CT: Size Specific Dose Estimate (SSDE): Why We Need Another CT Dose Index

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INTRODUCTION

A. Image Gently Campaign
B. Pediatric CT Public Health Concerns
C. Affect of Patient Size on Dose Indices
D. Shortcomings of Dose Indices for CT
E. Clinical Dilemma
F. Interim Solution: AAPM TG204
G. Managing Pediatric CT Patient Doses
H. Applications of SSDE

MISSION STATEMENT

Alliance for Radiation Safety in Pediatric Imaging is a coalition of health care organizations creating an education, awareness and advocacy campaign dedicated to providing safe, high quality pediatric imaging worldwide.

- 75 health care organizations/agencies
  800,000 radiologists,
  radiology technologists,
  medical physicists
  worldwide

Adapted from Goske

Methods

Positive message

..resulting dose to population *will lead* to higher cancer rates, accounting for as many as 2% of all cancers in the U.S.

Enroll key organizations

Increase awareness

educate

advocate

change practice

Adapted from Goske

Founding Organizations

The Society for Pediatric Radiology

American Society of Radiologic Technologists

American Association of Physicists in Medicine

American College of Radiology

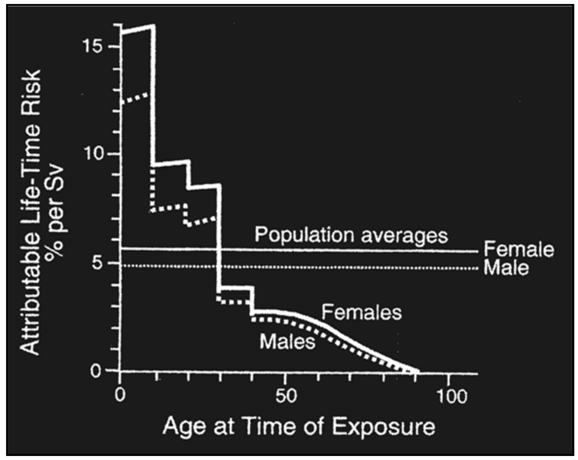
Alliance
For Radiation Safety
In Pediatric Imaging

Adapted from Goske

PEDIATRIC CONSIDERATIONS

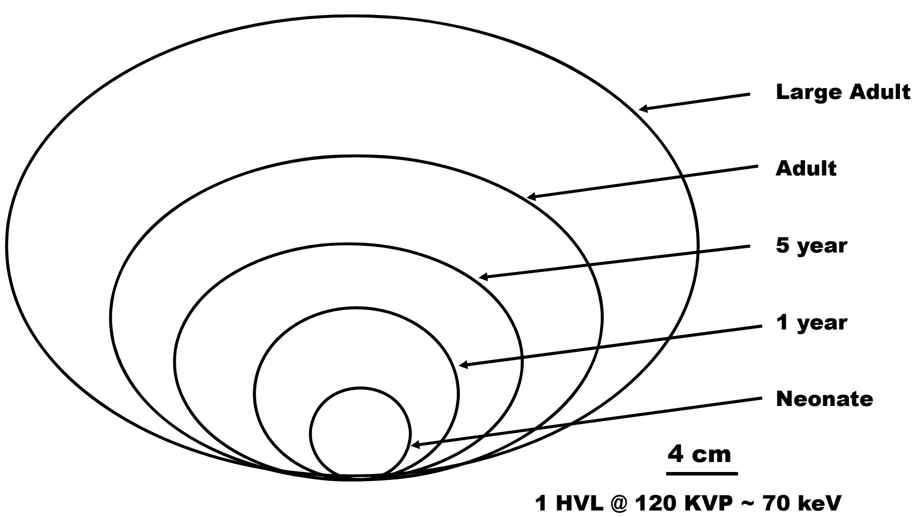
A. Radiation Induced Cancer Lifetime Risk From 1 Sv Dose

1. **Average**
   a. **5% Males**
   b. **6% Females**
2. **First Decade**
   13 - 15%
3. **Middle Age**
   2 - 3 %
4. **Children 3 – 5 times more sensitive**



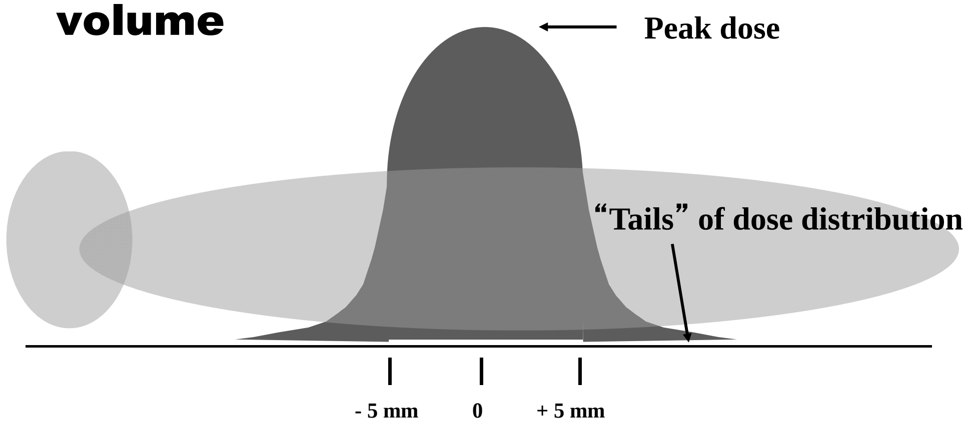
Adapted from Hall

AFFECT of PATIENT SIZE on DISPLAYED $CTDI_{VOL}$ & DLP



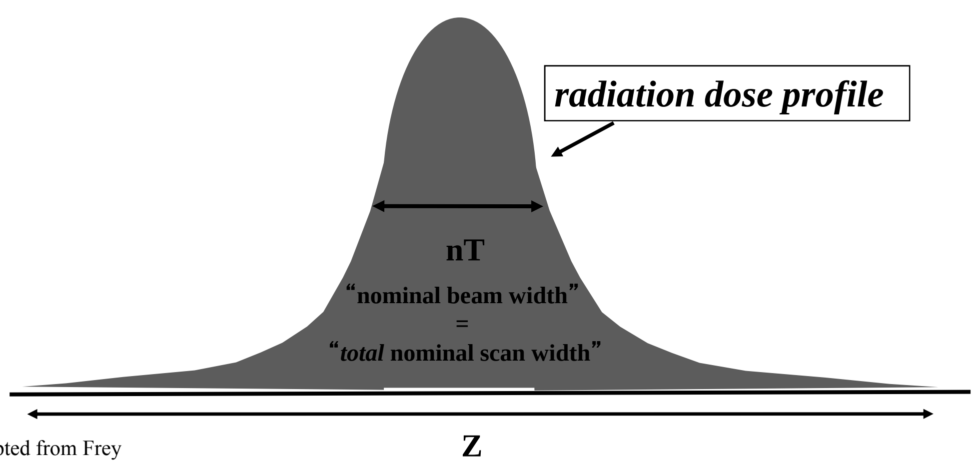
Real World ....

Radiation <u>distribution</u> *crosses* the imaged volume



Adapted from Frey

CTDI = Integral under the *radiation dose profile* along the z-axis from a <u>single *axial* scan</u> of width nT.



