CT Dose Reporting Requirements of CA Senate Bill 1237

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CT Dose to Patients
• In U.S., CT comprises only 11% of all exams but generates 67% of total diagnostic dose
  » Mettler 2000

Sources of Ionizing Radiation Exposure (then)
• U.S. average: about 360 mrem (3.6 mSv) /year
• 15% or about 60 mrem (0.6 mSv) from medical

Population Radiation Exposure (NOW) NCRP - 2008
6.2 mSv (620 mrem)
ED per US citizen
50% background still around 300 …
… But now 48% or 300 mrem (3 mSv) from medical and half of that from CT alone!
Increased Utilization: 
*Technology, Speed, Reimbursement*

- Sub-second, helical rotation, multi-slice technology increases throughput
- Potentially improved diagnostic capabilities & higher billing rates
- Significant increase in pediatric applications brings additional concerns
  - ↑ radio-sensitivity
  - ↑ organ and effective doses, particularly when technical factors are not adjusted

**Federal Stance (2005)**

- X-rays officially inducted to FDA list of carcinogens
- Sanction of the no-threshold model
- No safe dose of radiation
- Any increase in dose increases risk
Background: CT/Radiation News

- Literature & media: “high CT utilization increases cancer risk…”
  - Dose from CT same as Atomic Bomb survivor 1-2 miles from ground zero
  - In 2007 70 million CT scans → 29,000 cancers (Berrington, Arch Int Med 2009)
  - 600,000 annual CT scans on children under 15 → 500 cancer deaths (Brenner AJR)
    - Children more sensitive → Image Gently program
  - NY times 2010: Articles on radiation injuries from medical procedures prompts response from professional organizations

Physician Knowledge
(Radiology - May ’04)

- Patients not given information about dose, risk, and benefit from CT
- Only 47% of radiologists believe increased cancer risk from CT
- 9% of Emer. Dept. physicians & 3% patients believe increased risk
- Majority of radiologists/EDs unable to make a reasonable estimate of dose

Current Events

- CT “overdose” incidents & reaction (2009-2010)
  - Cedars: >200 patients overdosed over 18 months up to 10x “normal” dose → hair loss, skin burns, cataractogenesis?
  - Subsequent incidents/discoveries: Glendale Adventist, St. Josephs, Alabama
- Class action lawsuits against multiple hospitals and vendors
- Media attention & requests for CT experts/opinions

Facility Reactions

- Facility’s Reaction (day original story broke …)
  - Inquiries from Administrator’s office
  - Emergency meeting called by hospital administration
  - Requests through media relations office
  - … asking about doses, procedures, calibrations…
- Patient\referring physician reaction
  - Numerous prospective & retrospective dose requests
  - Inquiries about exam necessity, staff qualifications & training, equipment makes & models, calibrations, etc.
Professional Responses

- American College of Radiology and American Association of Physicists in Medicine:
  - Over reliance on automation
  - Review/consider dose reference levels
  - Importance of accreditation
  - Protocol review by lead radiologist, technologist, physicist
  - Enable dose reporting functions
  - CT specific training for all parties involved
  - Topic specific symposia already scheduled
  - Position statements in response to media stories on increase in medical radiation utilization, cancer risk, overdoses and accidents

Government Response

- Recommendations to Health Care Providers:
  - Investigate for potential injuries
  - Review protocols & implement QC procedures
  - Adjust for appropriate dose & be familiar with dose indices

- Recommendations to Public:
  - Consult with their physician
  - Track their individual dose (now an i-phone app.)

FDA initiative

(http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncement/ucm200085.htm)

Specific Government Response

- FDA Initiative to: “reduce unnecessary radiation from CT, fluoro, & nuc-med exams” 2/8/10
  - Safety including safeguards in scanner design, technology, and training
  - Processes for informed clinical decision making & appropriate use criteria
  - Increase patient awareness.
  - Display, record, & report equip. settings & rad. dose
  - Capture & transmit rad. dose to electronic med. record & dose registries
- NIH → now requires dose reporting mechanism for it’s imaging equipment
- Congressional investigation has been launched
  - Testimony from representatives of the AAPM and ACR
Specific Government Response

- Regulation – Senate Bill 1237 (California)
  - passed 8/30/2010, first in the country
  - Dose & incident requirements for CT
  - 2011: Repeats, or scan of unintended body part, that exceed specified dose limits (unless ordered by a physician) must be reported to CA DPH - Radiologic Health Branch
  - 2012: Record radiation dose on every CT study produced during a CT examination. Data must be sent to PACS & be included in Radiologist's Report. Displayed dose must be verified by a Medical Physicist
  - 2013: ALL CT facilities must be accredited

Who’s responsible?

