AAPM REPORT NO. 111

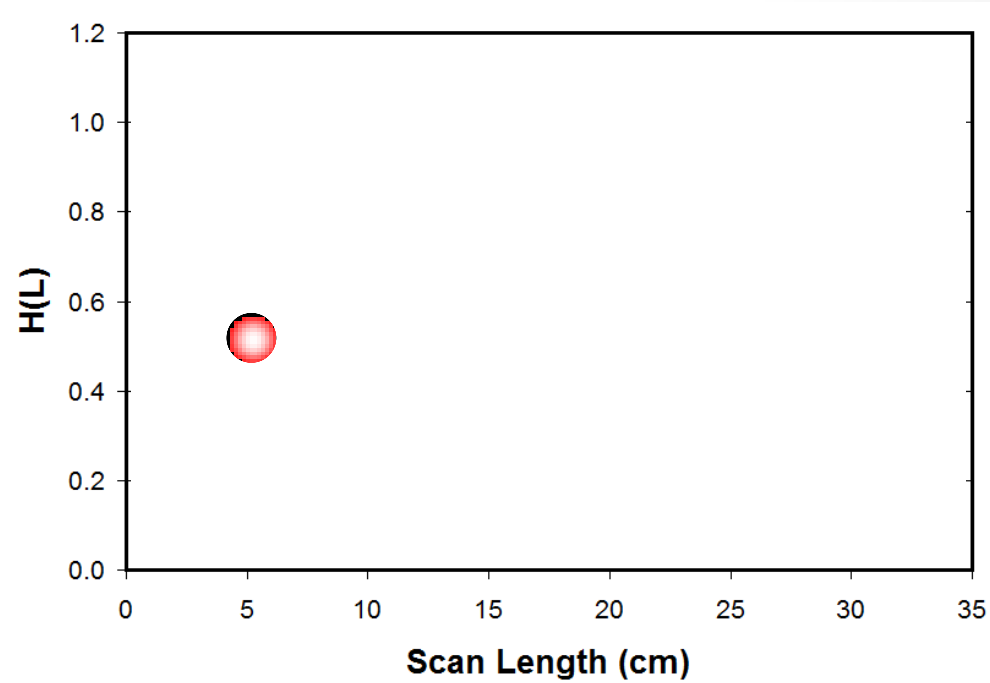
Comprehensive Methodology for the Evaluation of Radiation Dose in X-Ray Computed Tomography

A New Measurement Paradigm Based on a Unified Theory for Axial, Helical, Fan-Beam, and Cone-Beam Scanning With or Without Longitudinal Translation of the Patient Table