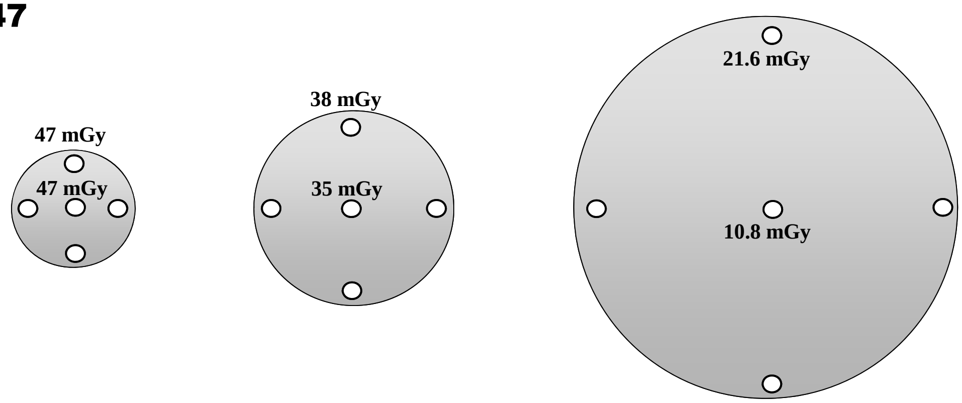
Adapted from Frey

CT SCANNER DOSE INDICES

C. Measure $CTDI_{vol}$

1. Measure $CTDI_{vol}$ with identical scan parameters
   a. kV
   b. mA
   c. Rotation time
   d. Bow Tie Filter
2. Use phantom 10, 16, and 32 cm diameter

Measured $CTDI_{vol}$ = 47 | **Measured $CTDI_{vol}$ = 37** | **Measured $CTDI_{vol}$ = 18**



10 cm Diameter | **16 cm Diameter** | **32 cm Diameter**

Measured $CTDI_{vol}$ increases 2.6 times as phantom size decreases!

CT SCANNER DOSE INDICES

D. Displayed $CTDI_{vol}$

1. Dose that represents distribution of dose given to cross-sectional area of a slab of the CTDI phantom (16 or 32 cm diameter)
2. Reflects changes in:
   a. Voltage to x-ray tube (kV)
   b. X-ray tube current (mA)
   c. Rotation time (sec)
   d. Pitch
   e. Bow tie filter shape, thickness, material
   f. Source to detector distance

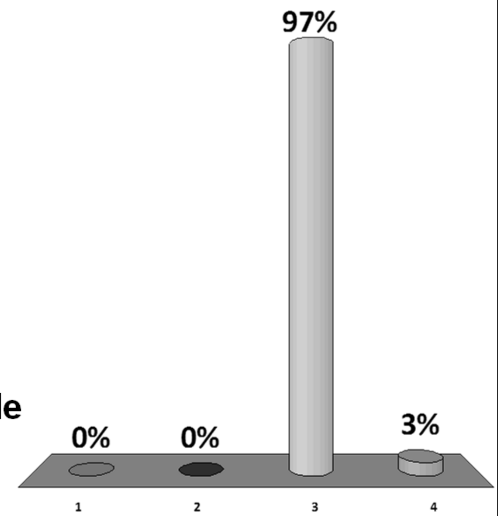
CT SCANNER DOSE INDICES

D. Displayed $CTDI_{vol}$

3. Standardized method to estimate and compare the radiation output of two different CT scanners to same phantom.

$CTDI_{vol}$

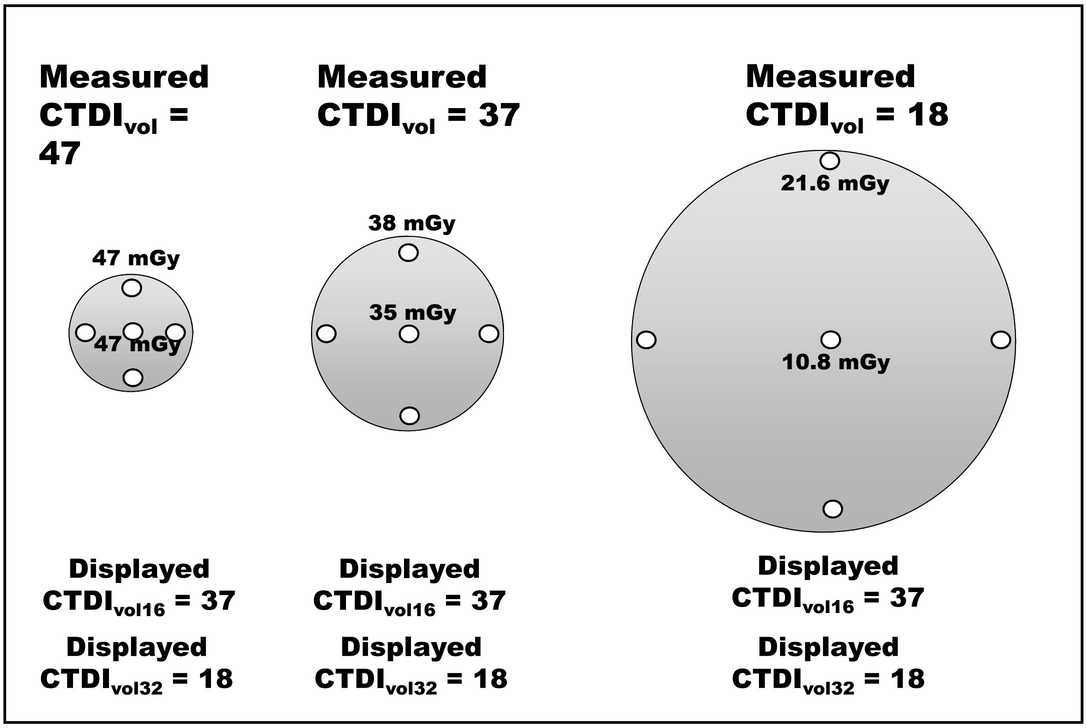
1. Is measured with a point ionization chamber such as a Farmer Chamber.
2. Displayed by the CT scanner represents the radiation dose delivered to the patient.
3. Is a standardized method to estimate and compare the radiation output of two different CT scanners to the same phantom.
4. Can be measured with a single measurement in the correct CTDI phantom.



1. $CTDI_{vol}$:

1. Is measured with a point ionization chamber such as a Farmer Chamber.
2. Displayed by the CT scanner represents the radiation dose delivered to the patient.
3. Is a standardized method to estimate and compare the radiation output of two different CT scanners to the same phantom.
4. Can be measured with a single measurement in the correct CTDI phantom.

Ref: "The Measurement, Reporting, and Management of Radiation Dose in CT", AAPM Report No. 96 (2008), p. 10.



CLINICAL DILEMMA

A. Displayed $CTDI_{vol}$ is independent of the patient size; displayed $CTDI_{vol}$ assumes either 16 or 32 cm CTDI phantom.

B. 16 cm CTDI phantom: adult dose over while pediatric dose under estimated.

C. 32 cm CTDI phantom: adult and pediatric dose under estimated ~ 2.5 times!

D. Propagated by DICOM Structured Reports and CT scanner dose reports.

CT SCANNER DOSE INDICES

D. Displayed $CTDI_{vol}$

5. does not represent . . .

Patient dose!!

PEDIATRIC CONSIDERATIONS CLINICAL EDUCATIONAL MATERIALS

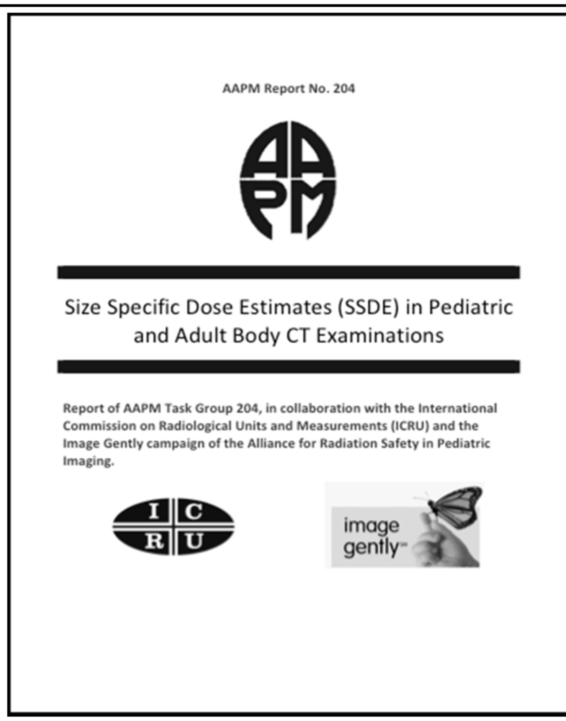
Abdomen	kVp	mA	Time (sec)	Pitch Abdomen	Pitch Thorax
Baseline:	fill in	fill in	fill in	fill in	fill in
		Abdomen		Thorax	
PA Thickness (cm)	Approx Age	mAs Reduction Factor (RF)	Estimated mAs = BL x RF	mAs Reduction Factor (RF)	Estimated mAs = BL x RF
9	newborn	0.43	#VALUE!	0.42	#VALUE!
12	1 yr	0.51	#VALUE!	0.49	#VALUE!
14	5 yr	0.59	#VALUE!	0.57	#VALUE!
16	10 yr	0.66	#VALUE!	0.64	#VALUE!
19	15 yr	0.76	#VALUE!	0.73	#VALUE!
22	small adult	0.90	#VALUE!	0.82	#VALUE!
25	med adult	1.0	fill in	0.91	#VALUE!
31	large adult	1.27	#VALUE!	1.16	#VALUE!

