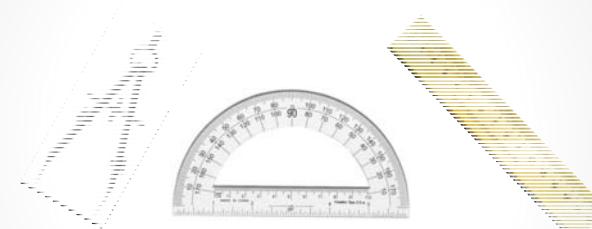


2013 Annual Meeting of the American Association of Physicists in Medicine
Indianapolis, Indiana

Measurements and Indices in CT Dose



John M. Boone
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Disclosures

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Alston and Bird LLC
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Samsung Corporation

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University of Pittsburgh
Siemens Medical Systems
Hologic Corporation
National Institutes of Health (NIBIB)



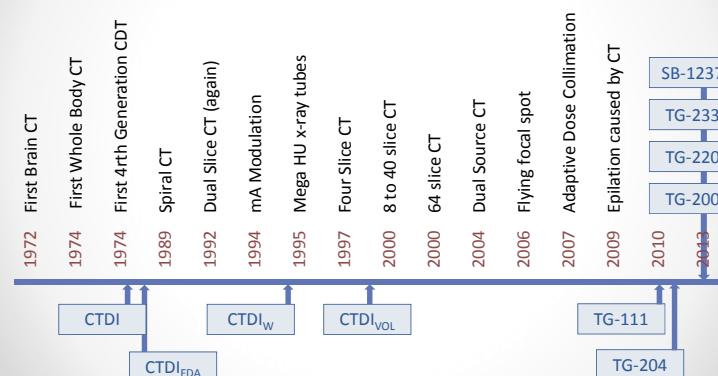
Measurements and Indices in CT Dose



- 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**

A brief history of the....

Evolution of CT Scanners and Dosimetry



Date	Event	Metric
1972	First Brain CT	
1974	First Whole Body CT	
1974	First 4th Generation CDT	CTDI
1989	Spiral CT	CTDI _{FDA}
1992	Dual Slice CT (again)	CTDI _W
1994	mA Modulation	CTDI _{VOL}
1995	Mega HU x-ray tubes	
1997	Four Slice CT	
2000	8 to 40 slice CT	
2000	64 slice CT	
2004	Dual Source CT	
2006	Flying focal spot	
2007	Adaptive Dose Collimation	
2009	Epilation caused by CT	
2010		TG-111
2013		TG-204

CTDI:
Computed Tomography Dose Index

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

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

Dose (rad)
x-axis position (mm)

• 5

CTDI - based Dose Metrics

32 cm diameter PMMA
16 cm diameter PMMA
100 mm pencil chamber

The Tools.....

•

CTDI - based Dose Metrics

CTDI₁₀₀ peripheral
CTDI₁₀₀ center

The Methods.....

•

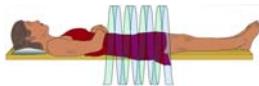
Measuring CTDI₁₀₀ in the real world

• 8

CTDI - based Dose Metrics

$\frac{2}{3} \times \text{CTDI}_{100} \text{ peripheral}$
 $+ \frac{1}{3} \times \text{CTDI}_{100} \text{ center}$

weighted CTDI, CTDI_w

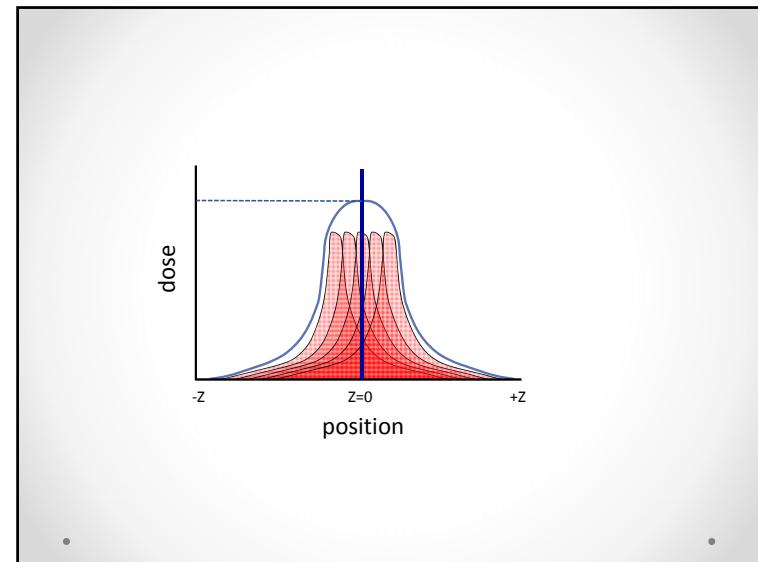


dose = 1 / pitch

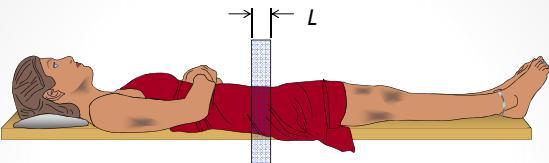
Volume CTDI, $\text{CTDI}_{vol} = \text{CTDI}_w / \text{pitch}$

The Mechanics.....

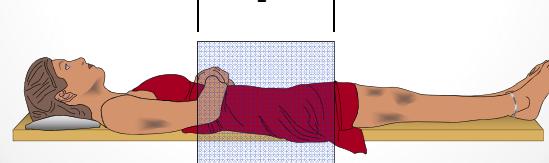
- W Leitz, et al., CT dose assessment – a practical approach, Radiat Prot Dosim 1995; 57: 377



Which scan has more “dose”?

