Managing Pediatric CT Patient Doses

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Acknowledgements

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G. Donald Frey, PhD

INTRODUCTION

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

MISSION STATEMENT

Alliance for Radiation Safety in Pediatric Imaging is a coalition of health care organizations dedicated to providing safe, high quality pediatric imaging **worldwide**.

The **primary objective** is to raise awareness in the imaging community of the need to adjust radiation dose when imaging children.

Adapted from Goske

Image Gently

A. The **ultimate goal** of the Alliance is to accelerate the change of local practice.
   1. Problem?
   2. Scientific observation to local practice change ~ **17 years!**[1]

[1]Greenberg SB. Trans Clin Climatol Assoc 119:2450261, 2008

Adapted from Goske

Does Practice Need to Change?
How much do we really understand?

TABLE 3
Dose Estimates for One CT Scan versus One Chest Radiograph

Respondent Group	CT ≤ CR	CT > CR < 10 × CR	CT ≥ 10 × CR < 100 × CR	CT = 100–250 × CR*	CT ≥ 500 × CR
Patients (n = 67)	19 (28)	43 (64)	5 (7)	0 (0)	0 (0)
ED Physicians (n = 45)	3 (7)	20 (44)	10 (22)	10 (22)	2 (4)
Radiologists (n = 39)	2 (5)	22 (56)	6 (15)	5 (13)	4 (10)

Note.—Data are the number of respondents. Numbers in parentheses are percentages. χ^2 test result, 67.04; $P < .001$. CR = chest radiograph.
* Accurate range.

Under estimation by 75% of MDs!

Lee et al. Radiology. 2004; 231:393-398

Does Practice Need to Change?
How much do we really understand?

Which of the following provides a reasonable estimate of a child's CT dose?

A. $CTDI_{vol}$ (mGy)
B. DLP (mGy-cm)
C. Effective Dose (mSv)
D. Values in DICOM Structured Report

E. None of the above!

Does Practice Need to Change?
How much do we really understand?

Which of the following provides a reasonable estimate of a child's CT dose?

A. $CTDI_{vol}$ (mGy)
B. DLP (mGy-cm)
C. Effective Dose (mSv)
D. Values in DICOM Structured Report

E. All of the above!

Founding Organizations

The Society for Pediatric Radiology

American Society of Radiologic Technologists

American Association of Physicists in Medicine

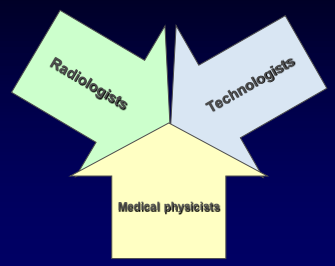
American College of Radiology

Alliance
For Radiation Safety
In Pediatric Imaging

Adapted from Goske

Critical Triad

To act together for radiation protection for children



Adapted from Goske

What is *Image Gently*

An education, awareness and advocacy campaign
To improve radiation protection for children
worldwide

Alliance for Radiation Safety in Pediatric Imaging

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

Adapted from Goske

Objectives

Decrease radiation dose in children

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

Use internal communication of each member organization

Campaigns in

- **CT**
- **CR / DR**
- **Interventional Radiology**
- **Flouroscopy**
- **Nuclear medicine**

Adapted from Goske

Adapted from Goske

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**
   b. **< 75 mGy Head**
2. **Pediatric Patient Dose ≤ Adult Dose**
3. **Conservatively high**
4. **Developed for adult department that images children occasionally**

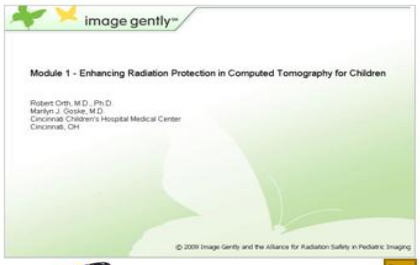
Image Gently Vendor Summit
August 20, 2008

$CTDI_{vol}$ is not an indication of patient dose

Pediatric Radiologists and Technologists have been asking for a reasonable estimate of CT radiation dose in children for over 10 years.

You need to provide better training on pediatric applications of your images!