IMAGE GENTLY BODY

Abdomen	kVp	mA	Time (sec)	Pitch Abdomen	Pitch Thorax
Baseline:	120	400	1	1.25	1.5
		Abdomen		Thorax	
PA Thickness (cm)	Approx Age	mAs Reduction Factor (RF)	Estimated mAs = BL x RF	mAs Reduction Factor (RF)	Estimated mAs = BL x RF
9	newborn	0.43	172	0.42	202
12	1 yr	0.51	204	0.49	235
14	5 yr	0.59	236	0.57	274
16	10 yr	0.66	264	0.64	307
19	15 yr	0.76	304	0.73	350
22	small adult	0.90	360	0.82	394
25	med adult	1.0	400	0.91	437
31	large adult	1.27	508	1.16	557

PEDIATRIC CONSIDERATIONS CLINICAL EDUCATIONAL MATERIALS

1. **$CTDI_{vol}$ for Adults**
   a. **< 25 mGy Body ($CTDI_{32}$)**
   b. **< 75 mGy Head ($CTDI_{16}$)**
   c. **< 20 mGy Pediatric Body ($CTDI_{16}$)**
   d. **< ?? mGy Pediatric Head ($CTDI_{16}$)**
2. **Pediatric Patient Dose $\leq$ Adult Dose**
   a. **Up to 2.6 times greater if do nothing**
3. **Developed for adult department that images children occasionally**


AAPM Report No. 204

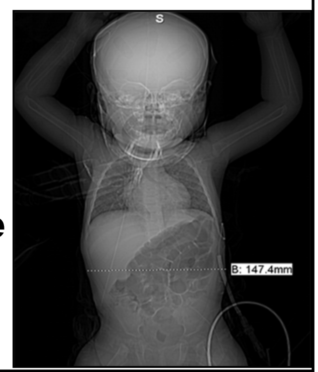
Size Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations

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

TG 204

E. Report does not:

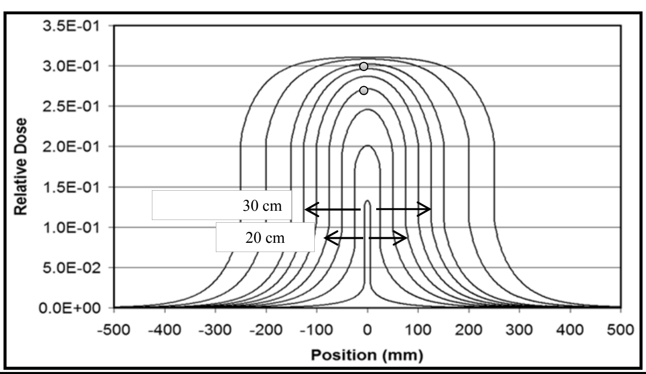
1. Address correction factors for heads
2. Correct small (< 1%) doses from scanned projection images
3. Correct for variation (~ 5%) in attenuation of thorax vs abdomen
4. Correct small variation in pre and post contrast scans



TG 204

E. Report does not address:

5. Changes in dose as a function of fan beam
   a. 20 cm: relative dose ~ 2
   b. 30 cm: relative dose ~ 2.3
   c. Dose Profiles vs Fan Beam Width



Adapted from J. Boone

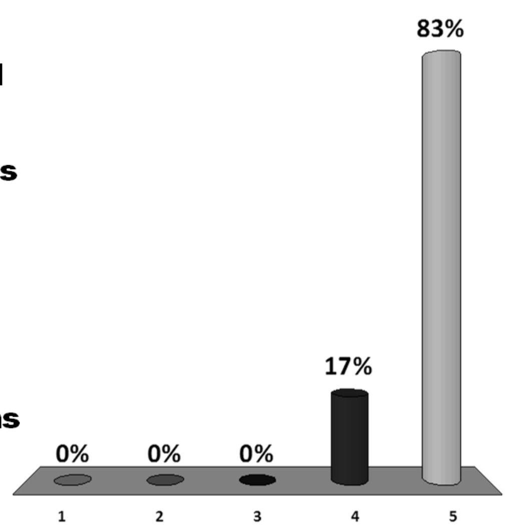
TG 204

F. So what is SSDE?:

1. Estimate of the average patient dose within the entire scan volume of patient.
   a. Adjusts for patient size and varying attenuation from overlying tissue thickness.
   b. Uses average scanner radiation output during CT scan: $CTDI_{vol}$
      i. Output varies along z axis
      ii. Output varies as beam rotates
      iii. Output varies based on bow tie filter

SSDE:

1. Calculations account for the differences in pre and post contrast scans.
2. Conversion factors for the head are smaller than those for the trunk.
3. Calculations include corrections for the dose of the projection scan
4. Reference values published by the ACR < 20 mGy for a pediatric 5 year old body.
5. Does not correct for the failure to capture complete scatter tails when using short phantoms as addressed in AAPM Task Group Report 111.



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Ref: "The Measurement, Reporting, and Management of Radiation Dose in CT", AAPM Report No. 96 (2008), p. 2.

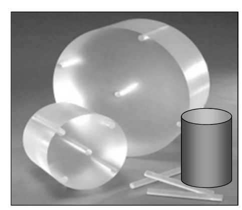
TG 204

F. Data from four independent investigators studying patient size correction factors.

Adapted from TG 204

1. Physical measurements on phantoms

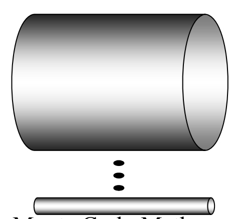
A. Anthropomorphic Phantoms (McCollough Laboratory "Mc")