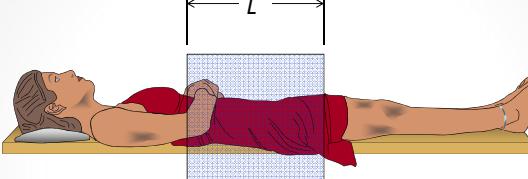


...to first order, the dose is the same



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Dose Length Product (DLP):



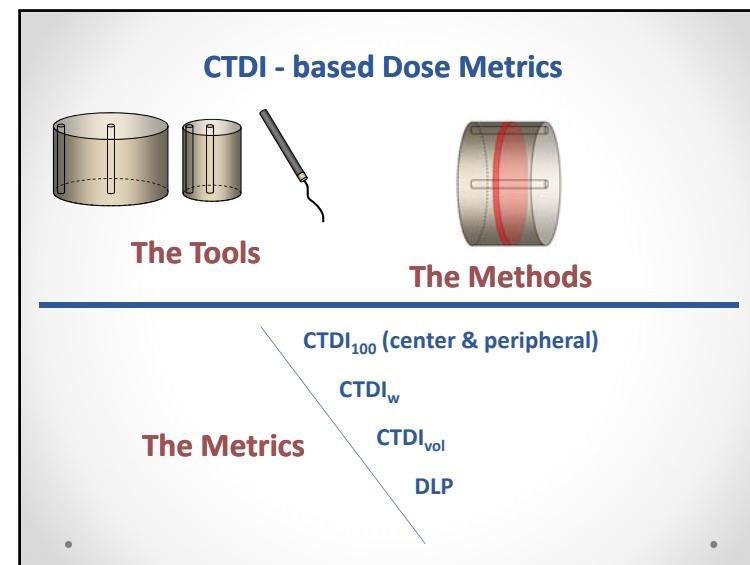
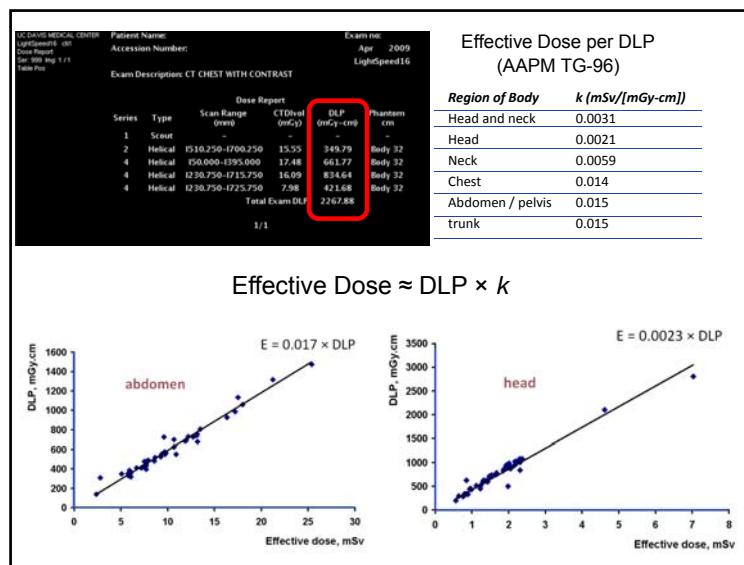
$$\text{DLP} = \text{CTDI}_{vol} \times L \quad (\text{mGy} \cdot \text{cm})$$

$$\text{dose} = \frac{\text{energy}}{\text{mass}} \quad \text{energy imparted} = \text{dose} \rho (L \times \pi r^2)$$

$$\text{energy} = \text{dose} \times \text{mass}$$

- DLP is related to the total energy deposited in the patient

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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 CTDI₁₀₀
John M. Boone
Department of Radiology and Biomedical Engineering, University of California Davis Medical Center, Olive Building, 4490 Y Street, Suite 5100, Sacramento, California 95817
(Received 1 September 2005; revised 26 October 2006; accepted for publication 8 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)

CT Dose Index and Patient Dose:
They Are *Not* the Same Thing¹

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)