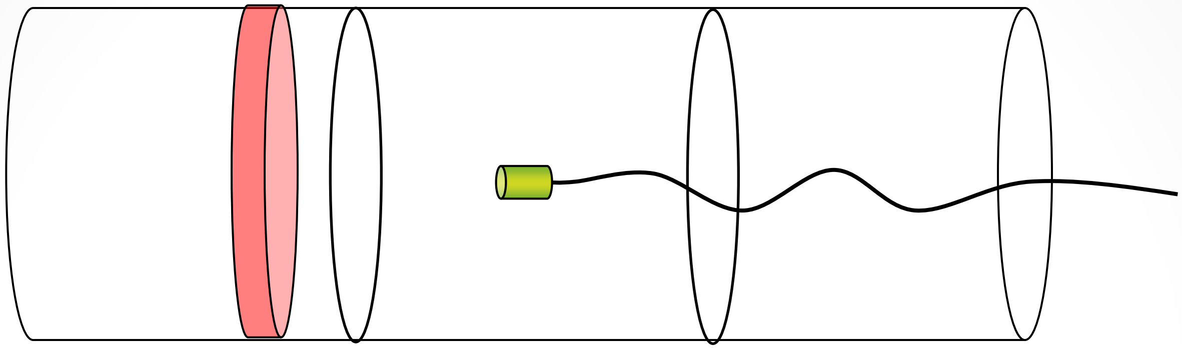
Integrating thimble chamber

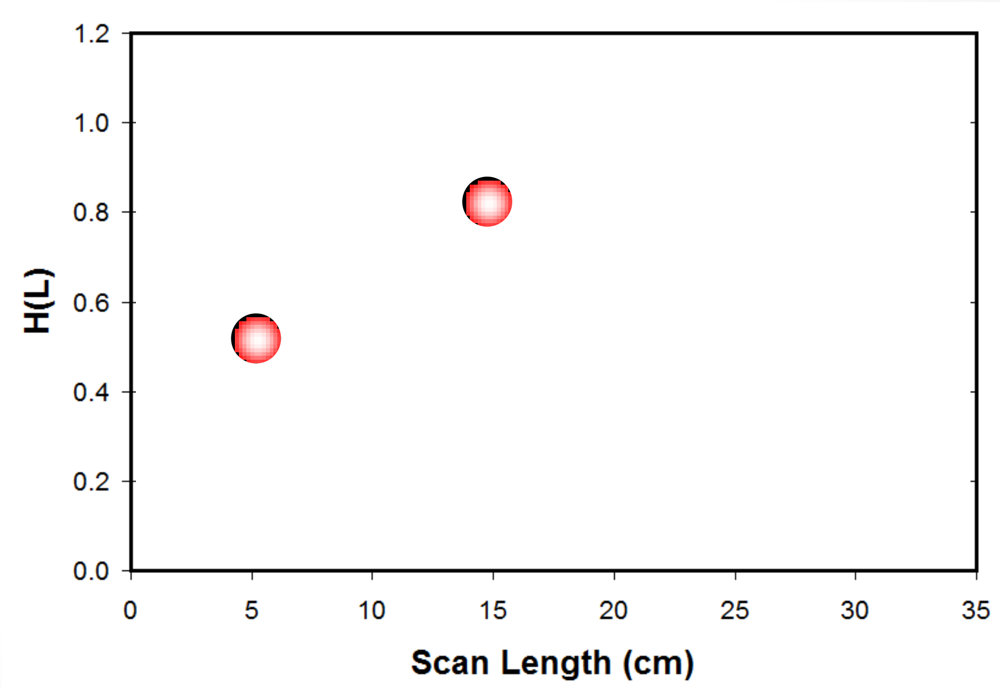
TG-111 Method



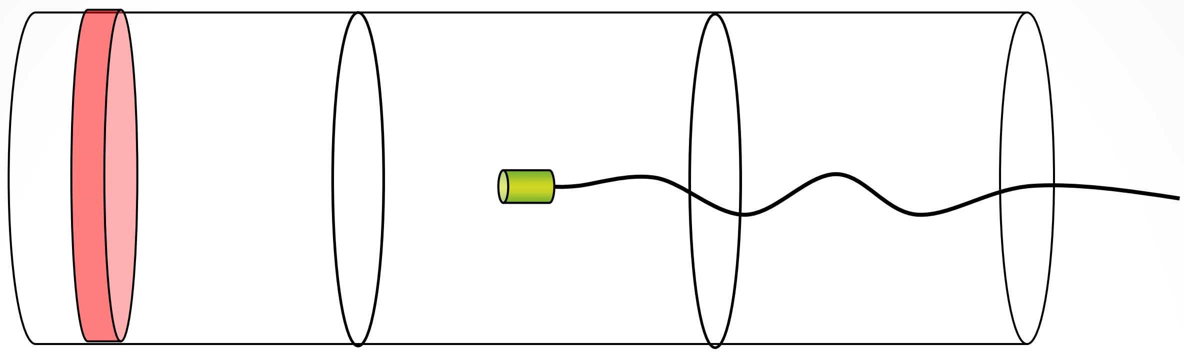


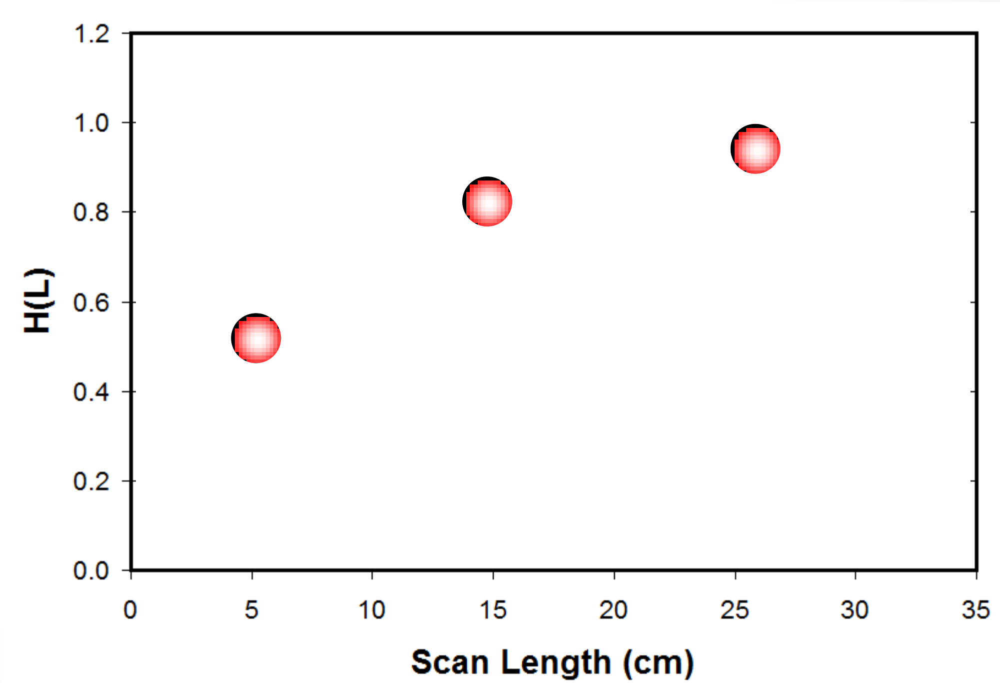
TG-111 Method



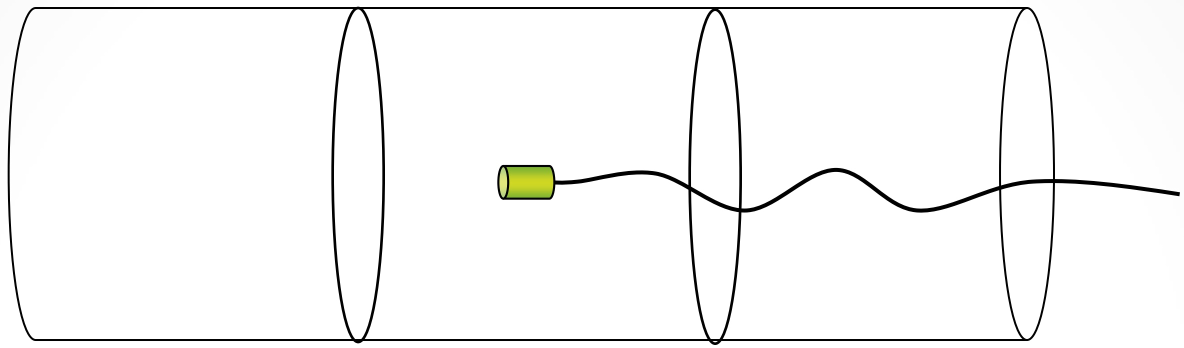


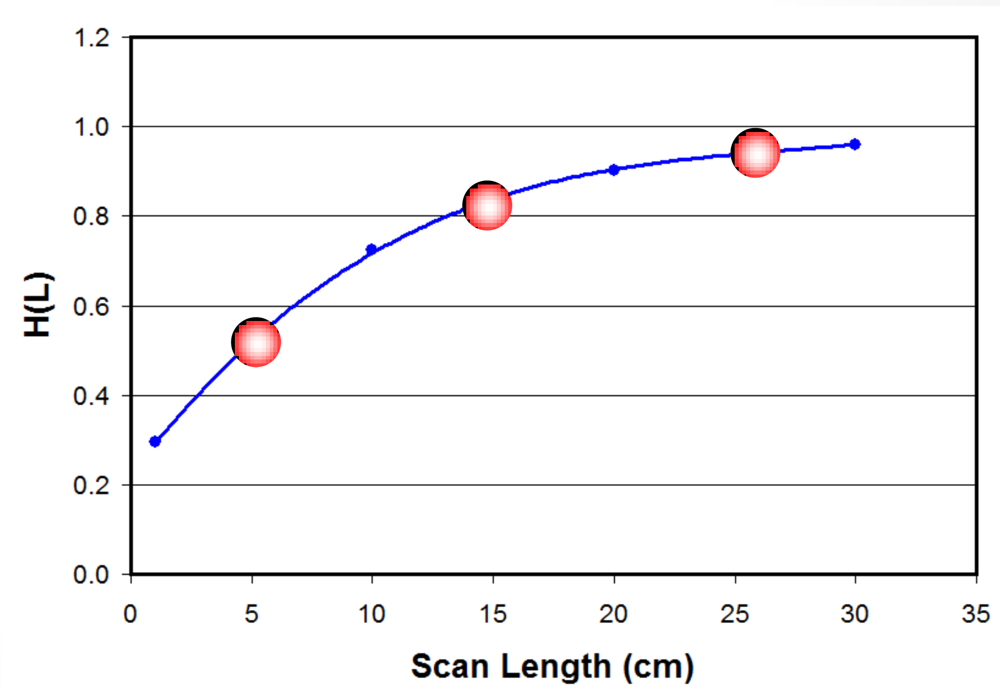
TG-111 Method





TG-111 Method





Cone beam CT dosimetry: A unified and self-consistent approach including all scan modalities—With or without phantom motion

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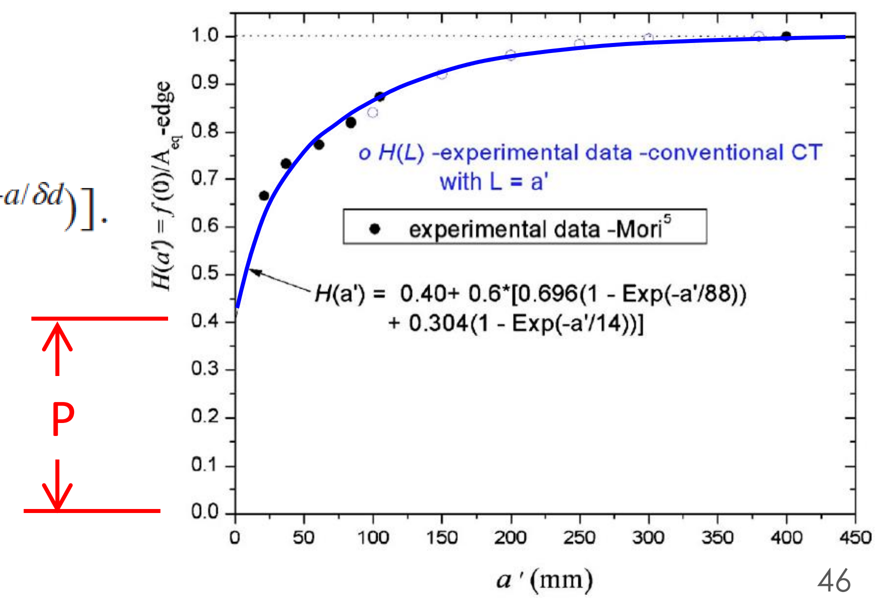
(Received 3 January 2010; revised 24 February 2010; accepted for publication 24 March 2010; published 19 May 2010)

$$\mathrm{lsf}(z) = (1-\varepsilon)\frac{1}{d}\exp(-2|z|/d) + \varepsilon\frac{1}{\delta d}\exp(-2|z|/\delta d),$$

$$H(a) = \underbrace{\frac{1}{1+\eta}}_{\mathbf{P}} + \underbrace{\frac{\eta}{1+\eta}}_{\mathbf{S}}[(1-\varepsilon)(1-e^{-a/d}) + \varepsilon(1-e^{-a/\delta d})].$$