B. Cylindrical PMMA phantoms (Toth / Strauss Collaboration "T-S")

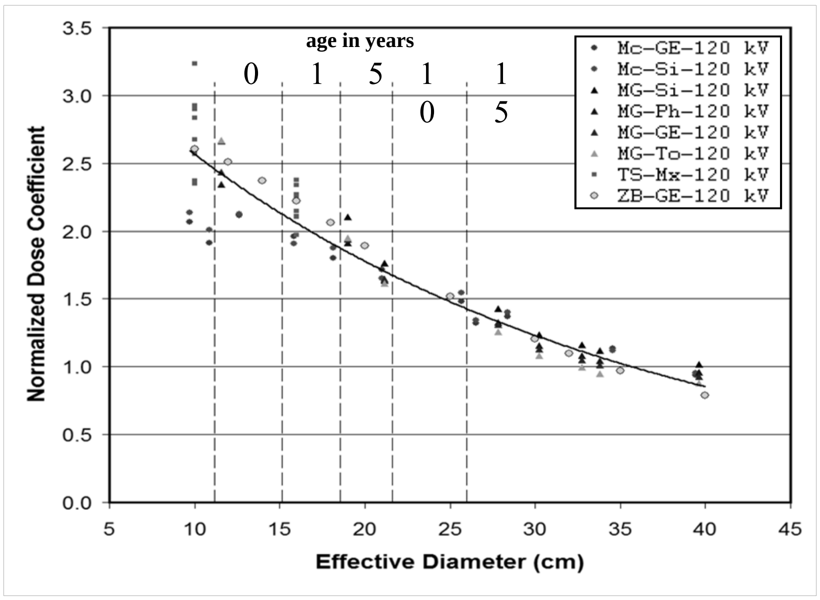
2. Monte Carlo computer modeling

C. Monte Carlo Voxelized Phantoms (McNitt-Gray Laboratory "MG")



D. Monte Carlo Mathematical Cylinders (Boone Laboratory "Z-B")

TG 204

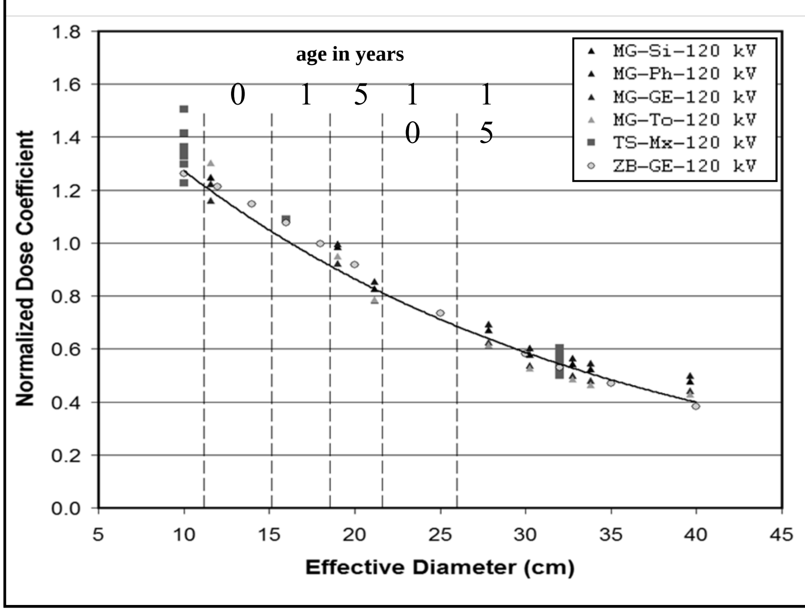


32 cm 120 kV

Adapted from TG 204

$y = 3.7044e^{-0.0367x}$
$R^2 = 0.9429$

TG 204



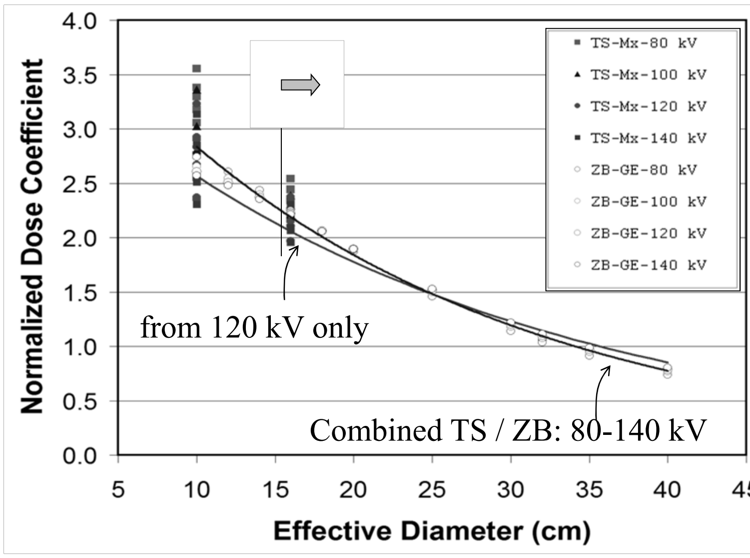
16 cm 120 kV

Adapted from TG 204

$y = 1.8748e^{-0.0387x}$
$R^2 = 0.9673$

TG 204

G. What about scans performed at 80, 100, or 140 kV?



1. **5% difference overall**
2. **3% difference between 1 yr old (15 cm) & adult (32 cm)**

$y = 4.37809e^{-0.04331x}$

$R^2 = 0.97327$

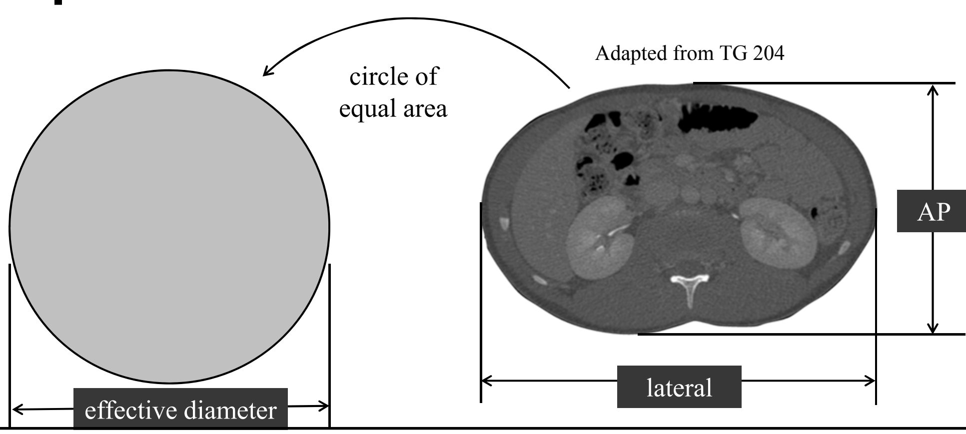
Adapted from TG 204

TG 204

I. What is an effective diameter?

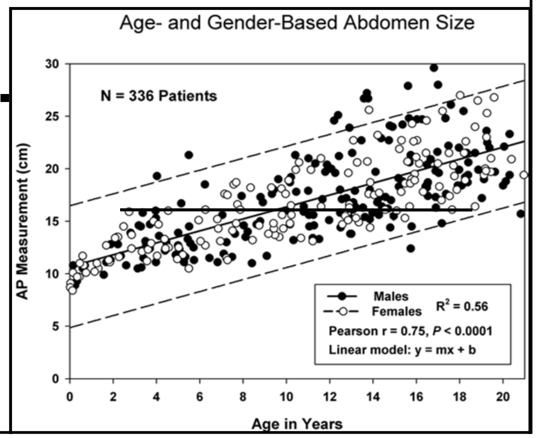
1. **Circle with area of patient's cross section**
2. **Effective diameter can be estimated if the patient's AP or lateral dimension is known.**

Adapted from TG 204



AGE vs PATENT SIZE

A. Same age patients vary dramatically in size.
Abdomens of:
1. Largest 3 year olds and
2. Smallest adults are the same size.

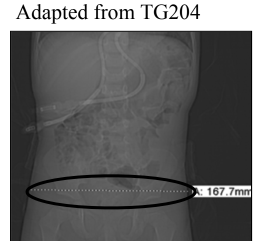


Patient cross section size, not age, should be used.

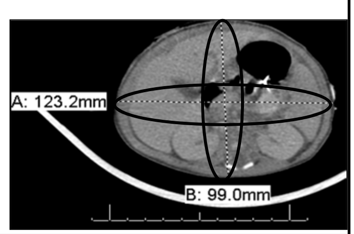
TG 204

L. Determining patient size
1. Measure Lateral dimension with mechanical calipers.
2. Measure Lateral or AP dimension from AP or Lateral projection scan.
   a. Magnification Error
3. Measure AP or LAT dimension from axial scan view.

AP or PA Projection Scan
Adapted from TG204



AP or PA Projection Scan
Adapted from TG204



TG 204

M. Determining size of CTDI phantom your CT scanner used to estimate $CTDI_{vol}$

1. **Failure to identify correct phantom, 16 or 32 cm leads to a systematic error of 100%.**
2. **No standard exists. Choice may depend on:**
   a. **Selected protocol: adult or pediatric**
   b. **Selected scan field of view**
   c. **Year of manufacture**
   d. **Software level**
3. **Make no assumptions: contact manufacturer of your unit through its service organization.**

TG 204

O.