Measurements and Indices in CT Dose

Introduction & Historical CT Dose Metrics

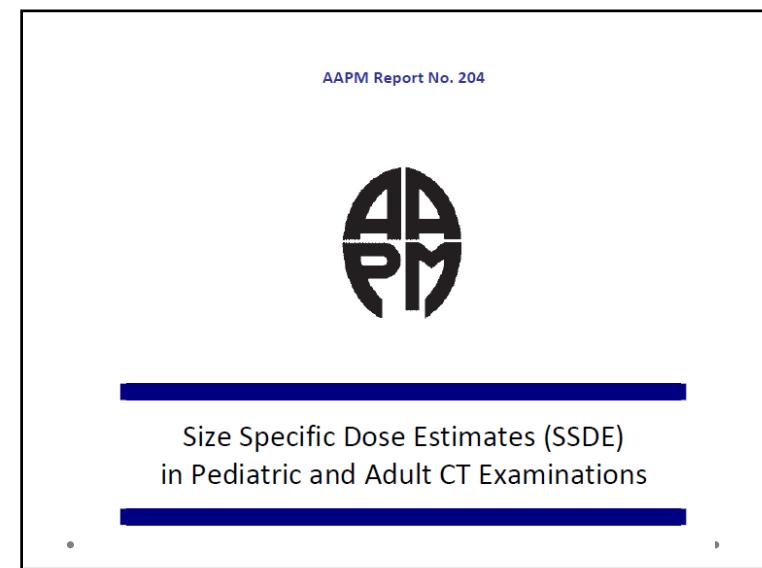
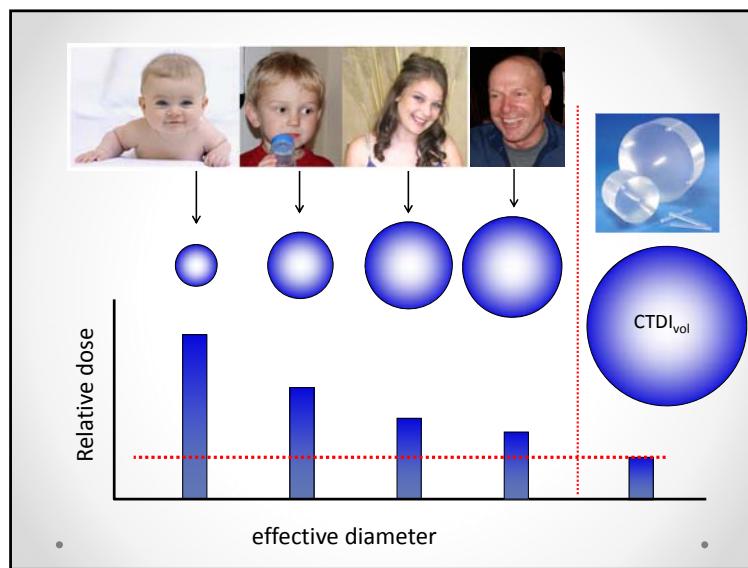
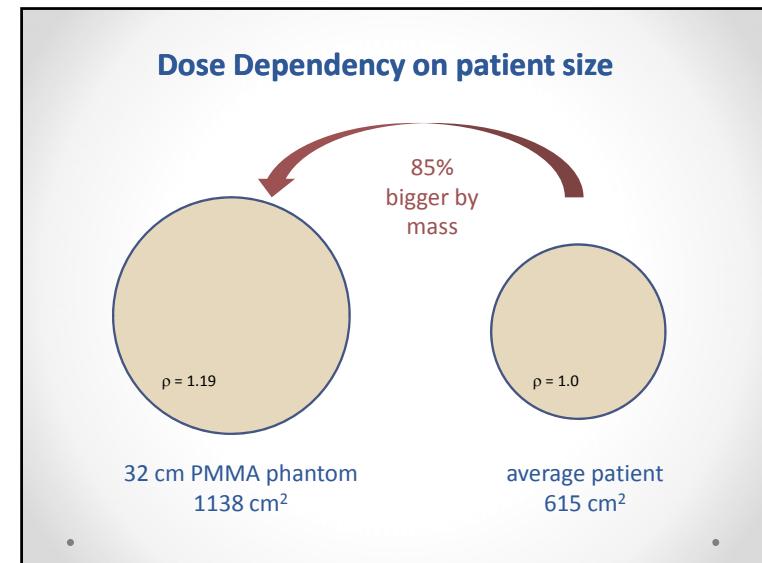
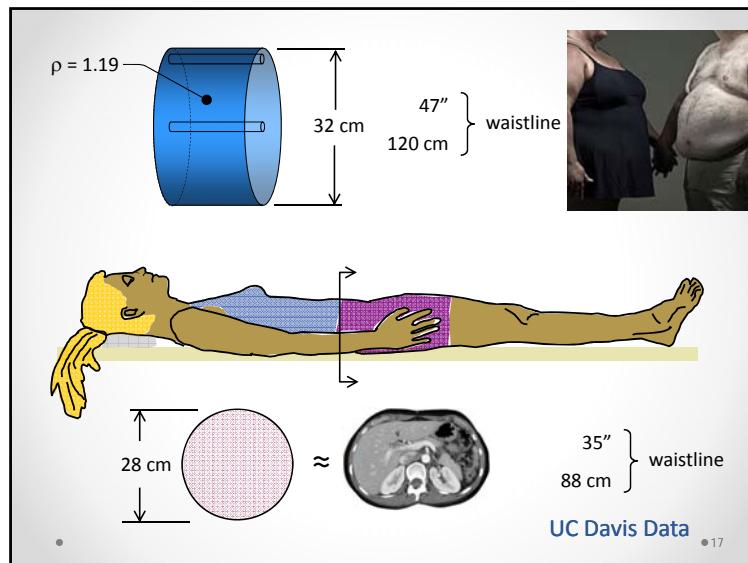
Dose dependency on patient size

Dose and CT scan length

Phantoms and radiation meters

ICRU extension to AAPM Report 111

Summary



TG-204 Approach

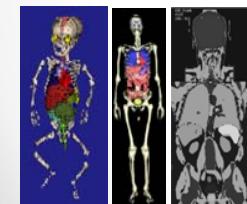
- Four Independent Research Groups
- Studied Size-dependent CT Dose



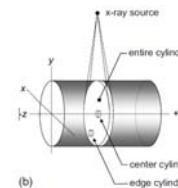
Keith Straus and Tom Toth



Cynthia McCollough et al.

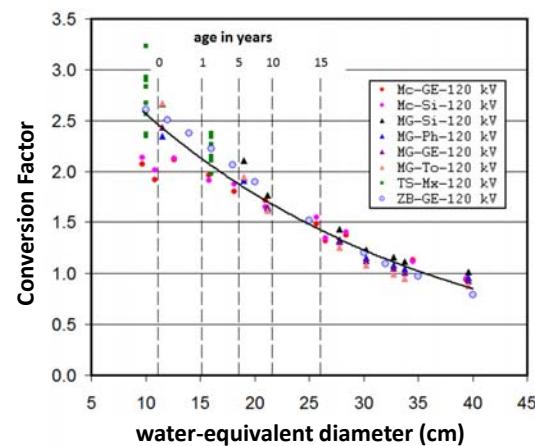


Mike McNitt-Gray, et al.



Hong Zhou and John Boone

32 cm 120 kV



CTDI_{vol} is indicated on most scanners.....