- FDA – regulates equipment design
- States regulate use of equipment and the users.
  - Supervisor & Operator (Typically Radiologist or specifically permitted physician)
  - Radiologic Technologist (Can only operate under supervision of above)
- Technologist watching dose numbers?
- Physician in charge supervising?
- Vendor responsibilities?

So what are we specifically concerned with when we use ionizing radiation in healthcare?

- Cancer?
- Genetic damage/Birth defects?
- Acute injury like skin burns or hair loss? For diagnostic exams??

How did this become an issue?

- Regardless of what stochastic risks may exist (cancer risks) it was the deterministic effects that got everyone’s attention …
CT perfusion scans in California
(Cedars-Sinai, Glendale Adventist, Providence St. Joseph)

CT perfusion study in Alabama

Within weeks of Alabama teacher Becky Coudert's CT perfusion brain scan, a bald strip circled her head. She reportedly had received several times the correct dose of radiation. (December 7, 2009)

Classification of Effects

• Stochastic
  – Probabilistic
  – Chances increase with dose
  – Behavior of most rad. induced cancers, genetic effects
  – Independent of severity of effect
    • A cancer deriving from 100 rads is no more virulent than one deriving from a 1 rad exposure.
  – Thought to have No threshold
  – Implies any small amount of radiation has some associated risk
  – Basis of ALARA and radiation protection programs

• Deterministic
  – Associated with “high” doses involved with cell killing
  – Need to exceed threshold to see effect
  – Severity of effect increases (often rapidly) with dose
    • Cataracts
    • Embryological effects
    • Skin Burns
    • Reproduction
Skin effects are deterministic
- Radiation dose must exceed threshold to occur.
- Past threshold, severity increases with dose.
- Some minimum number of cells damaged to manifest response. If enough dose will have 100% occurrence.
- Dependent on dose & dose rate, some effects occur immediately (weeks) while others may manifest over years.
- Skin is the limiting organ for X-ray procedures as it receives highest dose.
- Radiodermatitis: inflammatory changes occurring after irradiation.

Acute Radiation Health Effects-- Skin Effects
- 2 Gy -- Transient redness, bad erythema at 6 Gy (hrs) — vasodilation, perhaps vasculature damage
- 3 Gy -- Some hair loss, permanent at 6-7 Gy (3 wks)
- 8-10 Gy -- Dry desquamation (heavy peeling) (3 wks) — damage to germinal layer
- 15 Gy -- Wet desquamation with fluid exudate (4 wk) — heavily damaged germinal layer, some stroma degeneration
- 18 Gy -- Necrosis and Ulceration (6 weeks and on)

How do we estimate dose?
- Exposure (to air) — (Roentgen or coulomb/kg)
- Dose to a substance (e.g. water or tissue) — rad (100 erg/gm) or Gy (Joule/kg)
  - 100 rad per 1 Gy
  - Volume independent
- Effective dose or E.D. (100 rem or 1 Seivert)
  - Attempts to consider type of radiation and actual organs at risk exposed in a partial body exposure (as we typically experience in diagnostic X-ray)

Radiation Exposure
- The amount of ionization created in the air by the x-ray photons
- Not reported on the patient protocol (dose report)
- Measured using radiation detectors — Ionization chambers, TLDs, OSLs, etc.
Absorbed Dose (rad or Gray)

- Describes the amount of radiation energy deposited in the patient's body per unit mass as a result of exposure (1 Joules/kg = 1Gy).
- 1 Gy = 100 rad = 100 erg/gm
- Not reported on the patient protocol (dose report)
- Calculated from radiation exposure
- Volume independent!

Effective Dose (E.D. in rem or Sv)

- Attempts to determine stochastic risk from non-uniform exposures delivered to different parts of the body with risk from whole body exposure.
- Considers organs exposed: weighted average of the dose to different body tissues (H), with the weighting factors (W) for different radiosensitivities of the tissues: $$E = \sum H_i W_i$$
- (breast has higher risk & weight than brain)

Effective Dose organ weighting coefficients

<table>
<thead>
<tr>
<th>Tissue</th>
<th>ICRP 60 Tissue weights (wT)</th>
<th>ICRP 103 Wgts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gonads</td>
<td>0.20</td>
<td>0.08</td>
</tr>
<tr>
<td>Red Bone Marrow</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Colon</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Lung</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Breast</td>
<td>0.05</td>
<td>0.12</td>
</tr>
<tr>
<td>Liver</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Esophagus</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Skin</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Bone Surface</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

How do we determine CT Dose?