Correction Factor based on 32 cm CTDI Phantom

Lat + AP Dim (cm)	Effective Dia (cm)	Correction Factor
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
31	15.2	2.12
32	15.7	2.08
33	16.2	2.05
34	16.7	2.01
35	17.2	1.97
36	17.6	1.94
37	18.1	1.90
38	18.6	1.87
39	19.1	1.83
40	19.6	1.80
41	20.1	1.77
42	20.6	1.74
43	21.1	1.71
44	21.6	1.67
45	22.1	1.64
46	22.6	1.62
47	23.1	1.59
48	23.6	1.56
49	24.1	1.53
50	24.6	1.50
51	25.1	1.47
52	25.6	1.45
53	26.1	1.42

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
21	17.2	1.97
22	17.9	1.92
23	18.7	1.86
24	19.5	1.81
25	20.3	1.76
26	21.1	1.70
27	22.0	1.65
28	22.9	1.60
29	23.8	1.55
30	24.7	1.50
31	25.6	1.45
32	26.6	1.40
33	27.6	1.35
34	28.6	1.30
35	29.6	1.25
36	30.6	1.20
37	31.7	1.16
38	32.7	1.11
39	33.8	1.07
40	34.9	1.03
41	36.1	0.98
42	37.2	0.94
43	38.4	0.90
44	39.6	0.87
45	40.8	0.83

AP Dim (cm)	Effective Dia (cm)	Correction Factor
8	8.8	2.68
9	10.2	2.55
10	11.6	2.42
11	13.0	2.30
12	14.4	2.18
13	15.7	2.08
14	17.0	1.98
15	18.3	1.89
16	19.6	1.81
17	20.8	1.73
18	22.0	1.65
19	23.2	1.58
20	24.3	1.52
21	25.5	1.45
22	26.6	1.40
23	27.6	1.34
24	28.7	1.29
25	29.7	1.25
26	30.7	1.20
27	31.6	1.16
28	32.6	1.12
29	33.5	1.08
30	34.4	1.05
31	35.2	1.02
32	36.0	0.99
33	36.8	0.96
34	37.6	0.93
35	38.4	0.91
36	39.1	0.88
37	39.8	0.86
38	40.4	0.84
39	41.1	0.82
40	41.7	0.80
41	42.3	0.78
42	42.8	0.77
43	43.4	0.75
44	43.9	0.74
45	44.4	0.73

Effective Dia (cm)	Correction Factor
8	2.76
9	2.66
10	2.57
11	2.47
12	2.38
13	2.30
14	2.22
15	2.14
16	2.06
17	1.98
18	1.91
19	1.84
20	1.78
21	1.71
22	1.65
23	1.59
24	1.53
25	1.48
26	1.43
27	1.37
28	1.32
29	1.28
30	1.23
31	1.19
32	1.14
33	1.10
34	1.06
35	1.02
36	0.99
37	0.95
38	0.92
39	0.88
40	0.85
41	0.82
42	0.79
43	0.76
44	0.74
45	0.71

Adapted from TG 204

TG 204

Q. SSDE Accuracy

1. **20%**
2. **Product is an *estimate* of patient dose**
3. **Report dose estimates with proper number of significant digits**

   a. **SSDE $\geq$ 5 mGy: integers only, e.g. 7 or 23 mGy**

   b. **SSDE < 5 mGy: one decimal point, e.g. 2.7 or 4.5 mGy**

SAMPLE CALCULATION: PRESCAN

A. Determine size of patient

1. AP Projection Scan: 16.8 cm

B. 16 cm CTDI phantom used by scanner to calculate $CTDI_{vol}$

C. Displayed $CTDI_{vol}$ = 9.29 mGy

D. 9.29 mGy x 1.08 = 10 mGy SSDE

Lateral Dim (cm)	Effective Dia (cm)	Correction Factor
8	9.2	1.32
9	9.7	1.29
10	10.2	1.26
11	10.7	1.24
12	11.3	1.21
13	11.8	1.19
14	12.4	1.16
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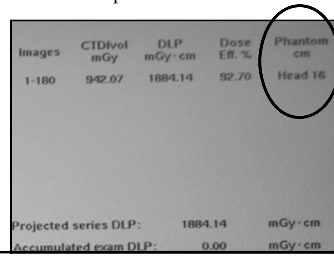
30	24.7	0.72
31	25.6	0.70
32	26.6	0.67

Adapted from TG 204



Images	CTDIvol mGy	DLP mGy·cm	Dose Eff. %	Phantom cm
1-180	942.07	1884.14	92.70	Head 16

Projected series DLP: 1884.14 mGy·cm

Accumulated exam DLP: 0.00 mGy·cm

TG 204

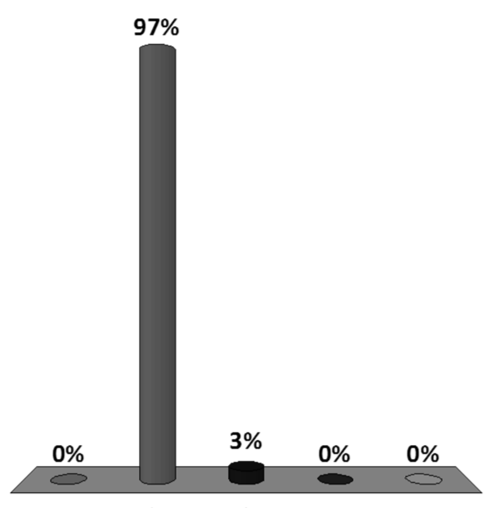
R. Dose Reporting by Radiologists

The $CTDI_{vol}$ value reported on the scanner for the [32 or 16] PMMA phantom was used with correction factors obtained from AAPM Report 204. The correction factor for this patient was based on the patient's [AP, LAT, AP + LAT, or effective dimension] This method is thought to produce dose estimates with accuracy to within 20%. For this patient, the size corrected (SSDE) estimate for this CT scan is _____ mGy.

Adapted from TG 204

SSDE:

1. **Calculation has an estimated error of 10%.**
2. **Accounts for both the radiation output of the scanner and patient size.**
3. **Cannot be estimated until after the CT examination of the patient is completed.**
4. **Is more accurate if patient size is estimated based on the patient's age.**
5. **Should not be used for CT examinations of the thorax.**



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Ref: "Size Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations", AAPM Report No. 204 (2011), p. 2.

Effective Dose Issues

T. Caution:

SSDE can NOT be substituted in place of $CTDI_{vol}$ when using k-factors to$_{100}$ estimate Effective Doses from CT exam

Effective Dose Issues

G. Effective Dose was originally defined to address radiation protection concerns of occupationally exposed workers.

H. Effective dose can be used to facilitate a comparison of biological effects between diagnostic exams of different types.

Effective Dose Issues

I. Effective Dose is <u>NOT</u>:

1. A patient dose
2. To be used for an individual
3. Defined for children
4. For estimating cancer risk; it assesses more than just cancer risk.

Christner JA, Sturchio G, McCollough CH, et al. Use of Effective Dose in Medical Imaging. Mayo Clinic Rochester, MN

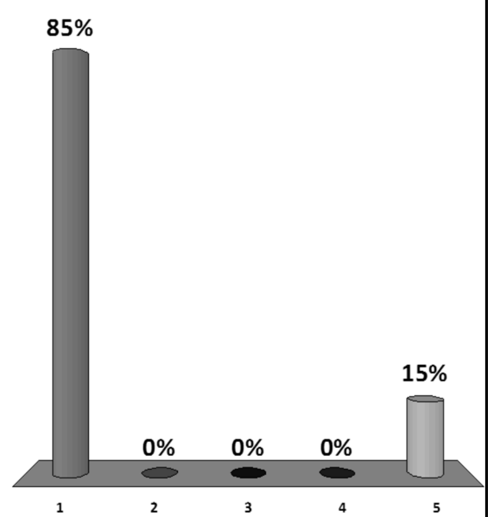
Effective Dose Issues

J. Effective Dose Recommended Reading

1. ICRP 103 Executive Summary
2. AD Nixon, "New ICRP recommendations", J Radiol Prot 2008.
3. CJ Martin, "Effective dose: How should it be applied to medical exposures?", BJR 2007
4. "Rational approach to the clinical use of effective dose estimates", AJR 2011.

Effective Dose:

1. Can be used to compare biological effects diagnostic exams of different types.
2. Accuracy is improved when SSDE is multiplied times the appropriate k-factor instead of $CTDI_{vol}$.
3. Can be used to estimate an individual patient's radiation dose.
4. Can be used to estimate organ doses.
5. Was originally defined to address radiation protection concerns of medically exposed patients.



Effective Dose:

1. Can be used to facilitate a comparison of biological effects between diagnostic exams of different types.
2. Accuracy is improved when SSDE is multiplied times the appropriate k-factor instead of $CTDI_{vol}$.
3. Can be used to estimate an individual patient's radiation dose.
4. Can be used to estimate organ doses.
5. Was originally defined to address radiation protection concerns of medically exposed patients.