8 FREE online modules for CT technologists



Toshiba, GE Healthcare, Philips, Siemens

Adapted from Gosk

TRAINING

Training is only as effective as the trainer's <u>understanding</u> of their trainees

Each trainee may have a bit different

- **Perspective!**
- **Pediatric needs are Different**

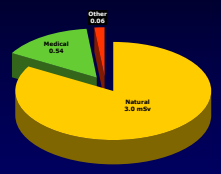
YOUR HOUSE as seen by...
Yourself

Your Appraiser

Your Tax Assessor

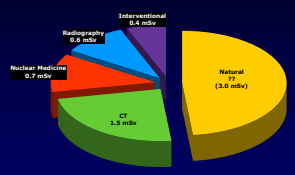
Preliminary estimate of changes in Medical radiation exposure to US population

US 1980*



Medical 0.54 mSv per capita
Total 3.6 mSv per capita

US 2006

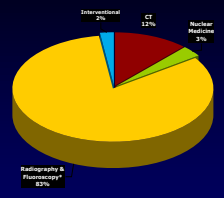


Medical 3.2 mSv per capita
Total 6.2 mSv per capita

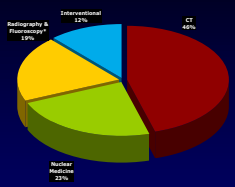
* NCRP 93

Adapted from Mahesh

Procedures vs Effective dose contributions



Percent Procedures



Effective Dose Contributions

17% of All Exams Deliver 81% of Total Effective dose

91% of Pediatric Dose in the ED comes from CT

Adapted from Mahesh

GROWTH OF MEDICALRADIATION DOSE

C. General Radiography

1. 85% of dose from exams of Abdomen Pelvis/Hips, or Spine
2. 280,000 person Sv
3. ~ 0.62 mSv

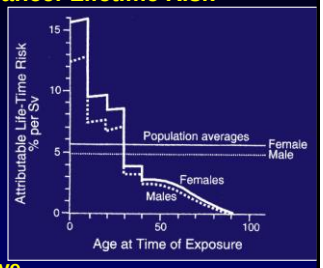
	Number millions	%	Collective Person Sv	%
Pelvis/Hips	20	5	45,700	24.8
Upper GI	4	1	38,000	20.7
Spine	17	4	57,000	31.0
Abdomen	15	4	16,000	8.7
Head Face	2.4	0.6	2,300	1.2
Chest	126	31	6,500	3.5
IVP	1.2	0.3	3,700	2.0
Barium enema	0.65	0.2	8,500	4.6
Extremities	56	14	1,900	1.0
Mammography	34	9	2,200	1.2
Dental	125	31	2,300	1.2
Total	~401		~184,000	

Adapted from Mahesh

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

PEDIATRIC CONSIDERATIONS

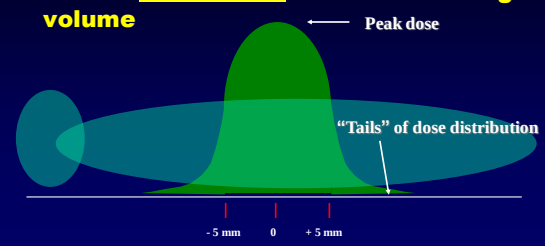
Radiation Risk based on Effective Dose?

A. Almen and S. Mattsson, J. Radiol. Prot. 16 (2), 81-89 (1996).

	Somatic risk %/Sv	Hereditary risk %/Sv	Total risk %/Sv
Children Aged 0-9	14.5	2.5	17
Children Aged 10-19	8.5	2.5	11
Whole population	5	1	6

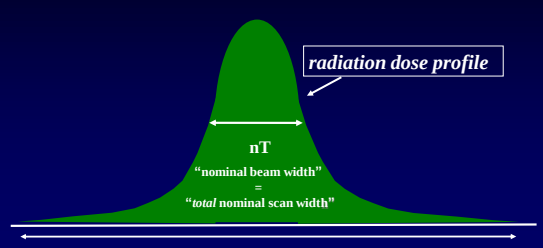
Real World ....

