CT Dose Indices

Keith Strauss, MSc, FAAPM, FACR
Cincinnati Children’s Hospital
University of Cincinnati College of Medicine
CT Dose Indices

- Past
  - CTDI
  - DLP
- Short term Future
  - Size Specific Dose Estimate (SSDE)
- Long term Future
  - Organ Doses
CTDI = Integral under the *radiation dose profile* along the z-axis from a *single axial scan* of width nT.

Adapted from Frey
Measurement of CT Radiation Dose

- Plastic cylindrical phantoms: CTDI Phantoms
  - (PMMA)
  - 16 & 32 cm diameter

- Pencil chamber moved into provided holes to measure radiation dose
  - Center of phantom

- Non measured holes plugged

Adapted from TG204
CT SCANNER DOSE INDICES

Measurement of CT Radiation Dose

32 and 16 cm CTDI standard phantoms positioned to measure CT doses.

Images Courtesy of John Boone
CT SCANNER DOSE INDICES

Measured $\text{CTDI}_{\text{vol}}$

- Measure $\text{CTDI}_{\text{vol}}$ with **identical** scan parameters
  - kVp
  - mA
  - Rotation time
  - Bow Tie Filter

- Use phantom 10, 16, and 32 cm diameter
Measured $\text{CTDI}_\text{vol} = 47$

10 cm Diameter

$47 \text{ mGy}$

38 mGy

16 cm Diameter

35 mGy

32 cm Diameter

21.6 mGy

10.8 mGy

Measured $\text{CTDI}_\text{vol}$ increases 2.6 times as phantom size decreases!
Measured $\text{CTDI}_{\text{vol}} = 47$

Displayed $\text{CTDI}_{\text{vol16}} = 37$
Displayed $\text{CTDI}_{\text{vol32}} = 18$

Measured $\text{CTDI}_{\text{vol}} = 37$

Displayed $\text{CTDI}_{\text{vol16}} = 37$
Displayed $\text{CTDI}_{\text{vol32}} = 18$

Measured $\text{CTDI}_{\text{vol}} = 18$

Displayed $\text{CTDI}_{\text{vol16}} = 37$
Displayed $\text{CTDI}_{\text{vol32}} = 18$
CT SCANNER DOSE INDICES

Displayed $\text{CTDI}_{\text{vol}}$

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

does not represent . . .

Patient dose!!
DISPLAYED CTDI SHORTCOMING

Same radiographic technique

Displayed $\text{CTDI}_{\text{vol}}$ based on 32 cm CTDI Phantom

18 mGy for both patients!
CLINICAL DILEMMA

• CTDI Phantoms are not clinical models
CLINICAL DILEMMA

- Anthropomorphic Phantoms only approximate the human body
CT SCANNER DOSE INDICES

Displayed Dose Length Product (DLP)

DLP (mGycm) = $\text{CTDI}_{\text{vol}} \times \text{Scan Length}$

Scan length is the length of phantom irradiated.
‘Represents’ energy transferred.

DLP is not a patient dose index because $\text{CTDI}_{\text{vol}}$ does not represent patient dose.

‘SSDELP’ = SSDE $\times$ Scan Length

Better estimate of energy transferred.
DLP = 200 mGy•cm

CTDI_{vol} = 20 mGy
ten 1-cm slices

DLP = 400 mGy•cm

CTDI_{vol} STILL = 20 mGy
twenty 1-cm slices

So, DLP represents the greater biologic risk!

Adapted from Frey
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.
Clinical Applications of SSDE

So what is SSDE?:

- Estimates the peak soft tissue dose of the patient at the center of the scan length.
- Adjusts for patient size and varying attenuation from overlying tissue thickness.
- Uses **average** scan radiation output: $\text{CTDI}_{\text{vol}}$
- Useful first approximation of organ dose?

Adapted from McCollough
Patient trunk dose > CTDI_{vol} by 2.5 x for smallest patients

\[
y = 3.7044e^{-0.0367x}
\]

\[R^2 = 0.9429\]
TG 204

16 cm 120 kVp
Adapted from TG 204

Patient head dose ≥ CTDI_{vol} for smallest patients by only 20%

\[ y = 1.8748e^{-0.0387x} \]
\[ R^2 = 0.9673 \]
AGE vs PATENT SIZE

Same age patients vary dramatically in size.

• Abdomens of:
  • Largest 3 year olds and
  • Smallest adults are
    the same size.

• Patient cross section size, not age, should be used.
Determining patient size

- Measure Lateral dimension with mechanical calipers.
- Measure Lateral or AP dimension from AP or Lateral projection scan.
  - Magnification Error
- Measure AP or LAT dimension from axial scan view.

Leng S, et.al. SSDE for chest, abdomen, & pelvic CT: Effect of intrapatient Variability in water equivalent diameter. Radiology 2/15:142160
TG 204

Determining size of CTDI phantom your CT scanner used to estimate $\text{CTDI}_{\text{vol}}$

- Failure to identify correct phantom, 16 or 32 cm leads to a systematic error of up to 100%.
- No standard exists. Choice may depend on:
  - Selected protocol: adult or pediatric
  - Selected scan field of view
  - Year of manufacture
  - Software level
- Make no assumptions: contact manufacturer of your unit through their service organization.
SSDE Accuracy

• 20%
• Product is an estimate of patient dose
• Report doses with proper number of significant digits
  • SSDE $\geq 5$ mGy: integers only, e.g. 7 or 23 mGy
  • SSDE $< 5$ mGy: one decimal point, e.g. 2.7 or 4.5 mGy
SAMPLE CALCULATION: POST SCAN

- Determine size of patient
  - AP = 9.9 cm; LAT = 12.3 cm
  - AP + LAT = 22.2 cm
- 32 cm CTDI phantom assumed
- Displayed CTDI$_{vol}$ = 5.4 mGy
- 5.4 mGy x 2.5 = 13 mGy SSDE

Adapted from TG 204
SAMPLE CALCULATION: POST SCAN

E. Where measure $D_w$ along $z$ axis

1. Every slice: $CTDI_{vol} \; \& \; D_w$
   vs
2. Average $CTDI_{vol} \; \& \; \text{central } D_w$
3. Error was 9% or 1.4 mGy

Leng S. et al. SSDE for chest, abdominal, and pelvic CT: Effect of inpatient variability in water-equivalent diameter. Radiology 2/25/15, 142160
CT Dose Indices

- **Past:** CTDI DLP are not patient doses

- **Short term Future**
  - SSDE will be displayed on all new CT scanners in < 5 years

- **Long term Future**
  - Organ Doses will be more available