η = scatter / primary

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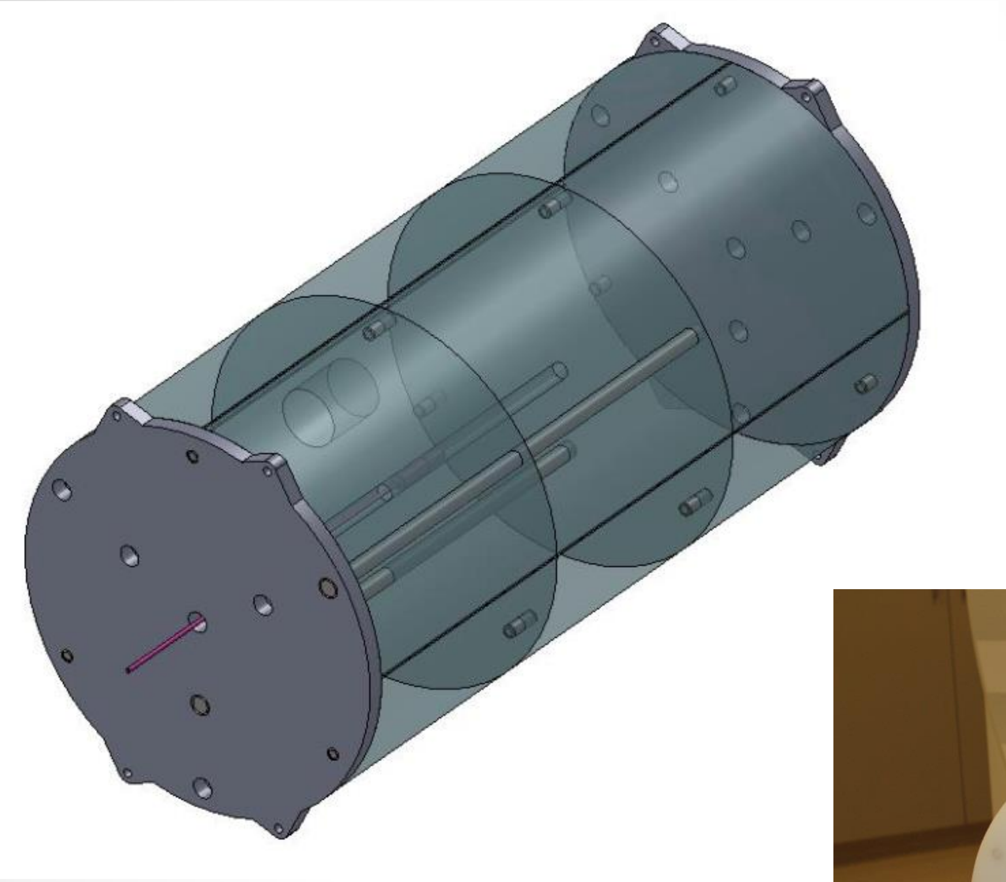
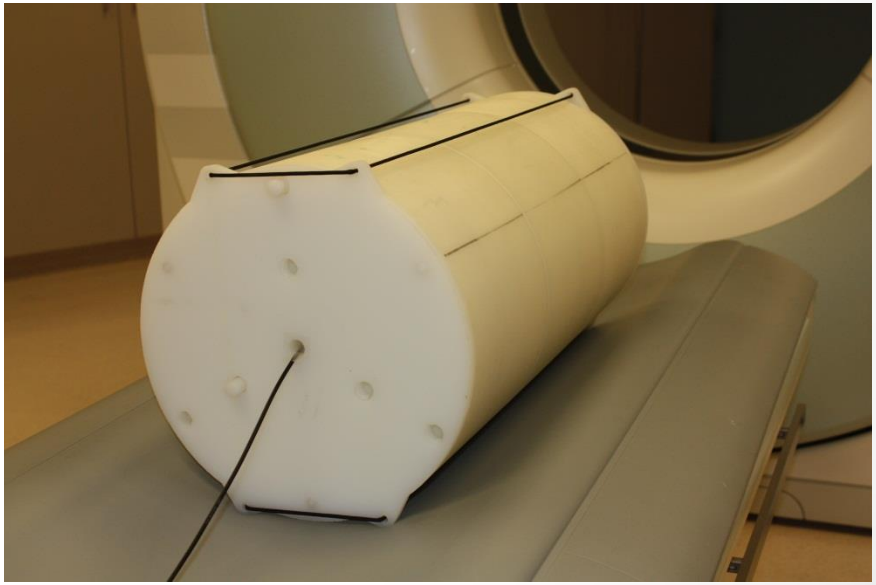
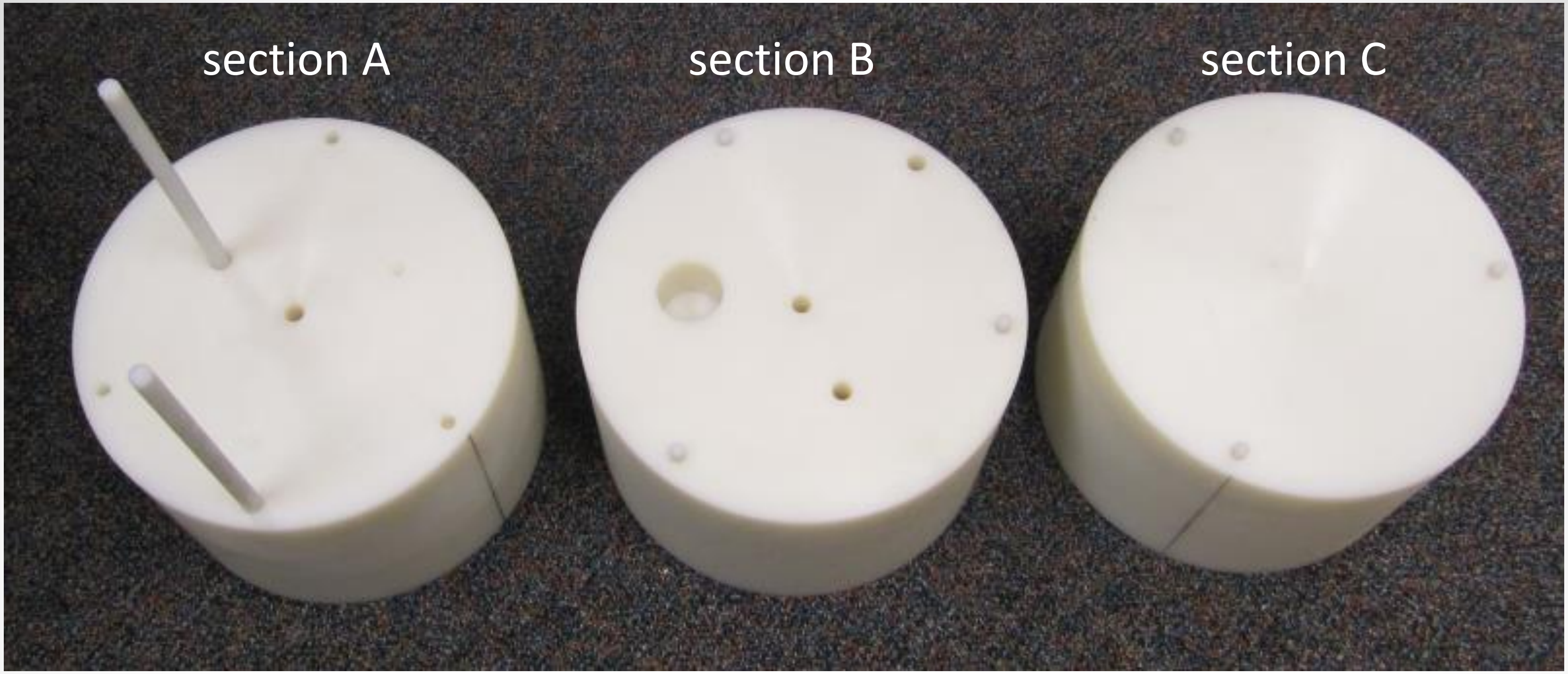
Summary



ICRU / AAPM (TG-200) Dosimetry Phantom



phantoms



Phantom is polyethylene 60 cm long by 30 cm in diameter

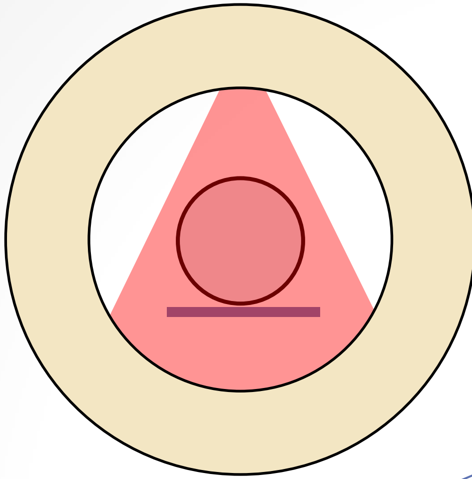
Each section is 20 cm long and weighs 13.7 kg (30 lbs)