Radiation distribution *crosses* the imaged volume



Adapted from Frey

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

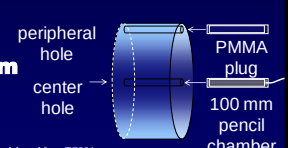


Adapted from Frey

CT SCANNER DOSE INDICES

B. Measurement of CT Radiation Dose

1. Plastic cylindrical phantoms: CTDI Phantoms
   a. (PMMA)
   b. 16 & 32 cm diameter
2. Pencil chamber moved into provided holes to measure radiation dose
   a. 1 cm under surface
   b. Center of phantom
   c. Non measured holes plugged



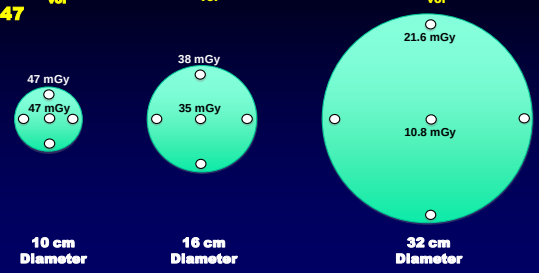
Adapted from TG204

$CTDI_{vol}$ = [2 * surface dose / 3 + central dose / 3] / Pitch

CT SCANNER DOSE INDICES

C. Measure $CTDI_{vol}$

1. Measure $CTDI_{vol}$ with **identical** scan parameters
   a. kVp
   b. mA
   c. Rotation time
   d. **Bow Tie Filter**
2. Use phantom 10, 16, and 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. High voltage to x-ray tube (kVp)
   b. X-ray tube current (mA)
   c. Rotation time (sec)
   d. Bow tie filter shape, thickness, material
   e. Pitch
   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.
4. Dose index of CT scanners if the fan beam width in z direction of the patient is small (< 1 cm)
   a. AAPM TG111 addresses these shortcomings
   b. Beyond scope of this presentation.

CT SCANNER DOSE INDICES

D. Displayed $CTDI_{vol}$

5. does not represent . . .

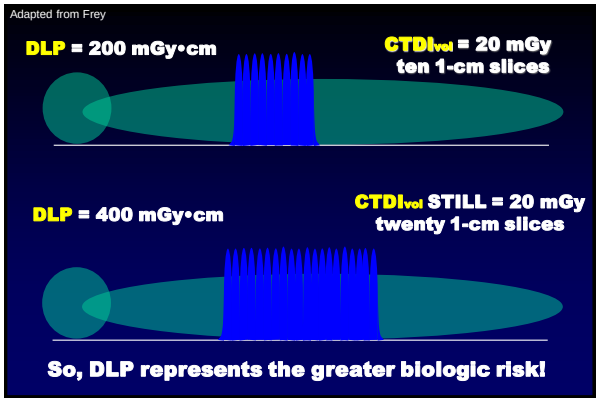
Patient dose!!

CT SCANNER DOSE INDICES

E. Displayed Dose Length Product (DLP)

1. DLP (mGycm) = $CTDI_{vol}$ * Scan Length
   a. Scan length is the length of phantom irradiated.
   b. 'Represents' energy transferred.
2. DLP is not a patient dose index because $CTDI_{vol}$ does not represent patient dose.

Adapted from Frey



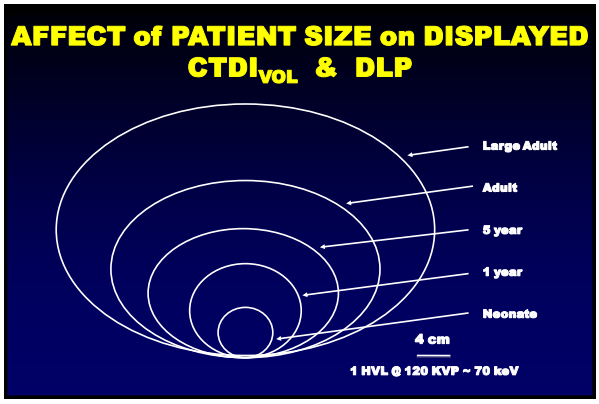
So, DLP represents the greater biologic risk!

CT SCANNER DOSE INDICES

E. Displayed Dose Length Product (DLP)

1. Previous example: radiation doses equal.
2. Second patient at greater risk because a larger length of body was scanned.
3. While DLP is the dose to a standard phantom, increases in DLP indicate increases in risk to patient.