UC DAVIS MEDICAL CENTER	Patient Name:		Exam no:	
LightSpeed16 ctrl	Accession Number:		Apr 2009	
Dose Report				LightSpeed16
Ser: 999 Img: 1 / 1				
Table Pos				
	Exam Description: CT CHEST WITH CONTRAST			
		Dose Report		
Series	Type	Scan Range (mm)	CTDI _{vol} (mGy)	DLP (mGy·cm)
1	Scout	-	-	Phantom cm
2	Helical	I510.250-I700.250	15.55	349.79
4	Helical	I50.000-I395.000	17.48	661.77
4	Helical	I230.750-I715.750	16.09	834.64
4	Helical	I230.750-I725.750	7.98	421.68
		Total Exam DLP:	2267.88	
				1/1

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Size-Specific Dose Estimate (SSDE)

SSDE conversion factor

$$\text{CTDI}_{\text{vol}} \text{ (mGy)} \times f = \text{SSDE} \text{ (mGy)}$$

air kerma

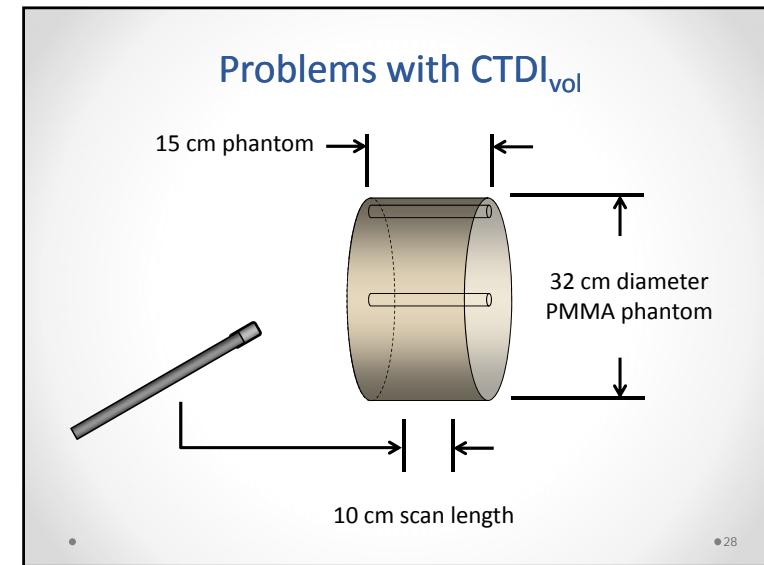
absorbed dose

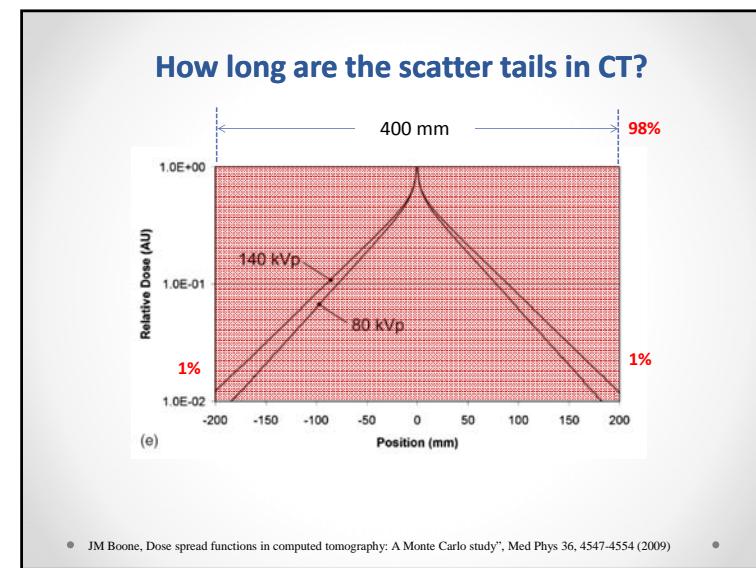
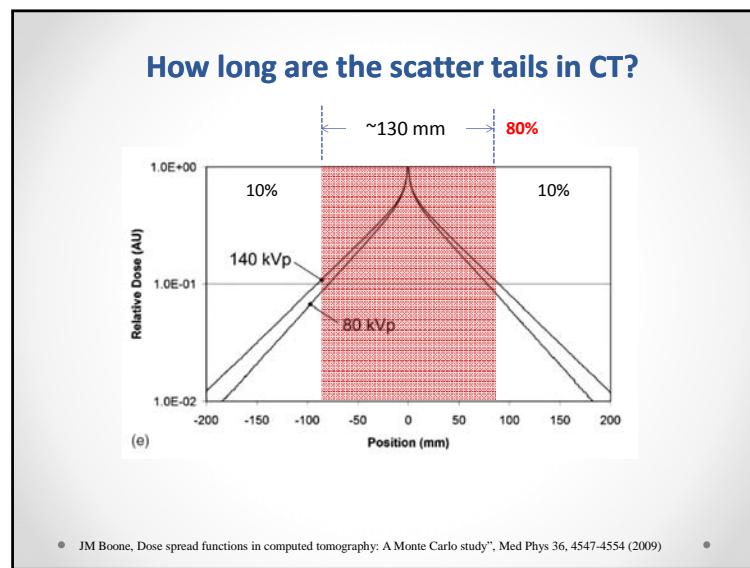
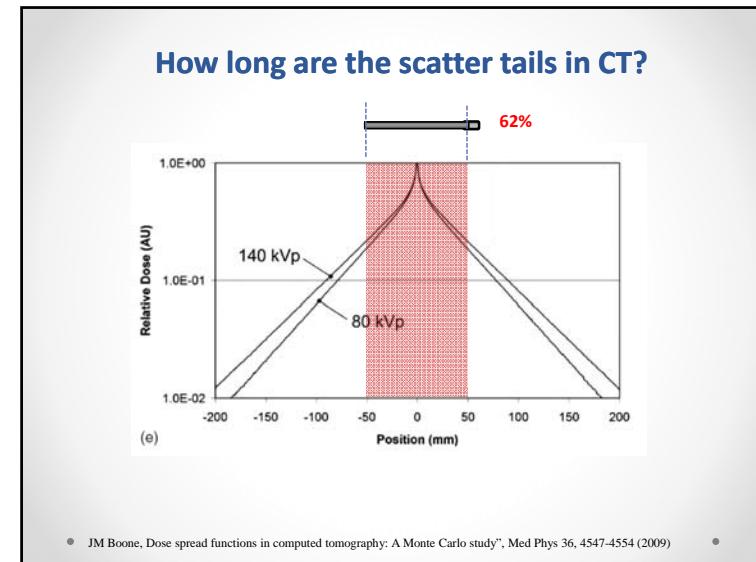
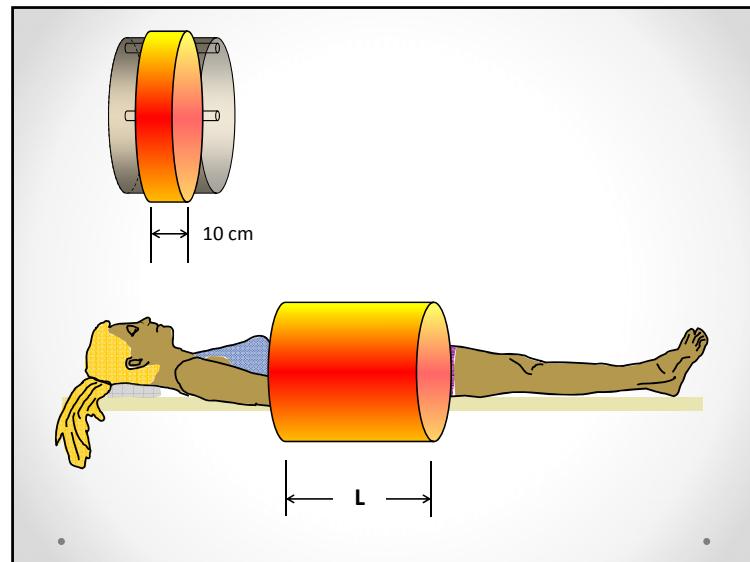
Measurements and Indices in CT Dose