Ref: "The Measurement, Reporting, and Management of Radiation Dose in CT", AAPM Report No. 96 (2008), p. 11.

Clinical Applications of SSDE

I. Ideally, unique scan parameters should be established for each individual patient accounting for:
   1. Patient size
   2. Type of CT examination
   3. Design of actual CT scanner

J. This can be done in academic centers with diligent effort.

Clinical Applications of SSDE

K. What are the odds this will happen for the occasional pediatric CT scan completed at a good community hospital?

SLIM & NONE!

Yet, majority of pediatric CT imaging in US DOES NOT occur in dedicated pediatric hospitals?

Clinical Applications of SSDE

L. What is a solution?

1. Review the $CTDI_{vol}$ measurements completed by the facility's medical physicist.
   a. Site $CTDI_{vol}$ < ACR Reference Values
   b. Verification that adult patient doses of site is reasonable.

Clinical Applications of SSDE

L. What is a solution?

2. Calculate SSDE after scan projection image of pediatric patient is complete.

a. Measured patient width

b. Size of CTDI phantom used by imager

c. $CTDI_{vol}$

3. Compare calculated SSDE to reference SSDE

4. Adjust scan parameters as necessary.

Managing Pediatric CT Patient Doses

M. Starting Reference Doses (SSDE) in an <u>adult</u> department might be:

1. 10 cm (Newborn) ~ adult SSDE
2. 11 cm (1 yr old) ~ adult SSDE
3. 14 cm (5 yr old) ~ adult SSDE
4. 17 cm (15 yr old) ~ adult SSDE
5. 23 cm (Adult) ~ adult SSDE

Managing Pediatric CT Patient Doses

N. Reduce the radiation output of scanner if calculated SSDE > reference SSDE

1. Use original high Voltage
2. Reduce the mAs:

mAs * reference SSDE / calculated SSDE

3. Reasonable dose with less image quality which may not be acceptable.

Managing Pediatric CT Patient Doses

O. Should voltages < 120 kV be used for Children?

1. Reduced high voltage; same dose
   a. Set appropriate reduced mAs
   b. Note displayed $CTDI_{vol\ 120}$
   c. Reduce kV to desired value
   d. mAs up until $CTDI_{vol\ kVr} = CTDI_{vol\ 120}$
   e. Increased Contrast at ~ same dose

Managing Pediatric CT Patient Doses

2. Reduced high voltage; reduced dose
   a. Dial up reduced mAs technique
   b. Note displayed $CTDI_{vol\ 120}$
   c. Measure increased contrast at kVr compared to 120 kV.
      i. ACR accreditation phantom or
      ii. CTDI phantom with Iodine Pin(s)
      iii. Clinical FoV / Bow tie Filter

Managing Pediatric CT Patient Doses

2. Reduced high voltage; reduced dose
   d. Estimate increase in noise by comparing $CTDI_{vol\ 120}$ & $CTDI_{vol\ kVr}$
   e. Contrast Up 40% / Noise Up 60%
   f. Increase mAs at kVr until Noise increases only 40%
   g. $CNR_{kVr} = CNR_{120\ kV}$
   h. Same Image Quality; Reduced Dose

Managing Pediatric CT Patient Doses

3. Additional Considerations
   a. How much can the high Voltage be lowered for
      i. Each diagnostic task?
      ii. Patient size?

Managing Pediatric CT Patient Doses

3. Additional Considerations
   b. How does this choice affect:
      i. Contrast
      ii. Noise
      iii. Artifacts
      iv. Scanning speed: Motion Unsharpness

Managing Pediatric CT Patient Doses

4. Contrast
   a. Improved
   b. Higher Noise levels
   c. Typically mAs must be increased

Managing Pediatric CT Patient Doses

5. Scanning Speed may suffer
   a. Radiation output of scanner is limited
   b. Pitch may need to be reduced
   c. Rotation time may need to be reduced
   d. b & c increase scan time and motion unsharpness

Managing Pediatric CT Patient Doses

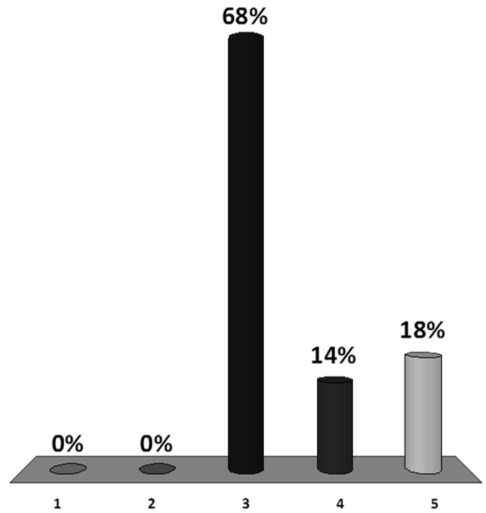
6. Artifacts increase with lower Voltage
   a. Beam hardening
   b. Streak artifacts
   c. Problematic for images with
      i. High contrast objects
      ii. Dense materials

Managing Pediatric CT Patient Doses

7. Pediatric Considerations
   a. Higher CNR needed for infants and small children.
      i. Less adipose tissue between organs and tissue interfaces
      ii. Thinner slices typically used
   b. Higher noise levels tolerated for adult images.

When reducing the high voltage of the CT scanner in an effort to improve image quality and reduce the radiation dose to pediatric patients one can ignore the effect on:

1. **Contrast.**
2. **Noise.**
3. **Sharpness**
4. **Artifacts**
5. **Scanning speed**

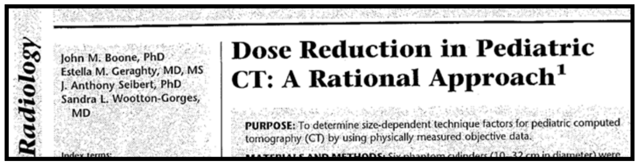


When reducing the high voltage of the CT scanner in an effort to improve image quality and reduce the radiation dose to pediatric patients, for each type of clinical examination one can ignore the effect on:

1. **Contrast.**
2. **Noise.**
3. **Sharpness.**
4. **Artifacts.**
5. **Scanning Speed**

Ref: Yu L, Bruesewitz MR, Thomas KB, Fletcher JG, Kofler JM, McCollough CH. Optimal tube potential for radiation dose reduction in pediatric CT: principles, clinical implementations, and pitfalls. Radiographics 2011 May-Jun;31(3):835-48, p 835.

CT Automatic Exposure Control: Pediatric Challenges and Solutions


Radiology

John M. Boone, PhD
Estella M. Geraghty, MD, MS
J. Anthony Seibert, PhD
Sandra L. Wootton-Gorges, MD

Dose Reduction in Pediatric CT: A Rational Approach[1]

PURPOSE: To determine size-dependent technique factors for pediatric computed tomography (CT) by using physically measured objective data.

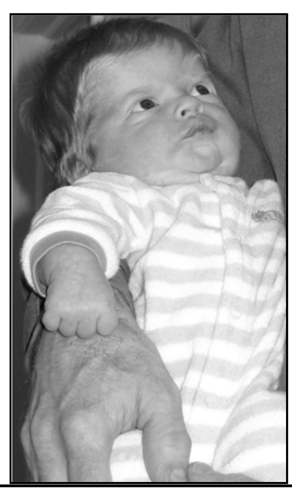
2003: Dose Reduction Principle

1. **Reduce radiographic techniques such that CNR remains constant as path length of x-rays changes!**
2. **Technique (mAs) reduction 35x from 28 – 12 cm effective diameter!**
3. **Why does it not work?**

CT Automatic Exposure Control: Pediatric Challenges and Solutions

Infants compared to adults

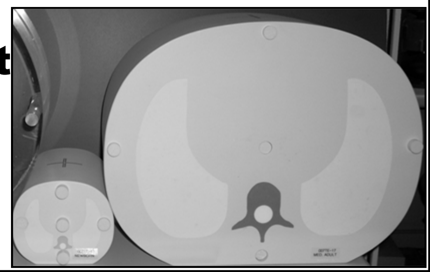
1. **Natural Subject Contrast significantly less in infants**
2. **Size of body parts:**
   Different: Req Resolution
   a. **Head: 1.4 : 1**
   b. **Abdomen: 2 : 1**
3. **Require more image quality**