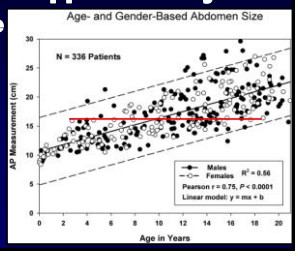
AFFECT of PATIENT SIZE on DISPLAYED $CTDI_{VOL}$ & DLP



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

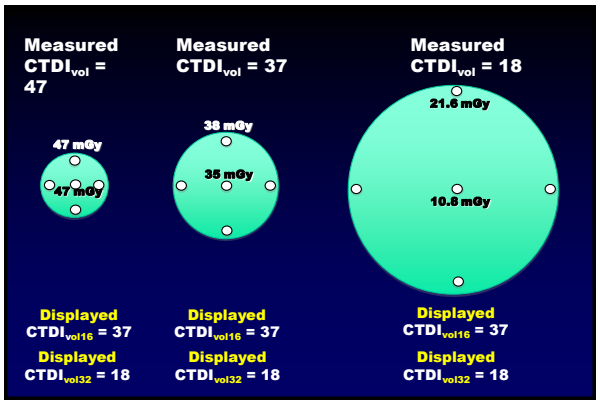
A. Patients of a given age vary dramatically in size. Abdomens of the largest 3 year olds are approximately the same size as the abdomens of the smallest adults.

Size of patient, not age should be used.



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

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



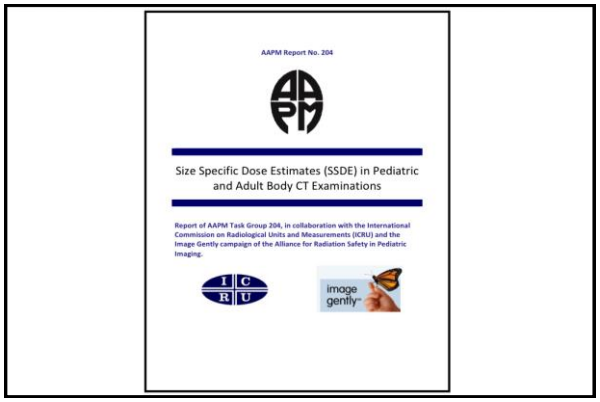
CLINICAL DILEMMA

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.


AAPM Report No. 204

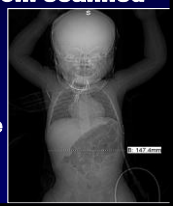
Size Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations

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:

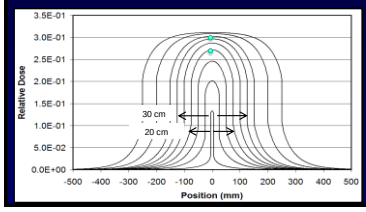
1. **Address correction factors for heads**
2. **Correct small (< 1%) doses from scanned projection images**
3. **Correct for variation (~ 5%) in attenuation of thorax vs abdomen**
4. **Correct small variation in pre and post contrast scans**



TG 204

E. Report does not address:

5. **Changes in dose as a function of fan beam**
   a. **20 cm: relative dose ~ 2.7**
   b. **30 cm: relative dose ~ 3**
   c. **Dose increases ~ 10%**
   d. **Dose Profiles vs Fan Beam Width**



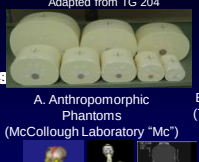
Adapted from J. Boone

TG 204

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

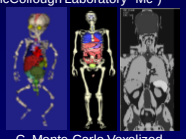
Adapted from TG 204

1. **Physical measurements on phantoms**
2. **Monte Carlo computer modeling**



A. Anthropomorphic Phantoms (McCollough Laboratory "Mc")

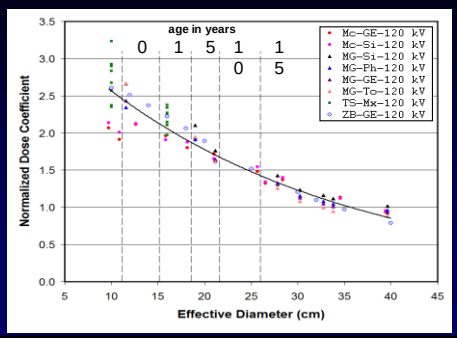
B. Cylindrical PMMA phantoms (Toth / Strauss Collaboration "T-S")