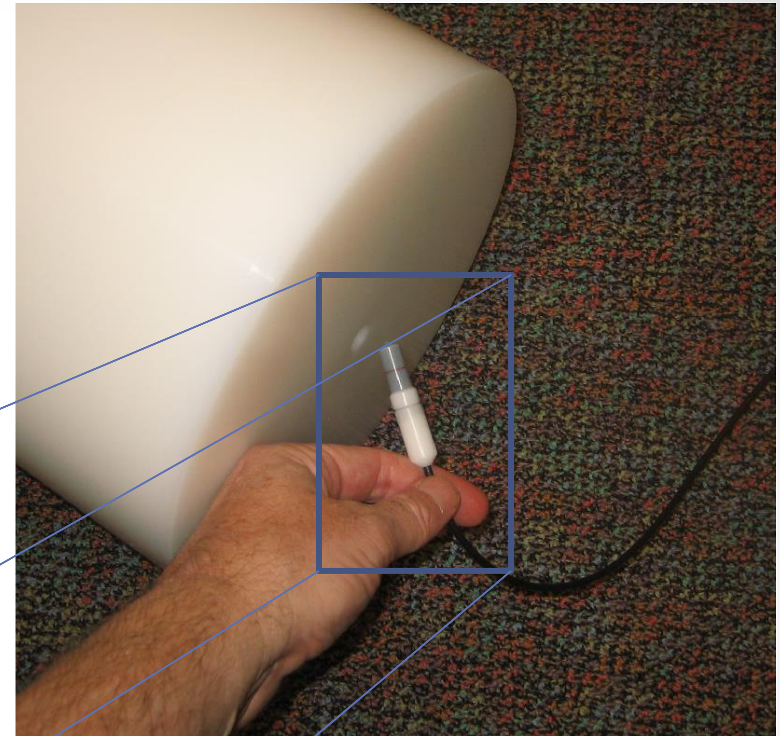
compared to 32 cm diameter PMMA: 14.4 kg (5% lighter)

Total phantom 41.1 kg (90 lbs)


PHILIPS


PHILIPS

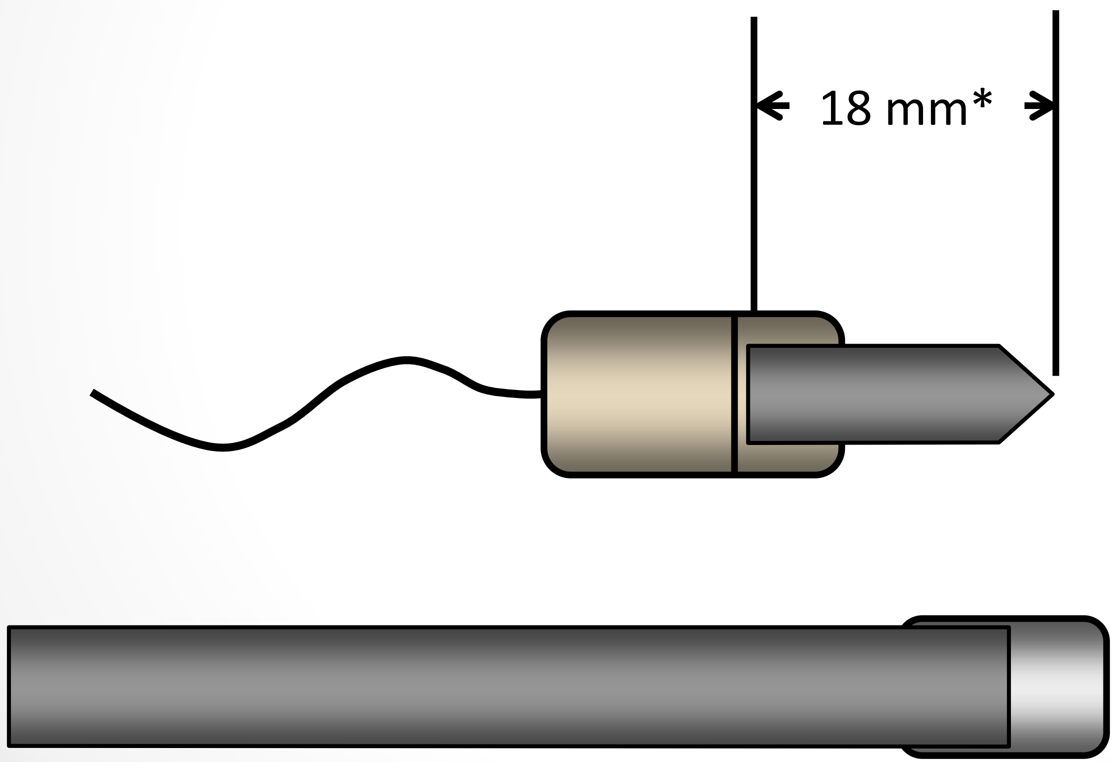




Integrating thimble chamber


signal
real time probes
time

The thimble chamber with real time (>1000 Hz) readout rates



*active length

ICRU Report on CT Dosimetry

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ICRU extension to AAPM Report 111