- Unique geometry of multiple, relatively thin, axial exposures, where the source of exposure completely encircles the body.
• $D(z)$ = dose profile along z-axis (along the table) from:

Single acquisition

Multiple slice acquisition

Multiple Slices

Total dose at any point is **higher** than from a single slice due to scatter from adjacent slices

**CTDI (CT Dose Index)**

- Fundamental radiation dose parameter in CT
- Represents the average absorbed dose to a specific homogenous, cylindrical plastic phantom, along the longitudinal axis, from a series of contiguous exposures
- Measured in milligray (mGy) or rad

$\text{CTDI} \neq \text{patient dose}$

**CTDI** – defined

- How to get area under single scan dose profile?
  - Using a 100 mm “pencil” chamber
  - One measurement of an axial scan
  - Includes the primary and scatter
CTDI
- CTDI\textsubscript{100} Measurements are done in both head & body phantoms:
- CTDI\textsubscript{w} is a \textit{weighted average} of center and peripheral CTDI\textsubscript{100} to arrive at a single descriptor
  \quad \text{CTDI}_w = (1/3) \text{CTDI}_{100,\text{center}} + (2/3) \text{CTDI}_{100,\text{peripheral}}
- Same scan \textit{technique} will lead to very different doses in the two different size phantoms!

\begin{itemize}
  \item Head (16cm)
  \item Body (32cm)
\end{itemize}

Volume CTDI (CTDI\textsubscript{vol})
- Calculated from CTDI\textsubscript{w}
- Represents the \textit{average dose} in the central region of a multiple scan exam
- Takes into account scan pitch

\[ \text{CTDI}_{\text{vol}} = \frac{\text{CTDI}_w}{\text{Pitch}} \]

\text{PITCH} = \text{table index per rotation (I)} / \text{total nominal scan width (NT)}

CTDI\textsubscript{vol}
- Represents dose from a \textit{specific CT imaging protocol} to the homogenous CTDI phantom
  \quad \text{32 cm} diameter phantom is used for Adult Abdomen protocols
  \quad \text{16 cm} diameter phantom is used for pediatric and head protocols
- CTDI\textsubscript{vol} is affected by:
  \quad \text{kVp, mAs (tube current \textendash time product), pitch, beam collimation}
  \quad \text{Other factors (e.g. scanner make and model, bowtie filter, etc.)}

\text{For Helical Scans, Siemens uses the term “effective mAs”}
\[ \text{Effective mAs} = \frac{\text{Tube current} \times \text{Rotation time}}{\text{Beam pitch}} \]

- CTDI\textsubscript{vol} is \textit{STILL} = 20 mGy

\text{How do we represent the greater biologic risk?}
Dose Length Product (DLP)

- Represents integrated dose in terms of total scan length (# slices • slice width)
- \( \text{CTDI}_{\text{vol}} \text{(mGy)} \times \text{scan length (cm)} = \text{DLP (mGy-cm)} \)

Patients vs. phantoms

- Patients are not standard, cylindrical, or homogeneous plastic
- CTDI tends to:
  - overestimate dose for large patients and
  - underestimate dose for small/pediatric patients

Patient Size Effects

- A larger patient has more mass than a smaller or pediatric patient
- As dose is energy deposited PER unit mass (erg/gm or joules/kg) then a given CT technique used on a larger patient will result in LESS absorbed dose because there's more mass
- Conversely, an adult technique used on a child or small person will result in INCREASED absorbed dose
- So even to keep the SAME dose in a child as for an adult the technologist would need to reduce the tube current and would need to reduce current even further to reduce pediatric dose to below adult levels → IMAGE GENTLY
**Tube Current Modulation**

- An “automatic” exposure mechanism that adjusts tube output (mA) to compensate for differences in patient size/attenuation
- Can compensate for overall patient size
- Can compensate for changes in patient attenuation from PA to lateral projection
- Can compensate for changes in patient attenuation along the axis of the patient