C. Monte Carlo Voxelized Phantoms

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

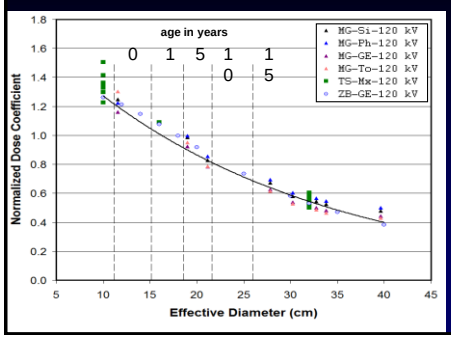
TG 204



32 cm 120 kVp

Adapted from TG 20

TG 204

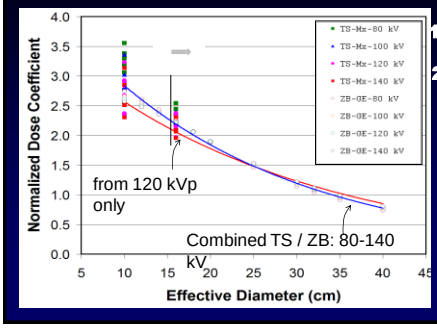


16 cm 120 kVp

Adapted from TG 204

TG 204

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



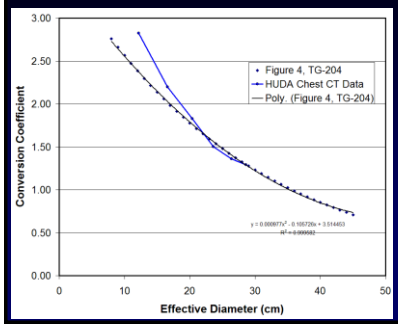
1. **5% difference overall**
2. **3% difference between 1 yr old (15 cm) & adult (32 cm)**

$y = 4.37809e^{-0.04331x}$
$R^2 = 0.97327$

Adapted from TG 204

TG 204

H. What about scans performed in the thorax?



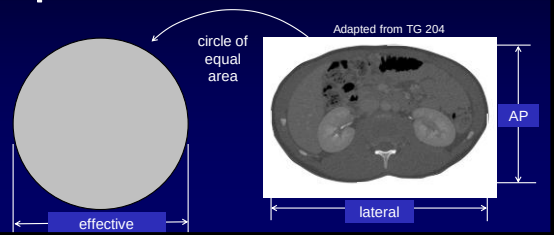
1. **Thorax data from Huda et al.**
2. **16% dif @ 12 cm**
3. **7% dif @ 17 cm**
4. **< 3% dif > 17 cm**

Adapted from Boone

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.

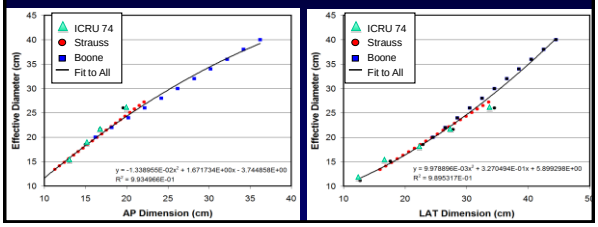


Adapted from TG 204

TG 204

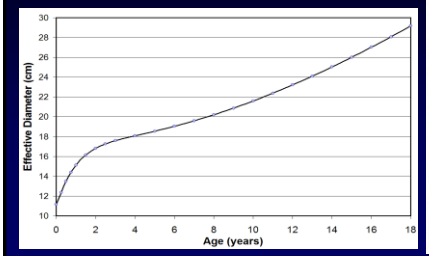
J. Fitted equations calculate the effective diameter from either AP or LAT dimension of patient based on published data of actual patient sizes.

Adapted from TG 204



K. What if I am doing retrospective dose analysis and I only know age of patient?

1. Corrections based on patient size are more accurate.



Age (years)	Effective Diameter (cm)
0.00	11.2
0.25	12.3
0.50	13.5
0.75	14.4
1.00	15.1
1.50	16.1
2.00	16.8
2.50	17.3
3	17.6
4	18.1
5	18.5
6	19.0
7	19.6
8	20.2
9	20.9
10	21.6
11	22.4
12	23.2
13	24.1
14	25.0
15	26.0
16	27.0
17	28.1
18	29.2

Adapted from TG 204

Effective Diameter as a function of age per ICRU 74

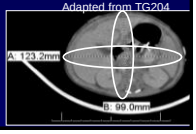
TG 204

L. Determining patient size

AP or PA Projection Scan
Adapted from TG204

1. Measure Lateral dimension with mechanical calipers.
2. Measure **Lateral** or AP dimension from **AP** or Lateral projection scan.
3. Measure AP or LAT dimension from axial scan view.
4. In #2 & #3 patient must be centered in gantry.
   a. **Magnification Error**

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
6	9.2	2.60
8	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	1.75
26	21.1	1.73
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	1.15
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
6	8.0	2.65
8	10.2	2.55
10	11.6	2.42
11	13.0	2.30
12	14.4	2.19
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
6	2.70
8	2.66
10	2.57
11	2.47
12	2.36
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

P.