Summary

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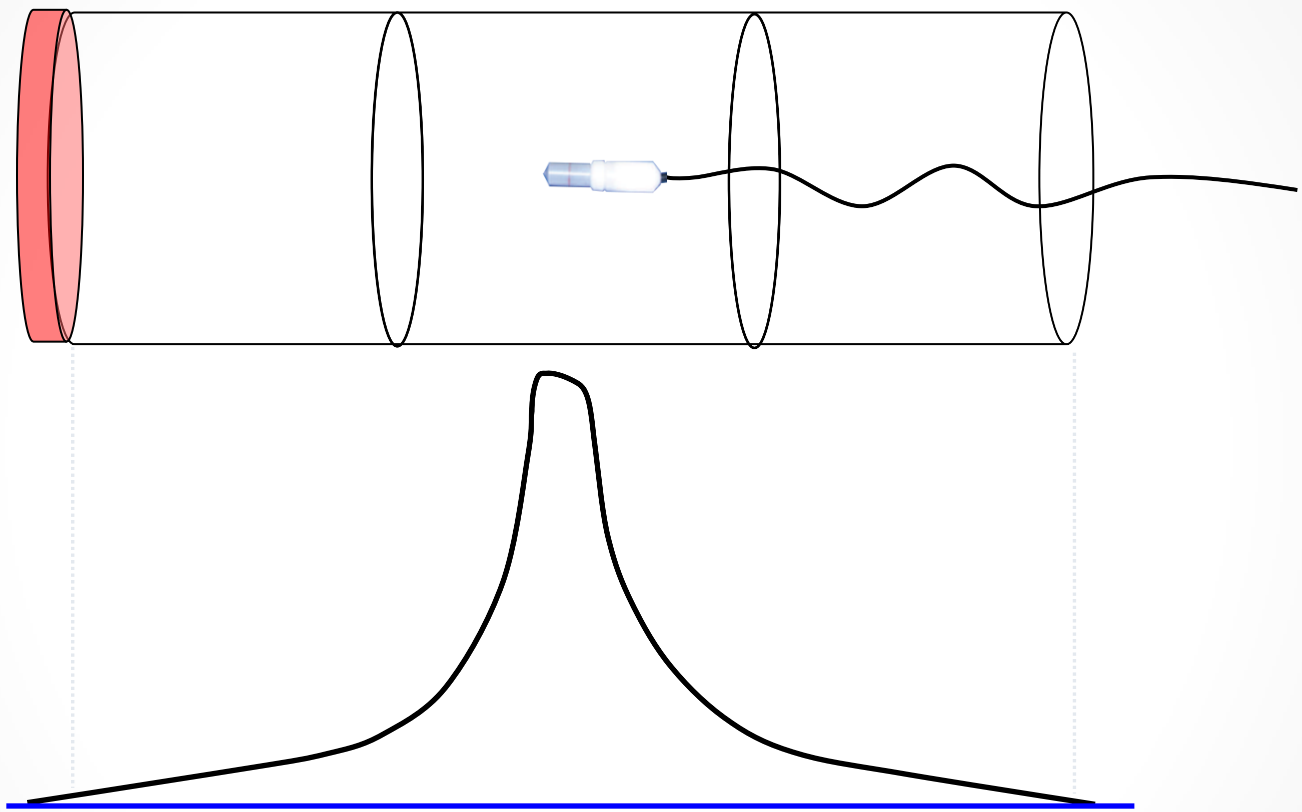
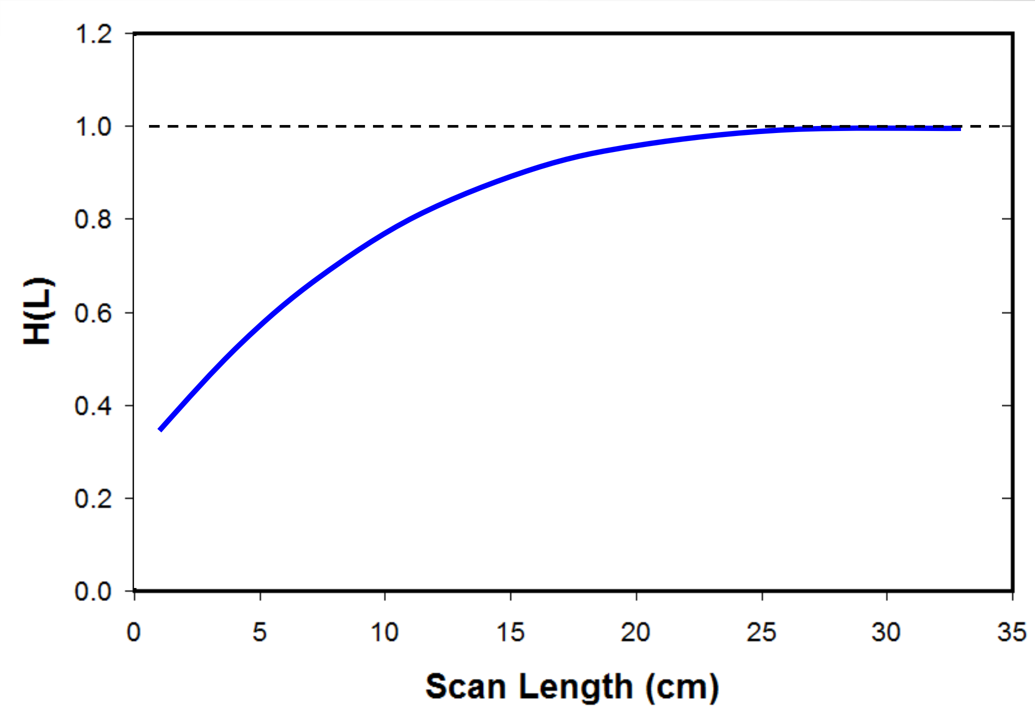
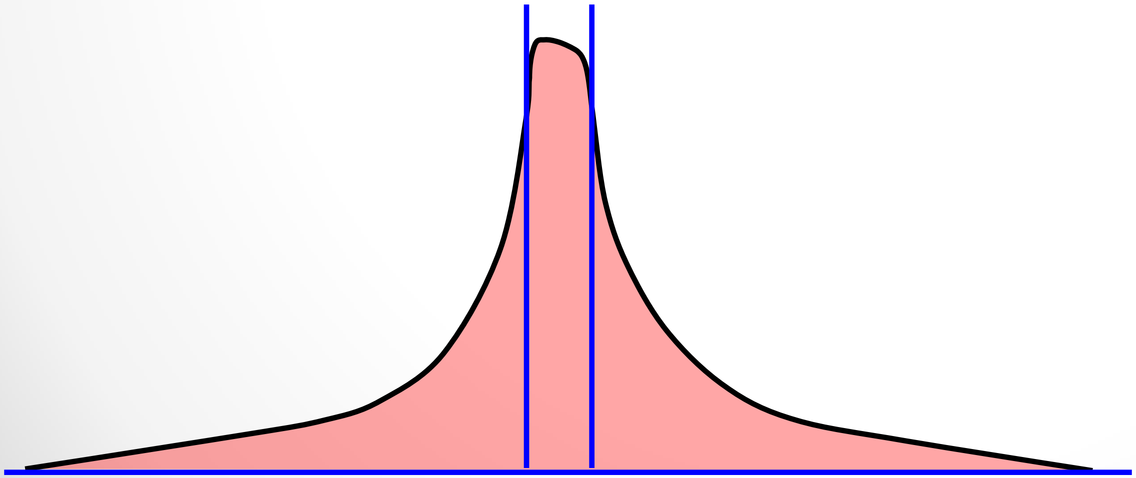
real time thimble chamber