**XY Modulation (in axial plane)**

- Diagram showing attenuation of object in axial plane with projections A (AP/PA) and B (lateral)
- CARE Dose 4D (Siemens)
Quality Reference mAs for CareDose4D

- A parameter defined by Siemens to represent the image quality that would have been achieved if a fixed tube current exam had been performed at that specific mAs level on an average sized patient.
- It is set by the user to select the desired image quality for a tube current modulated exam. – CareDose4D is Siemens’ version of tube current modulation

Average Effective mAs

- It is the total average effective mAs over the scan for a given TCM exam.

\[
\text{Effective mAs} = \frac{\text{Tube current} \times \text{Rotation time}}{\text{Beam pitch}}
\]

- This is what is reported in the Dose Report – under “mAs”
- Typically lower than Quality Ref mAs for smaller Pts
- Typically higher than Quality Ref mAs for larger Pts
- But not always....

Patient Protocol (Dose Report)

| Patient/Position | Scan | mAs | kVp | CTDIvol | DLP | Tl | cSt.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CTP/Right Post</td>
<td>1</td>
<td>80</td>
<td></td>
<td>2.49</td>
<td>2</td>
<td>05</td>
<td>1.5</td>
</tr>
<tr>
<td>FatHead</td>
<td>2</td>
<td>100</td>
<td>30</td>
<td>4.48</td>
<td>2</td>
<td>05</td>
<td>1.5</td>
</tr>
<tr>
<td>IV Ellis</td>
<td>3</td>
<td>100</td>
<td>20</td>
<td>2.49</td>
<td>2</td>
<td>05</td>
<td>1.5</td>
</tr>
<tr>
<td>Mammogram</td>
<td>4</td>
<td>100</td>
<td>65</td>
<td>4.48</td>
<td>107</td>
<td>05</td>
<td>1.5</td>
</tr>
<tr>
<td>Adult</td>
<td>4</td>
<td>100</td>
<td>65</td>
<td>4.48</td>
<td>107</td>
<td>05</td>
<td>1.5</td>
</tr>
<tr>
<td>Child</td>
<td>6</td>
<td>100</td>
<td>82</td>
<td>4.48</td>
<td>102</td>
<td>05</td>
<td>0.5</td>
</tr>
</tbody>
</table>

CTDIconv & DLP ≠ patient dose

Neither CTDI or DLP are patient dose

- CTDI & DLP do not consider patient size, age, gender, specific organs/region radiated
- A patient that has twice the DLP or CTDI of another does NOT necessarily receive more dose
- DLP underestimates dose considerably for exams where there is no table movement
- CTDI overestimates dose for stationary exams by a factor of approximately TWO
Estimating Effective Dose from DLP

- ED can be estimated from DLP multiplied by a coefficient specific for different body parts and sizes
- \( K \text{ (mSv mGy}^{-1}\text{cm}^{-1}) \times \text{DLP mGy-cm} = \text{Effective Dose (mSv)} \)
- Rough approximation dependent on several assumptions

Table 3. Normalized effective dose per dose-length product (DLP) for adults (standard physique) and pediatric patients of various ages over various body regions. Conversion factor for adult head and neck and pediatric patients assumes use of the head CT dose phantom (16 cm). All organ conversion factors assume use of the C2-cassette CT body phantom.\(^{10,11}\)

<table>
<thead>
<tr>
<th>Region of Body</th>
<th>0 year old</th>
<th>1 year old</th>
<th>5 year old</th>
<th>10 year old</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and neck</td>
<td>0.671</td>
<td>0.407</td>
<td>0.097</td>
<td>0.0432</td>
<td>0.001</td>
</tr>
<tr>
<td>Neck</td>
<td>0.017</td>
<td>0.012</td>
<td>0.011</td>
<td>0.0079</td>
<td>0.0003</td>
</tr>
<tr>
<td>Chest</td>
<td>0.030</td>
<td>0.020</td>
<td>0.018</td>
<td>0.013</td>
<td>0.014</td>
</tr>
<tr>
<td>Abdomen/Stomach</td>
<td>0.040</td>
<td>0.030</td>
<td>0.020</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>Trunk</td>
<td>0.065</td>
<td>0.038</td>
<td>0.039</td>
<td>0.016</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Limitations

- Extrapolating calculated organ dose estimates for mathematical models of a standard man to actual patients is problematic
- Actual patient size & morphology can have significant impact on dose (Huda, Cody) as can age, gender, and ethnicity
Monte Carlo Simulation Application: Evolution of Phantom Dosimetry