Correction Factor based on 16 cm CTDI Phantom

Lat + AP Dim (cm)	Effective Dia (cm)	Correction Factor
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

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
15	13.1	1.13
16	13.7	1.10
17	14.3	1.08
18	15.0	1.05
19	15.7	1.02
20	16.4	0.99
21	17.2	0.96
22	17.9	0.94
23	18.7	0.91
24	19.5	0.88
25	20.3	0.85
26	21.1	0.83
27	22.0	0.80
28	22.9	0.77
29	23.8	0.75
30	24.7	0.72
31	25.6	0.70
32	26.6	0.67

AP Dim (cm)	Effective Dia (cm)	Correction Factor
8	8.8	1.33
9	10.2	1.26
10	11.6	1.19
11	13.0	1.13
12	14.4	1.07
13	15.7	1.02
14	17.0	0.97
15	18.3	0.92
16	19.6	0.88
17	20.8	0.84
18	22.0	0.80
19	23.2	0.76
20	24.3	0.73
21	25.5	0.70
22	26.6	0.67
23	27.6	0.64
24	28.7	0.62
25	29.7	0.59
26	30.7	0.57
27	31.6	0.55
28	32.6	0.53
29	33.5	0.51
30	34.4	0.50
31	35.2	0.48
32	36.0	0.46

Effective Dia (cm)	Correction Factor
8	1.38
9	1.32
10	1.27
11	1.22
12	1.18
13	1.13
14	1.09
15	1.05
16	1.01
17	0.97
18	0.93
19	0.90
20	0.86
21	0.83
22	0.80
23	0.77
24	0.74
25	0.71
26	0.69
27	0.66
28	0.63
29	0.61
30	0.59
31	0.56
32	0.54

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 **≥ 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

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

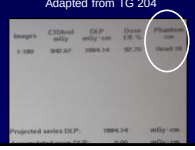
SAMPLE CALCULATION: PRESCAN

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



Adapted from TG 204

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
15	13.1	1.13
16	13.7	1.10
17	14.3	1.08
18	15.0	1.05
19	15.7	1.02
20	16.4	0.99
21	17.2	0.96
22	17.9	0.94
23	18.7	0.91
24	19.5	0.88
25	20.3	0.85
26	21.1	0.83
27	22.0	0.80
28	22.9	0.77
29	23.8	0.75
30	24.7	0.72
31	25.8	0.70
32	26.6	0.67

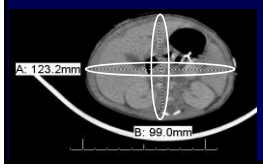
SAMPLE CALCULATION: POST SCAN

A. Determine size of patient
   1. AP = 9.9 cm; LAT = 12.3 cm
   2. AP + LAT = 22.2 cm

B. 32 cm CTDI phantom assumed

C. Displayed $CTDI_{vol}$ = 5.4 mGy

D. 5.4 mGy x 2.5 = 13 mGy SSDE



Adapted from TG 204

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

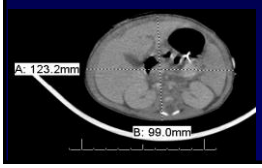
SAMPLE CALCULATION: POST SCAN

A. Determine size of patient
   1. AP = 9.9 cm; LAT = 12.3 cm
   2. AP + LAT = 22.2 cm

B. 16 cm CTDI phantom assumed

C. Displayed $CTDI_{vol}$ = 10.8 mGy

D. 10.8 mGy x 1.24 = 13 mGy SSDE



Adapted from TG 204

Lat + AP Dim (cm)	Effective Dia (cm)	Correction Factor
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

CLINICAL CHALLENGE

A. Child imaged on GE CT on Tuesday followed by second examination on Wednesday on Siemens CT in same department.

1. GE: Displayed $CTDI_{vol(16)}$ = 10.8 mGy
2. Siemens: Displayed $CTDI_{vol(32)}$ = 5.4 mGy

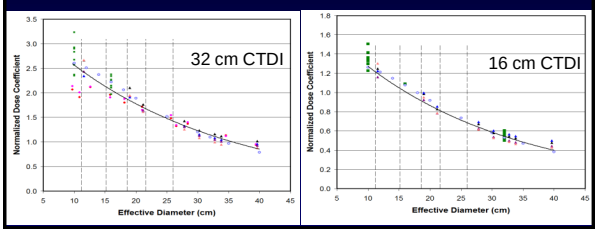
B. Mom & Dad were not happy campers!