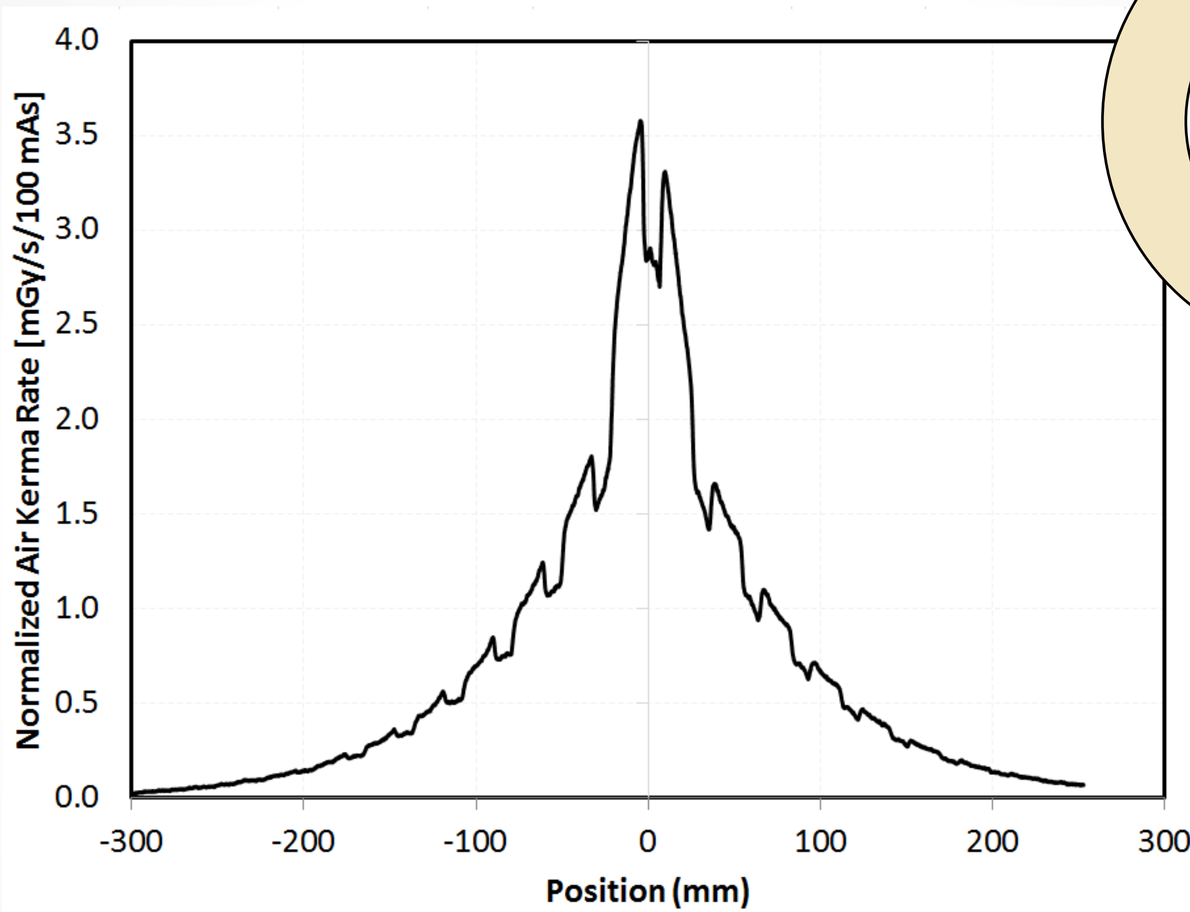
ICRU Method



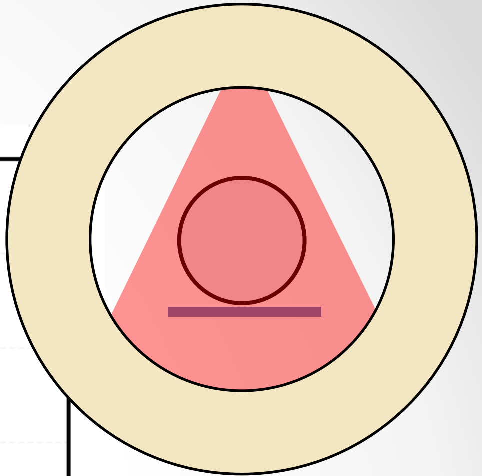


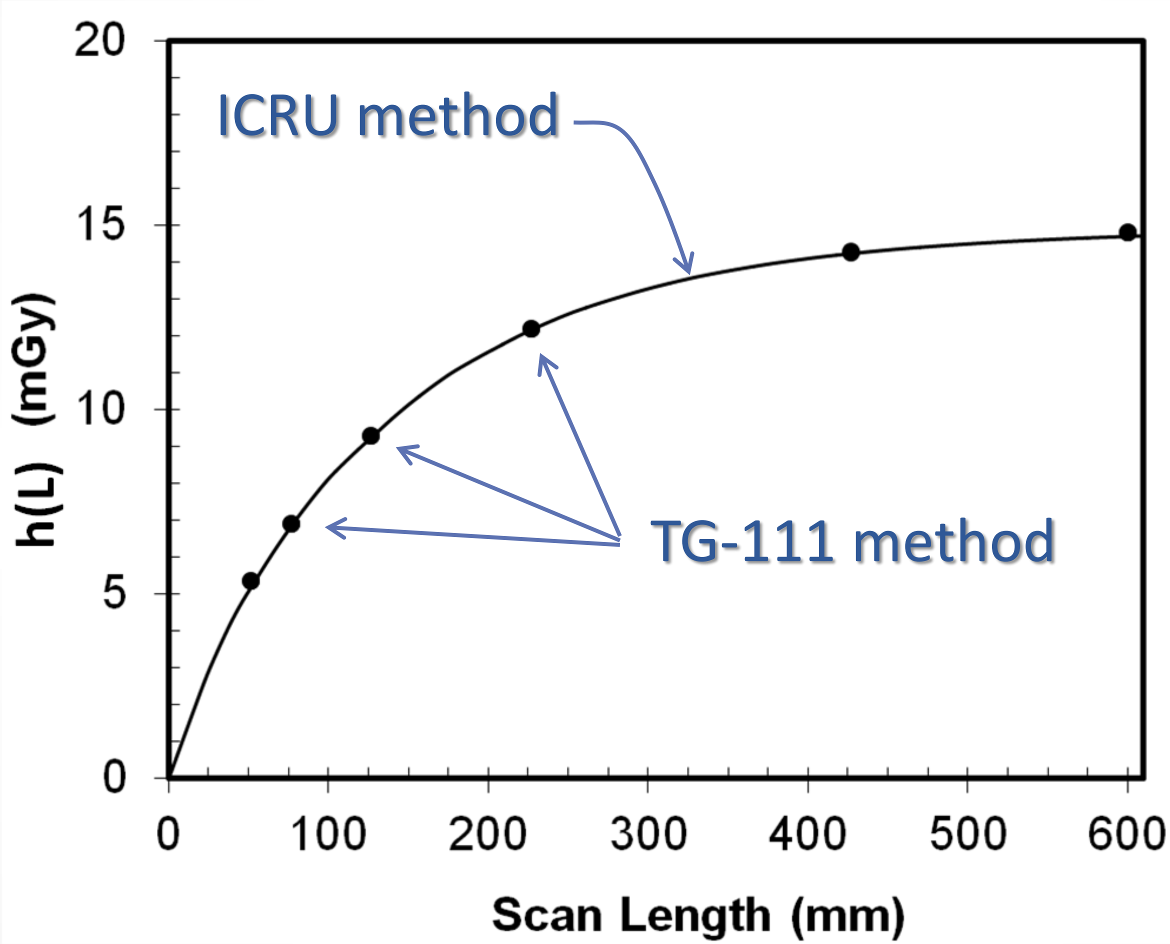


beam profile



4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Normalized Air Kerma Rate [mGy/s/100 mAs]
-300
-200
-100
0
100
200
300
Position (mm)





ICRU method
TG-111 method
h(L) (mGy)
Scan Length (mm)
0
5
10
15
20
0
100
200
300
400
500
600

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ICRU Report on CT Dosimetry

CTDI-based methods need to be updated

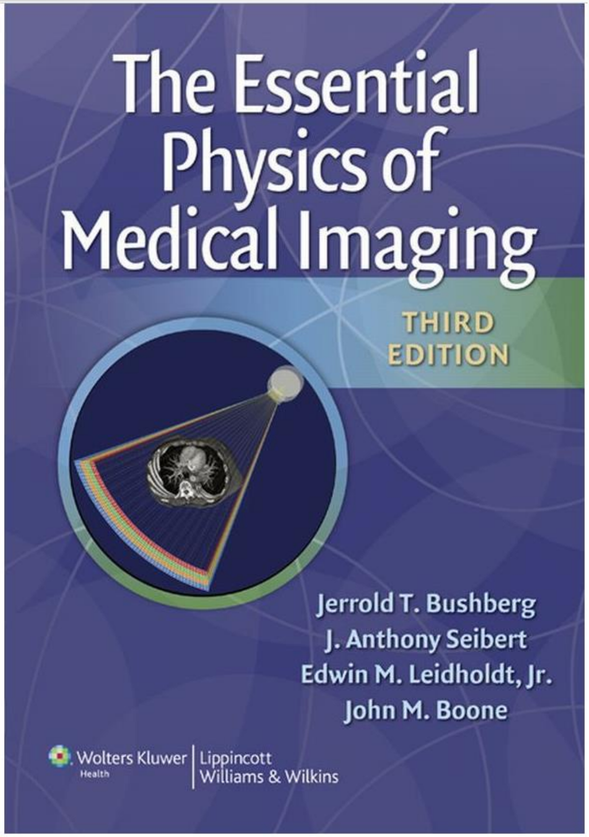
TG-204/ICRU SSDE is a method for adjusting for patient size

TG-111/ICRU Scan length dose dependencies ➡ *h(L)*

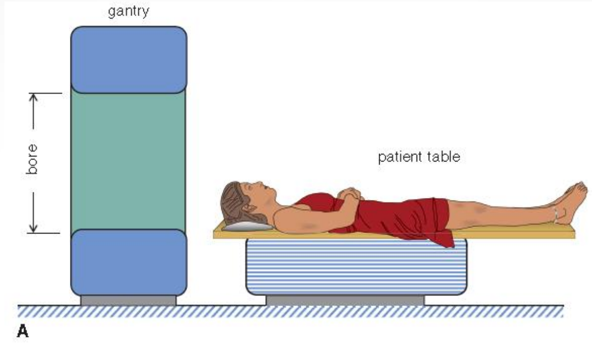
TG-200/ICRU Longer phantoms and faster radiation meters

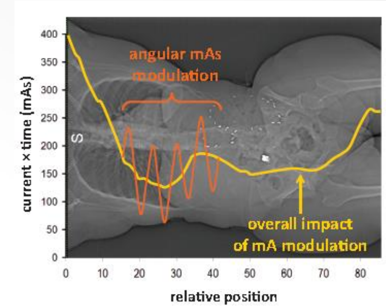
TG-220 Methods for automatic size detection