CT Automatic Exposure Control: Pediatric Challenges and Solutions

Manufacturers control AEC differently

1. **Manufacturer A: Reference mAs**
   a. **80 mAs < specified age**
   b. **200 mAs > specified age**
   c. **Not logical but works!**
   d. **From newborn to adult**
      i. **CNR decreases ~ 3x**
      ii. **mAs increases ~ 3x**
      iii. **Images acceptable**



CT Automatic Exposure Control: Pediatric Challenges and Solutions

Manufacturers control AEC differently

2. **Manufacturer B: Noise Index: NI**
   a. **NI α Std Dev of noise**
   b. **Min & Max mA; Scan time**
   c. **Adopted Boone Model:**
      i. **Constant NI as a function of size!**
      ii. **Constant CNR if kV is unchanged**
   b. **Failure**
      i. **NI restrained by max & min mA**
      ii. **Imaging requirements not constant**

CT Automatic Exposure Control: Pediatric Challenges and Solutions

Manufacturers control AEC differently

2. Manufacturer B: Noise Index: NI

- **e. From newborn to adult**
  - **i. CNR decreases ~ 3x**
  - **ii. mAs increases ~ 3x**
  - **iii. NI increases ~ 3x**
  - **iv. Must select**
    - **Min & max mA to allow selected NI to be expressed!**

Example Clinical Case

Courtesy J Seibert, UC Davis

Pediatric patient scanned initially with a Siemens scanner in outpatient clinic

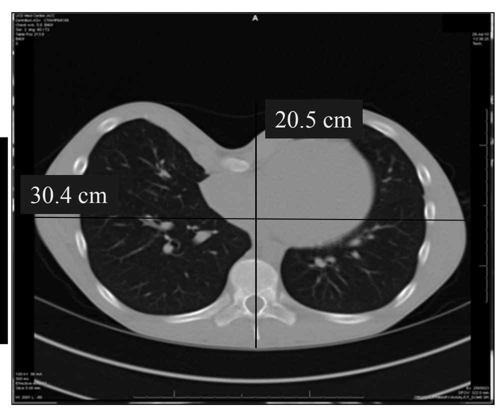
- **CareDose 4D used**
- **Dose report recorded**

29-Jul-2010 13:36

Ward: PEDCARD
Physician:
Operator:

Total mAs 1371 Total DLP 181 mGy*cm

	Scan	kV	mAs / ref.	CTDIvol mGy	DLP mGy*cm	TI s	cSL mm
Patient Position F-SP							
Topogram	1	120	20 mA			5.3	0.6
Chest w/o	2	100	120 / 120	4.78	181	0.5	0.6



Effective diameter = 25 cm
(20.5 cm x 30.4 cm)

Example Clinical Case

Courtesy J Seibert, UC Davis

Surgical intervention required placement of "Nuss Bars" to complete the treatment

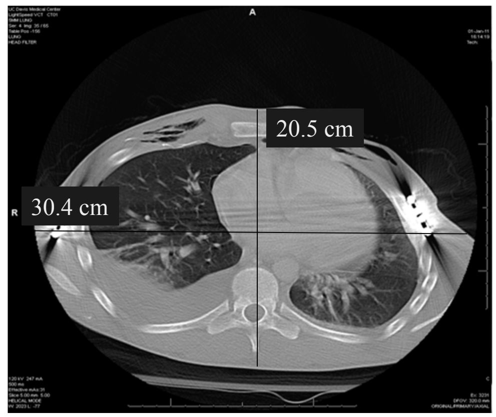
- **Smart mA used**
- **Dose report recorded**

Patient Name: Exam no: 3231
Accession Number: Jan 01 2011
Patient ID: LightSpeed VCT
Exam Description: CT CHEST WITH CONTRAST

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	S14.000-I266.000	17.73	536.72	Head 16
2	Helical	I271.000-I306.000	11.07	63.95	Head 16
		Total Exam DLP:		600.67	

1/1



Dose indicator Measurements

Courtesy J Seibert, UC Davis

	$\underline{\text{CTDI}_{vol}}$ (mGy)	DLP (mGy cm)
Siemens:	**4.8**	**181**
GE: (chest)	**17.7**	**537**
(abdomen)	**11.1**	**64**
(total)	**28.8**	**601**

First impression:

From CTDI_{vol}: 28.8 / 4.8 = 6X higher dose

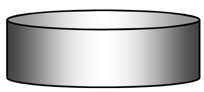
From DLP: 601 / 181 = 3.8X higher integral dose

WHY??

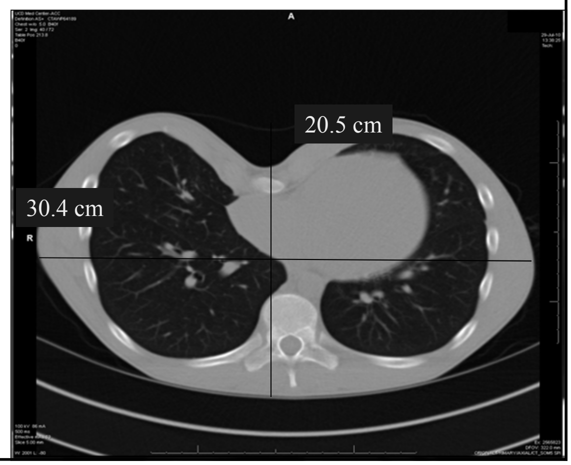
Example Clinical Case

Courtesy J Seibert, UC Davis

- **Pediatric patient scanned initially with a Siemens scanner in outpatient clinic**
  - **CareDose 4D used**
  - **$CTDI_{vol}$ = 4.78 mGy**
  - **Effective diameter = 25 cm**



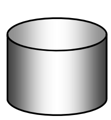
32 cm PMMA Dose Reference Phantom



Example Clinical Case

Courtesy J Seibert, UC Davis

- **Smart mA used**
- **Post-surgery, patient scanned in-patient GE scanner**
- **$CTDI_{vol}$ = 17.7 mGy**



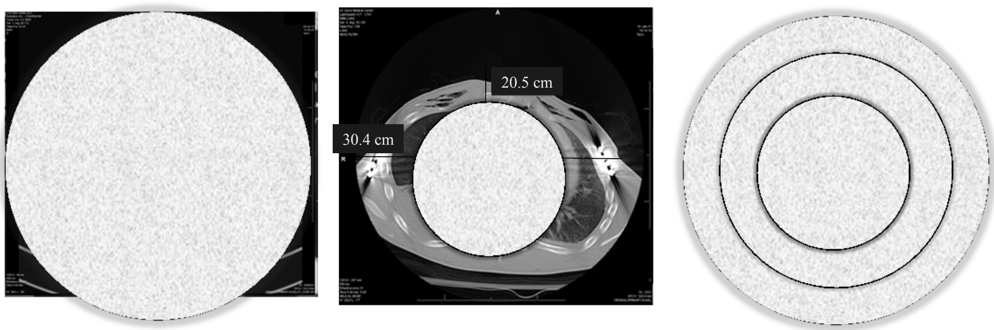
16 cm PMMA Dose Reference Phantom

Conversion for Size Discrepancy

Courtesy J Seibert, UC Davis

Differences in phantoms used for CTDI calibration:

- **Siemens – 32 cm will result in *underestimate***
- **GE – 16 cm, will result in *overestimate***



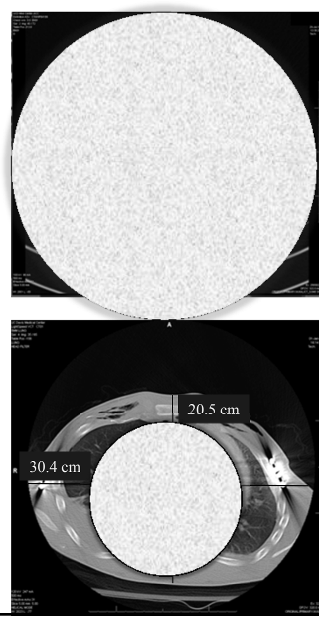
What is the conversion factor? …… AAPM TG 204