C. SSDE = 13 mGy for both studies!

CLINICAL CHALLENGE

D. Correction Factors for Heads

1. Will be published in the future
2. Correction factor not as large



Applications of SSDE

A. Understand difference between SSDE and $CTDI_{vol}$

1. SSDE may be useful as a first approximation of average organ dose to organs completely contained in scan volume.
2. SSDE can NOT be substituted in place of $CTDI_{vol}$ when using k-factors to estimate Effective Doses from CT exam

Applications of SSDE

B. Start calculating SSDEs

1. More accurate estimates of patient dose than $CTDI_{vol}$
2. Recorded values of SSDE in patient medical record have more applications than $CTDI_{vol}$.
3. DRLs could be based on SSDE values
4. Recorded SSDE values will lead to department dose standards.

Applications of SSDE

B. Start calculating SSDEs

5. SSDE values can be used as a tool to manage patient doses from CT.
6. Work ongoing to get CT manufacturers to calculate and display SSDE values.

Managing Pediatric CT Patient Doses

A. $CTDI_{vol}$ Measurements

1. 32 cm adult body measurement
2. 16 cm adult head measurement

B. Compare/adjust wrt ACR Reference Values

Establish reasonable adult doses

Are they high, moderate, or low?

1. < 25 mGy
2. < 75 mGy

Managing Pediatric CT Patient Doses

C. Establish Appropriate Pediatric Dose Levels by reducing mAs appropriately

1. Reduce mAs until pediatric SSDE ≤ adult SSDE for department.
   a. 10 cm AP
   b. 1 / 2.5 = 40% original mAs

Managing Pediatric CT Patient Doses

C. Establish Appropriate Pediatric Dose Levels by reducing mAs appropriately

1. Reduce mAs until pediatric SSDE ≤ adult SSDE for department.
2. IG website model of mAs reduction
   a. 10 cm AP dimension
   b. ~ 45% original mAs

PEDIATRIC CONSIDERATIONS CLINICAL EDUCATIONAL MATERIALS

Abdomen Baseline:	kVp	mA	Time (sec)	Pitch Abdomen	Pitch Thorax
	120	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 Baseline:	kVp	mA	Time (sec)	Pitch Abdomen	Pitch Thorax
	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

Managing Pediatric CT Patient Doses

D. Dose reduction of IG website results in <u>conservatively high</u> doses

E. Doses in a <u>pediatric</u> department might be:

1. 10 cm (Newborn) ~ 0.6 x adult SSDE
2. 11 cm (1 yr old) ~ 0.7 x adult SSDE
3. 14 cm (5 yr old) ~ 0.8 x adult SSDE
4. 17 cm (15 yr old) ~ 0.9 x adult SSDE
5. 23 cm (Adult) adult SSDE

Managing Pediatric CT Patient Doses

F. Should voltages < 120 kVp be used for Children?

1. **Reduced high voltage at same dose**
   a. Dial up reduced mAs technique
   b. Note displayed $CTDI_{vol\ 120}$
   c. Reduce kVp
   d. mAs up until $CTDI_{vol\ 80} = CTDI_{vol\ 120}$
   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 80 kVp compared to 120 kVp.
      i. ACR accreditation phantom
      ii. Clinical FoV / Bow tie Filter

Managing Pediatric CT Patient Doses

2. **Reduced high voltage; reduced dose**
   d. Estimate increase in noise by comparing $CTDI_{vol\ 120}$ & $CTDI_{vol\ 80}$
   e. Contrast Up 40% / Noise Up 60%
   f. Increase mAs at 80 kVp until $CNR_{80\ kVp} = CNR_{120\ kVp}$
   g. Same Image Quality; Reduced Dose

Conclusions

A. **Adult hospitals performing 80%** of all pediatric patients ***should*** manage pediatric radiation doses.
   1. Use adult protocols and calculate adult SSDE.
   2. **SSDE of pediatric patients prior to scan ≤ SSDE for adult patient.**
   3. Changing kVp in addition to mAs is more involved, but allows both image quality improvement and/or dose reduction.