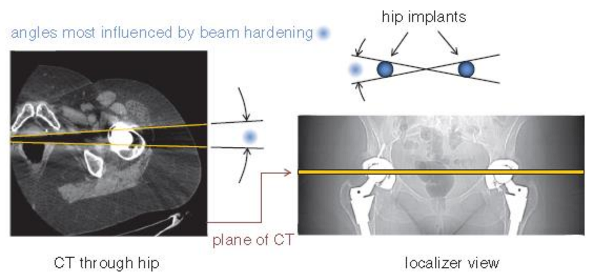
ICRU CT Report Available Q3 2013

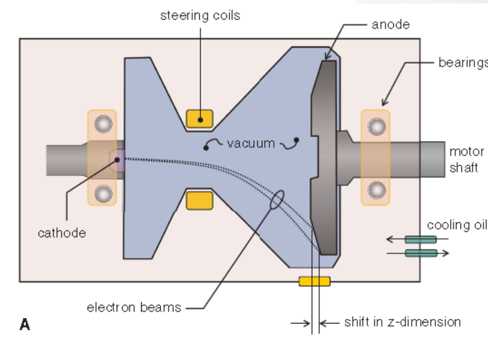


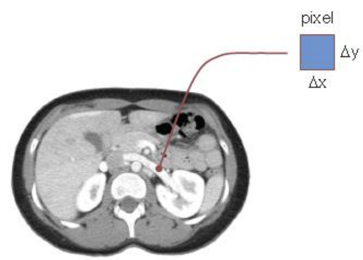
2012 edition

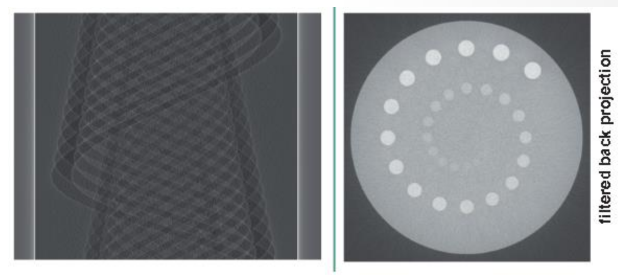


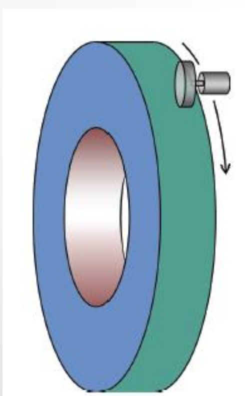


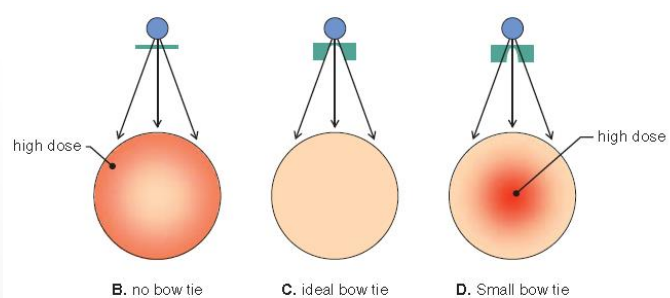


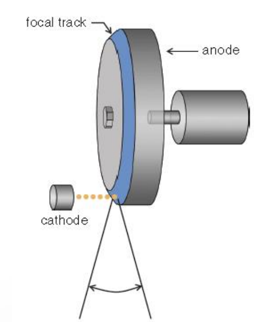


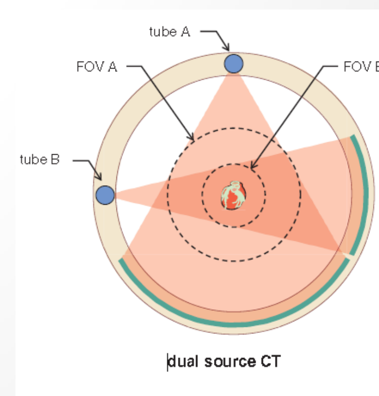












Figures from CT Chapter

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Method for evaluating bow tie filter angle-dependent attenuation in CT: Theory and simulation results

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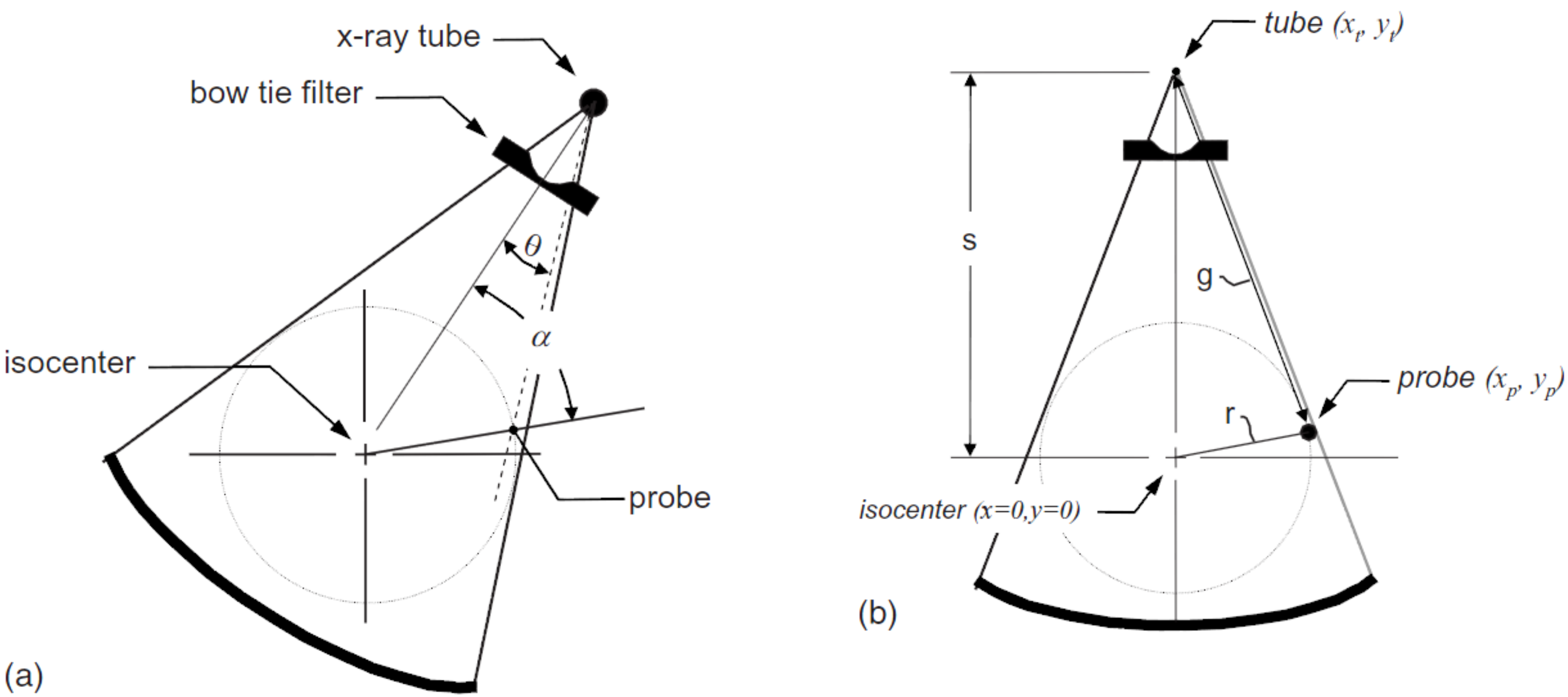
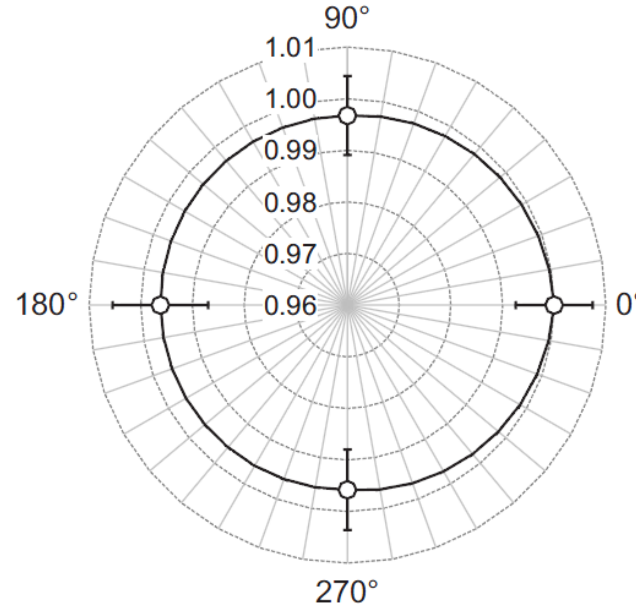
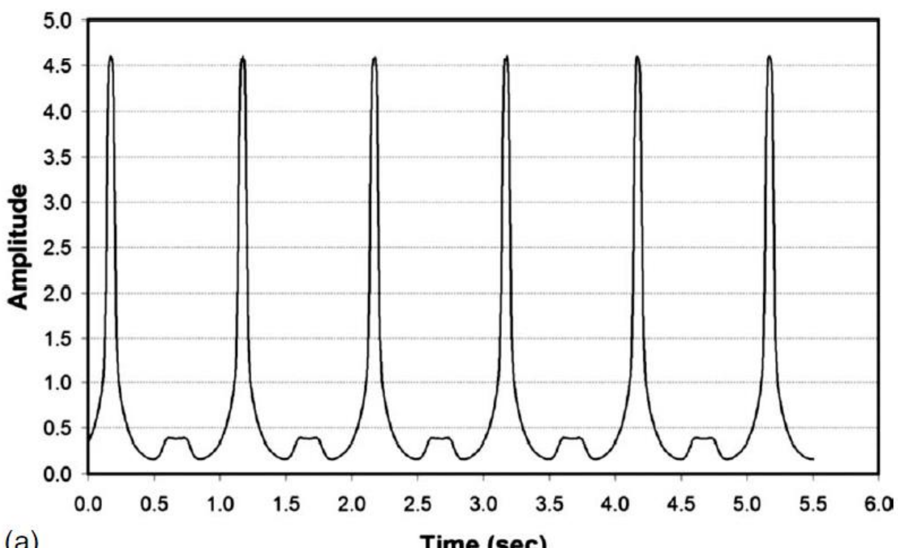
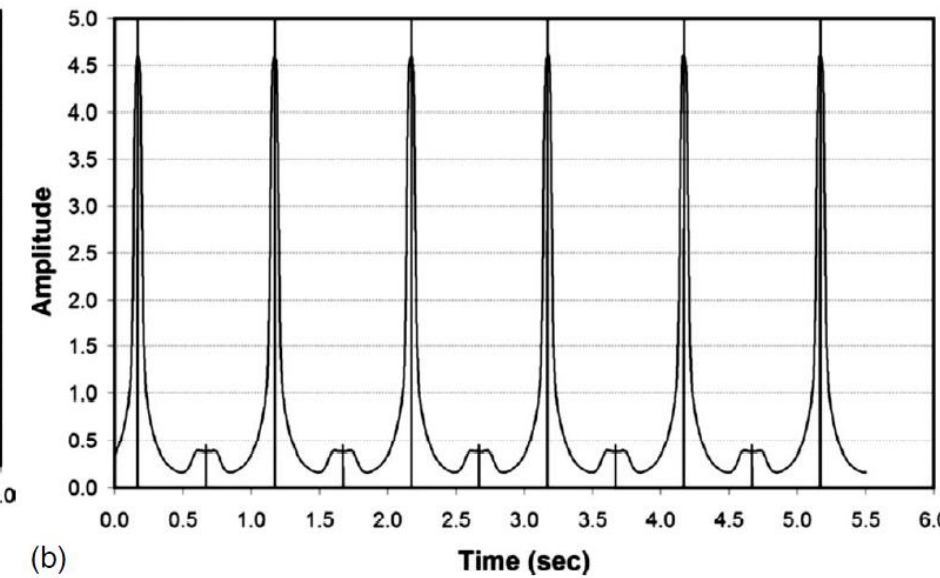