204 Size conversion factors for $CTDI_{vol}$

Courtesy J Seibert, UC Davis

Lat + AP Dim (cm)	Effective Dia (cm)	Correction Factor
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
31	15.2	2.12
32	15.7	2.08
33	16.2	2.05
34	16.7	2.01
35	17.2	1.97
36	17.6	1.94
37	18.1	1.90
38	18.6	1.87
39	19.1	1.83
40	19.6	1.80
41	20.1	1.77
42	20.6	1.74
43	21.1	1.71
44	21.6	1.67
45	22.1	1.64
46	[illegible]	1.62
47	[illegible]	1.59
48	[illegible]	1.56
49	[illegible]	1.53
50	24.6	[illegible]
51	25.1	1.47
52	25.6	1.45
53	26.1	[illegible]

1.47



Lat + AP Dim (cm)	Effective Dia (cm)	Conversion Factor
12	5.7	1.50
13	6.2	1.47
14	6.7	1.44
15	7.2	1.42
16	7.7	1.39
17	8.2	1.36
18	8.7	1.34
19	9.2	1.31
20	9.7	1.29
21	10.2	1.26
22	10.7	1.24
23	11.2	1.22
24	11.7	1.19
25	12.2	1.17
26	12.7	1.15
27	13.2	1.13
28	13.7	1.10
29	14.2	1.08
30	14.7	1.06
31	15.2	1.04
32	15.7	1.02
33	16.2	1.00
34	16.7	0.98
35	17.2	0.97
36	17.6	0.95
37	18.1	0.93
38	18.6	0.91
39	19.1	0.89
40	19.6	0.88
41	20.1	0.86
42	20.6	0.84
43	21.1	0.83
44	21.6	0.81
45	[illegible]	0.80
46	[illegible]	0.78
47	[illegible]	0.77
48	[illegible]	0.75
49	24.1	0.74
50	24.6	0.72
51	25.1	0.71
52	25.6	0.70
53	26.1	0.68
54	26.6	0.67
55	27.1	0.66
56	27.6	0.64
57	28.1	0.63
58	28.6	0.62
59	29.1	0.61
60	29.6	0.60
61	30.0	0.59

0.71

Uncorrected Data From Scanners

Courtesy J Seibert, UC Davis

17.7 mGy / 4.78 mGy ≈ 3.7× difference in *$CTDI_{vol}$*

<u>TG-204 SSDE Corrections:</u>

17.7 mGy (16 cm PMMA reference) × 0.71 ≈ 12.5 mGy

4.8 mGy (32 cm PMMA reference) × 1.47 ≈ 7.1 mGy

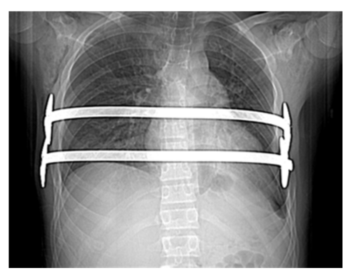
12.5 / 7.1 ≈ 1.7× difference in SSDE

<u>Even with correction, why was there a difference between scanners?</u>

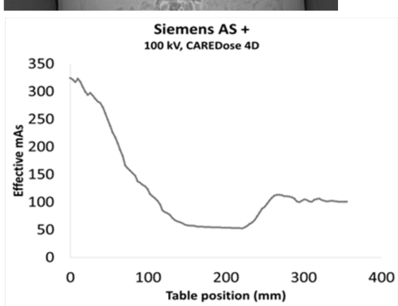
CT Digital Radiograph Localizer

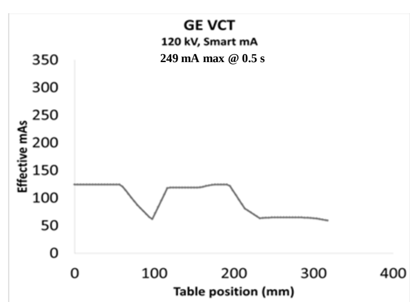
Courtesy J Seibert, UC Davis

Pre-surgery



Post-surgery





Example Clinical Case

Courtesy J Seibert, UC Davis

Comparison after SSDE conversion:

thorax: 12.5 / 7.1 = 1.7X higher dose

(with Nuss bar attenuators)

abdomen: 7.9 / 7.1 = 1.1X higher dose

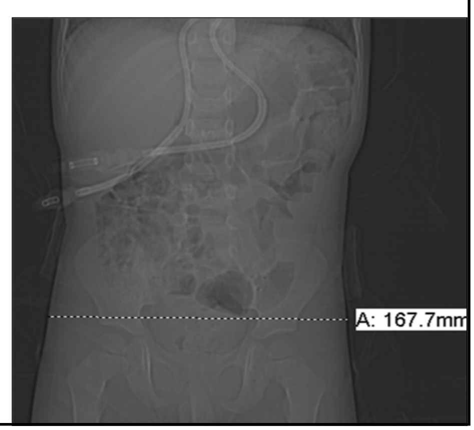
(without attenuators)

Should dose modulation be used in situations with highly attenuating materials? Maybe yes, maybe no!

Clinical Applications of SSDE

D. SSDE

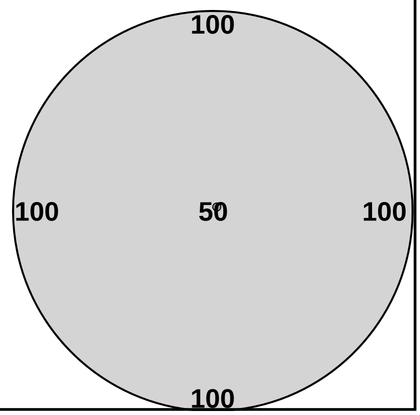
1. **Is useful as a first approximation of some organ doses**
    - a. **Soft tissues only**
    - b. **Organ completely in scan volume in z direction.**



Clinical Applications of SSDE

D. SSDE

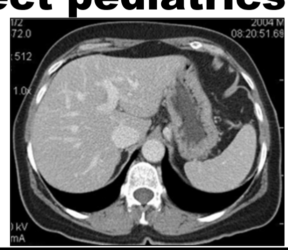
1. **Useful first approximation of some organ doses**
   - c. **Radial dose profiles**
   - d. **Range dependent on patient diameter**
     - i. **Pediatric vs Adult?**
   - e. **Single estimated $CTDI_{vol}$ (83)**



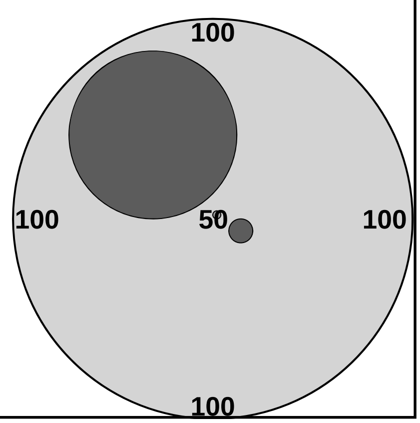
Clinical Applications of SSDE

D. SSDE

1. **Useful first approximation: organ dose**
   - f. **Increased error for small organs depending on location.**
     Less effect pediatrics



Adapted from McCollough



Conclusions

A. Due to variations in:
   1. Patient size,
   2. Type of CT examinations, and
   3. Design of actual CT scanners,

   Patient's CT dose should be appropriately
   1. Estimated,
   2. Managed during the examination, and
   3. Recorded,

   regardless of patient size!
   SSDE can help with all three tasks!

Conclusions

B. Adult hospitals performing 80% of all pediatric CT Examinations ***should*** manage their pediatric radiation doses.
   1. Use adult protocols and calculate adult SSDE.
   2. SSDE of pediatric patient prior to scan $\leq$ Established reference SSDE by Dept.

Conclusions

B. Adult hospitals performing 80% of all pediatric CT Examinations *should* manage their pediatric radiation doses.

3. Manage patient dose and image quality

a. Reducing mAs alone reduces:

i. Patient dose

ii. Image quality

b. Reducing kV and increasing mAs

i. Properly manages patient dose

ii. Improves image quality

Conclusions

3. Manage patient dose and image quality

c. Minor to moderate reductions in patient dose with minor loss of image quality (mAs reduction only)

IS PREFERRED OVER

d. Doing nothing because reduced voltage and increased mAs, is too TIME CONSUMING & IMPRACTICAL