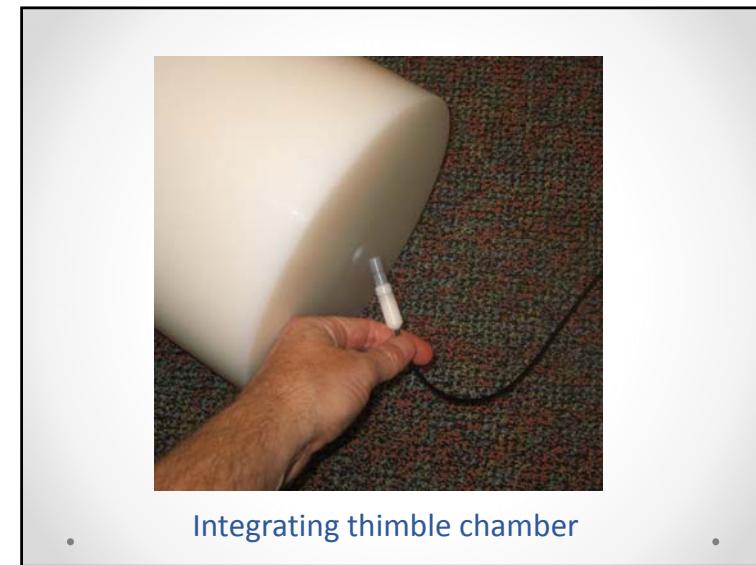
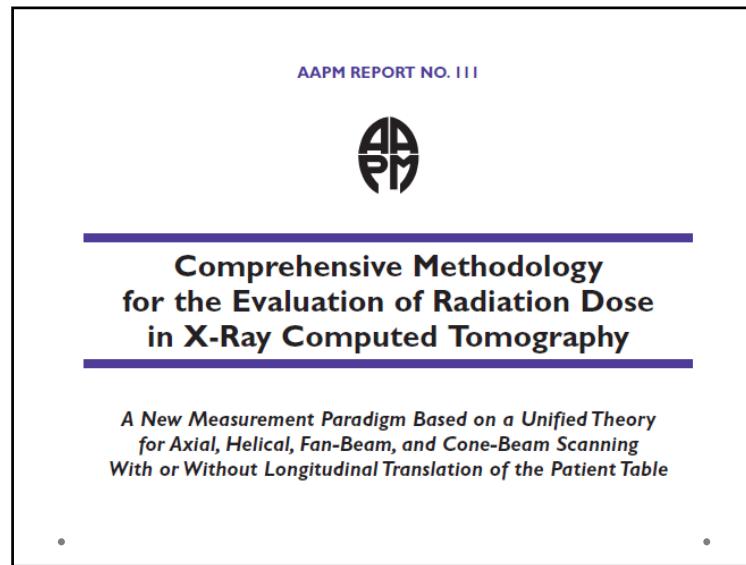
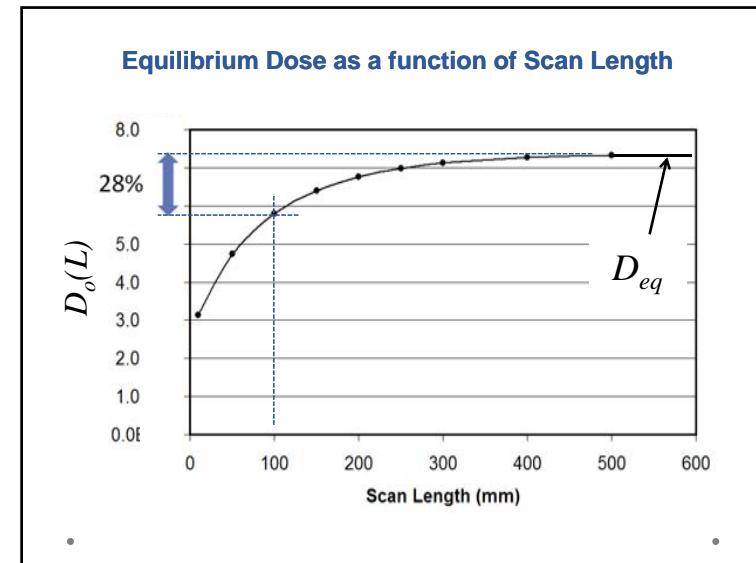
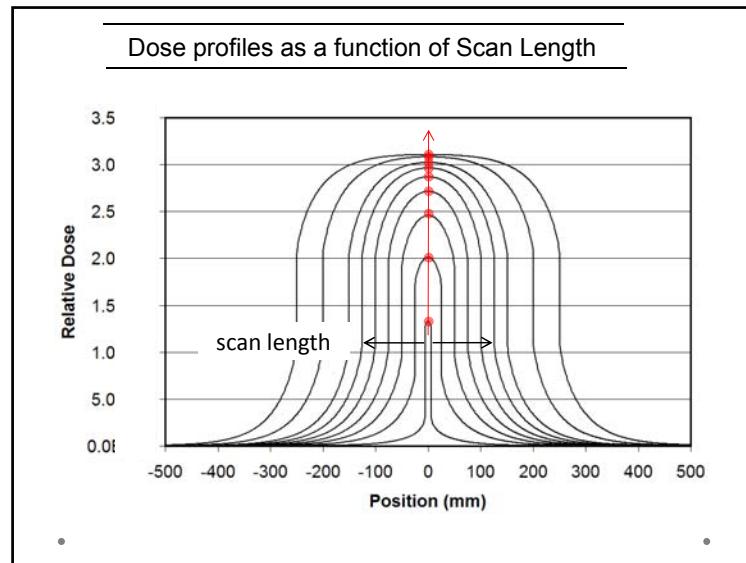
- Introduction & Historical CT Dose Metrics
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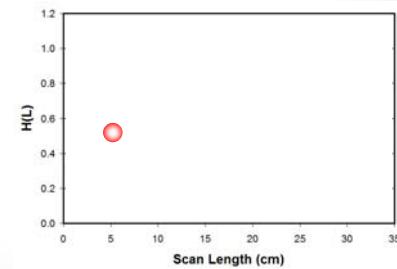
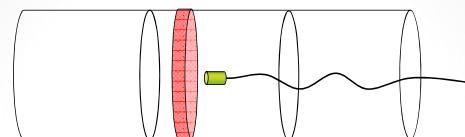