Computer simulation



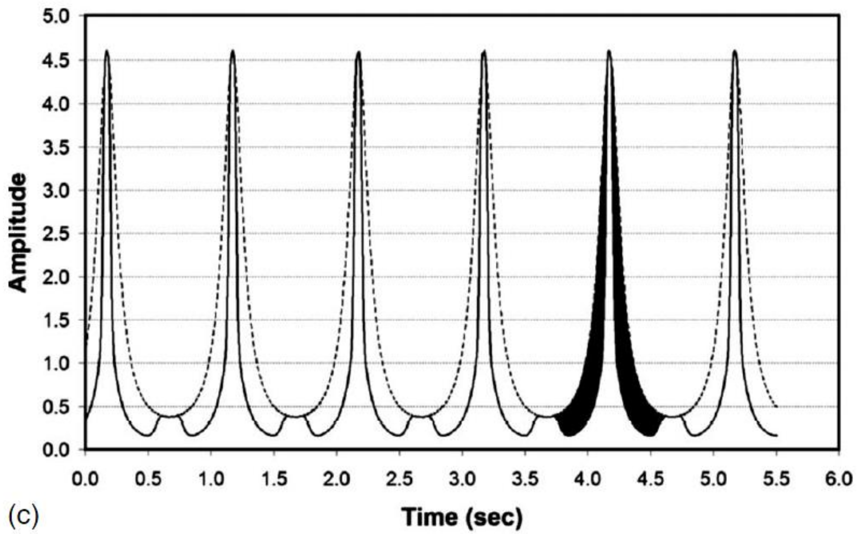


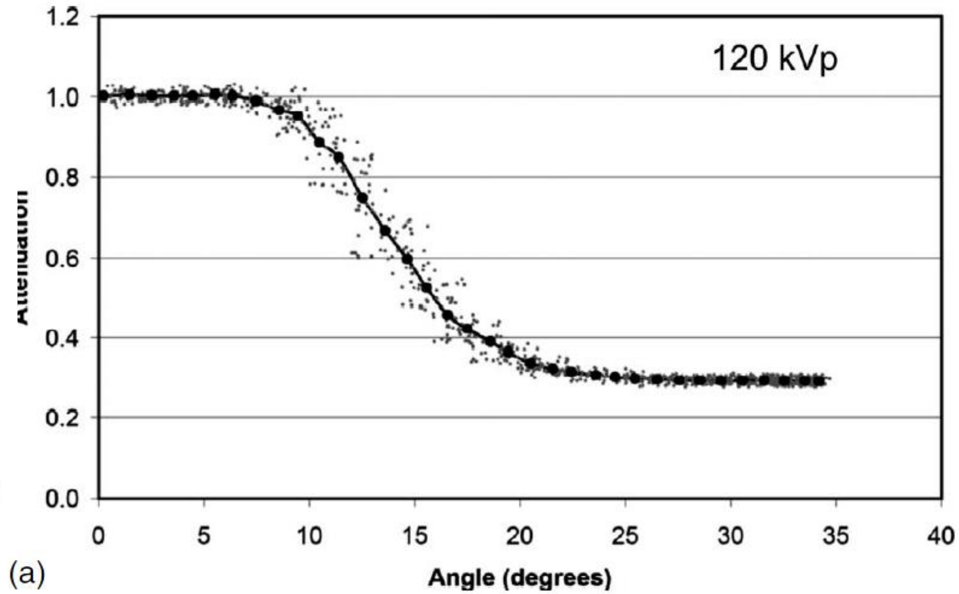
(a)

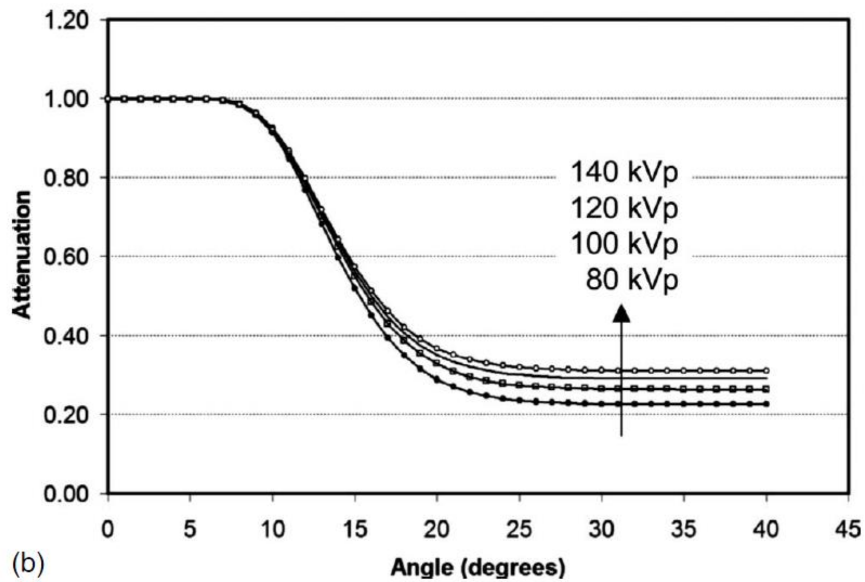


(b)

Computer simulation







Physical Measurement