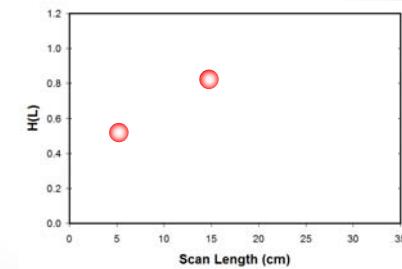
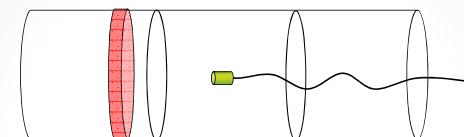
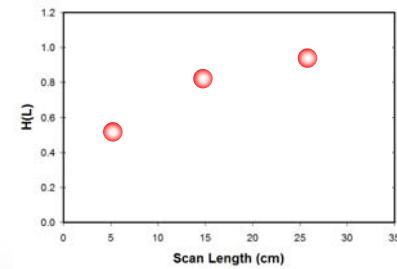
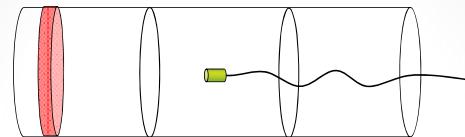
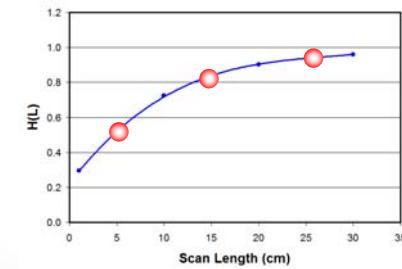
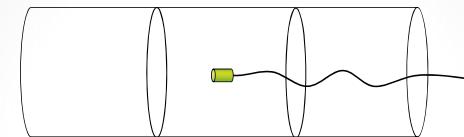
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TG-111 Method**TG-111 Method****TG-111 Method****TG-111 Method**

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

Robert L. Dixon^a

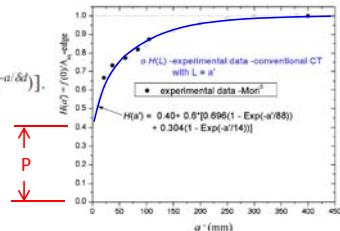
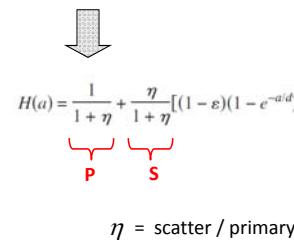
*Department of Radiology, Wake Forest University School of Medicine,
Winston-Salem, North Carolina 27760*

John M. Boone

*Department of Radiology, University of California Davis Medical Center,
Sacramento, California 95817*

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

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



Measurements and Indices in CT Dose

Introduction & Historical CT Dose Metrics

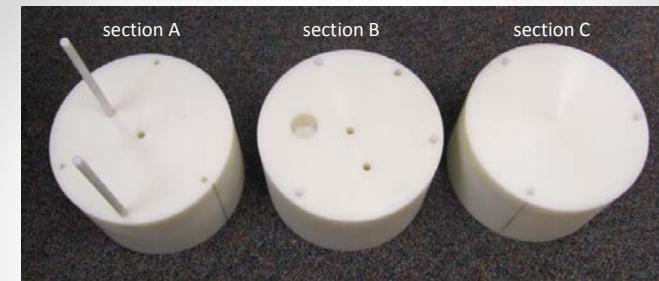
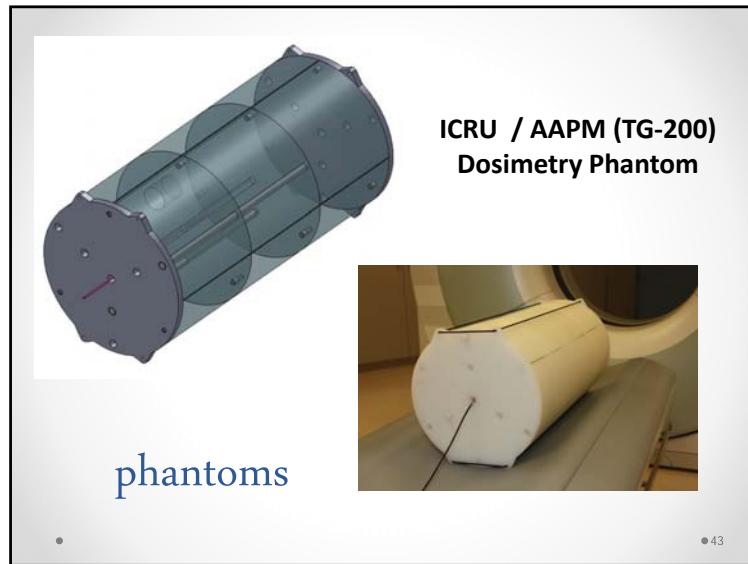
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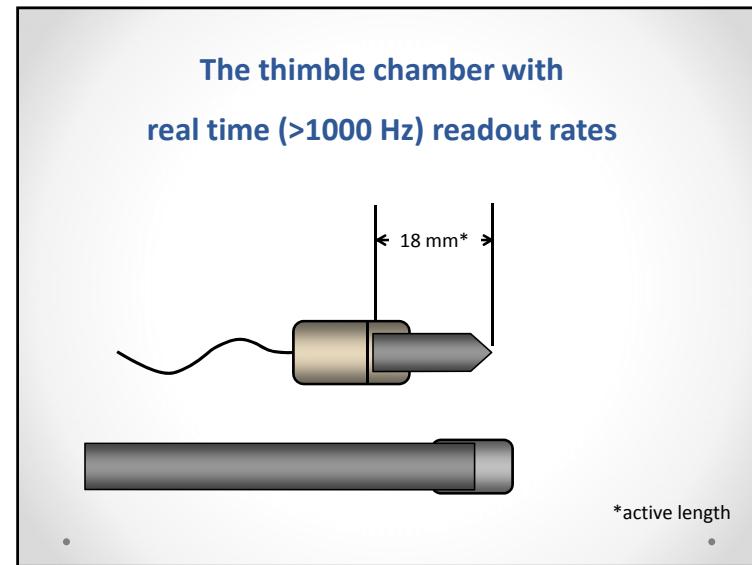
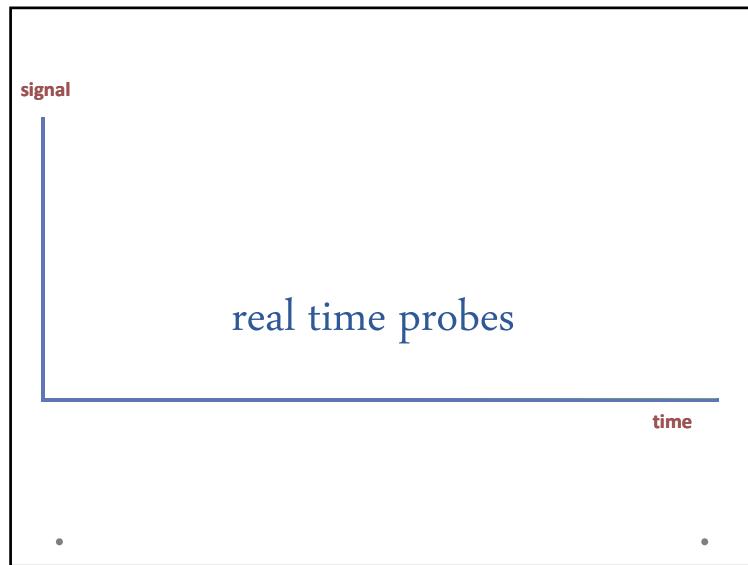


Phantom is polyethylene 60 cm long by 30 cm in diameter

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)



Measurements and Indices in CT Dose

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 **ICRU extension to AAPM Report 111**

Summary

 International Commission on
Radiation Units and Measurements, Inc.



RADIATION DOSE AND IMAGE QUALITY ASSESSMENT
IN COMPUTED TOMOGRAPHY

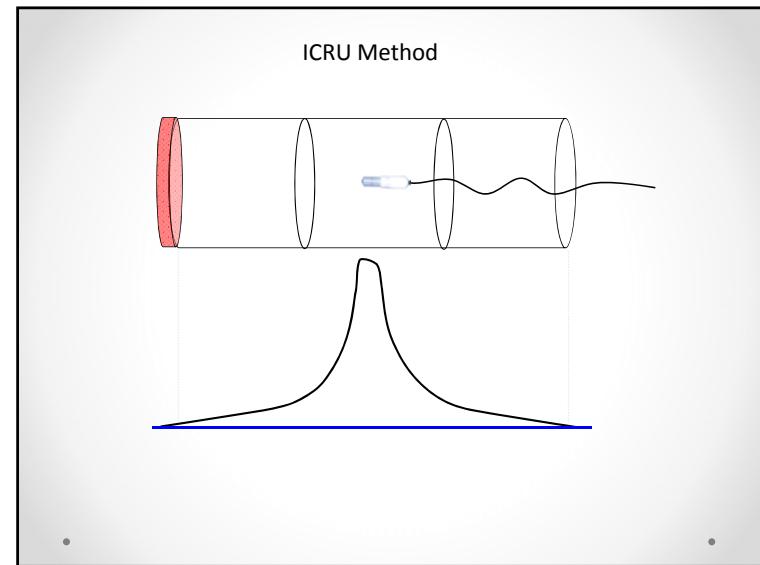
Report Committee

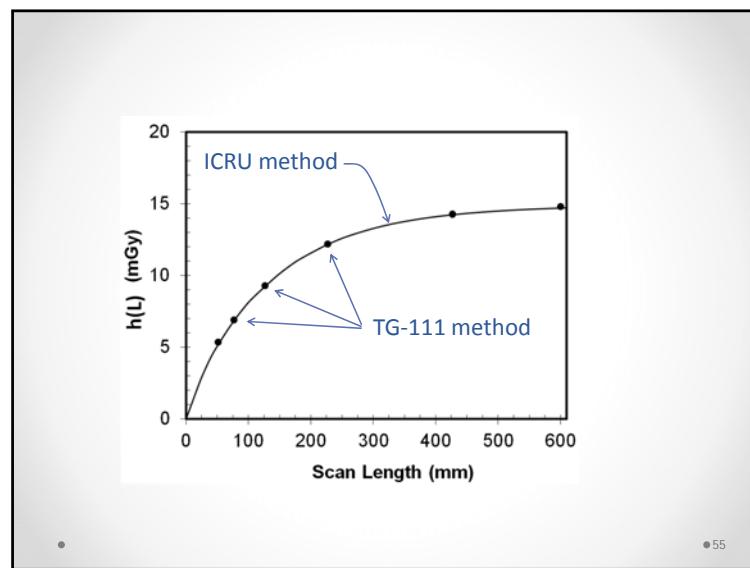
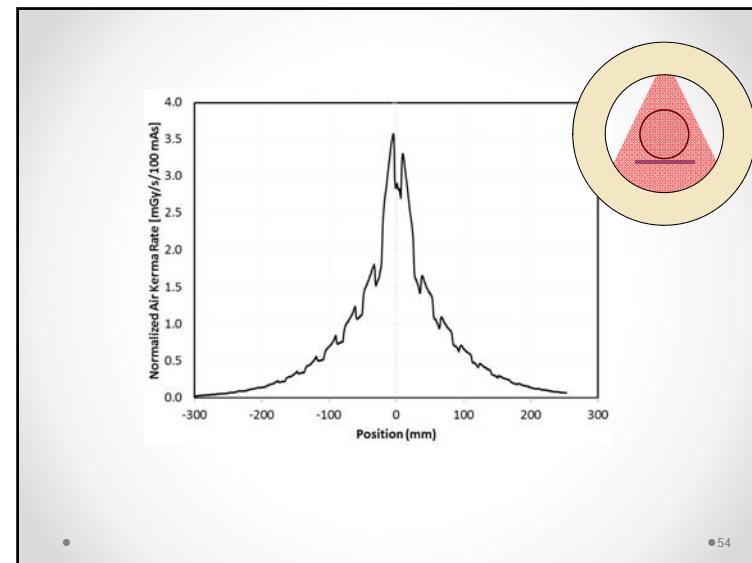
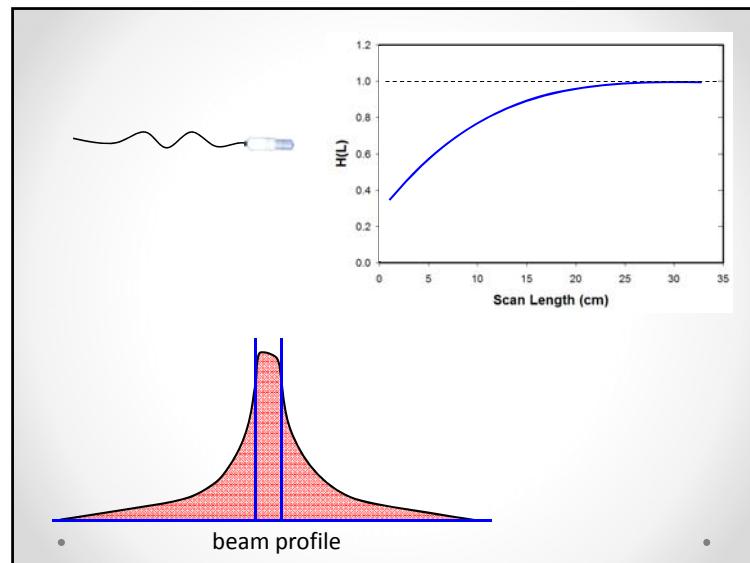
J.M. Boone (Chair), University of California Davis Medical Center, Sacramento, California, USA
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available soon!





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Measurements and Indices in CT Dose

CTDI-based methods need to be updated

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

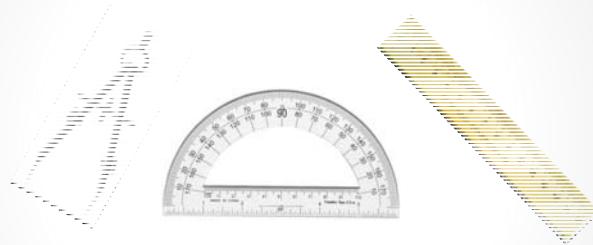
TG-111/ICRU Scan length dose dependencies $\rightarrow h(L)$

TG-200/ICRU Longer phantoms and faster radiation meters

TG-220 Methods for automatic size detection

ICRU CT Report Available Q3 2013

Measurements and Indices in CT Dose



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Professor of Biomedical Engineering
University of California Medical Center
Sacramento, California