Model and benchmark against “conventional” dosimetry phantoms

- Calculate the irradiation patterns and whole-body dose effective in patient-specific voxelized phantoms with segmented organs

Summary

<table>
<thead>
<tr>
<th>Term</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTDI&lt;sub&gt;100&lt;/sub&gt;</td>
<td>mGy (or cGy or Gy)</td>
<td>Dose in cylindrical phantom (CTDI phantom) over 100 mm pencil chamber (periphery or center)</td>
</tr>
<tr>
<td>CTDI&lt;sub&gt;w&lt;/sub&gt;</td>
<td>mGy (or cGy or Gy)</td>
<td>Weighted average of dose from periphery and center of CTDI phantom</td>
</tr>
<tr>
<td>CTDI&lt;sub&gt;vol&lt;/sub&gt;</td>
<td>mGy (or cGy or Gy)</td>
<td>CTDI&lt;sub&gt;w&lt;/sub&gt;/pitch</td>
</tr>
<tr>
<td>DLP</td>
<td>mGy – cm</td>
<td>Product of CTDI&lt;sub&gt;vol&lt;/sub&gt; and length of scan</td>
</tr>
<tr>
<td>Effective Dose*</td>
<td>mSv</td>
<td>Calculated value designed to assess whole body stochastic risk from partial body exposure</td>
</tr>
</tbody>
</table>

* NOT indicated at scanner. Estimate only. Difficult to calculate. Involves many assumptions

CT doses for “typical” Exams for website and/or pamphlet

- ACR has reference doses (CTDI) for three exams for accreditation purposes that can be quoted and compared to
  - Adult head → 75 mGy
  - Adult abdomen → 25 mGy
  - Peds abdomen (age 5) → 20 mGy
- Need to define/standardize facility’s typical exam, both in protocol and designation, e.g.
  - Routine head, abdomen, chest
- Need to determine representative doses for standard protocols at each facility

Calif. Senate Bill 1237 – Section 3

- Requires a facility that uses CT to report to DHS any scan that is repeated, or a scan of the wrong body part, that results in:
  - An Effective Dose (E.D.) that exceeds 0.05 Sv (5 rem)
  - A dose in excess of 0.5 Sv (50 rem) to any organ or tissue
  - Shallow dose to the skin of 0.5 Sv (50 rem) to the skin
- UNLESS:
  - Repeat due to movement or interference of patient.
  - Ordered by a physician
Practical Implementation

- While actual enforcement of these provisions may be problematic, failure to comply is a **CRIME**.
- In most clinical situations it is unlikely that the notification dose limits would be exceeded.
- The following slides are designed to assist the institution by alerting the user to scenarios that might exceed action levels by converting the state’s threshold dose reporting levels into CT dose values that are actually reported by the CT scanner.

Practical Implementation

- The following “trigger” values are **guidelines** only and should be considered as **investigatory thresholds** to engage a Qualified Medical Physicist to determine if reporting is required.
- The trigger values are based on **scanner displayed CTDI/DLP** values that should be verified by a Qualified Medical Physicist.

---

**Patient Effective Dose Threshold: 50 mSv**

- For most standard CT scans, an approximate patient effective dose can be estimated from the product of Dose Length Product (DLP) and a conversion factor (k-factors) specific for a given body part and patient age. Based on those k-values the following cumulative DLPs will yield effective doses exceeding 50 mSv.
- Table below is for scanners that use:
  - CTDIvol and DLP from 16 cm diameter phantom **ONLY** for pediatric head scans
  - CTDIvol and DLP from 32 cm diameter phantom **ONLY** for adult body scans

---

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- Table below is for scanners (e.g. Siemens) that use:
  - CTDIvol and DLP from 16 cm diameter phantom **ONLY** for head scans *(Pediatric and Adult head)*
  - CTDIvol and DLP from 32 cm diameter phantom for BOTH pediatric AND adult body scans

---

### DLP Reporting Thresholds for Incorrect/Repeated Exams

<table>
<thead>
<tr>
<th>DLP in mGy/cm</th>
<th>0 year old</th>
<th>5 year old</th>
<th>10 year old</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>head/neck</td>
<td>3846</td>
<td>5882</td>
<td>8772</td>
<td>15905</td>
</tr>
<tr>
<td>head</td>
<td>4345</td>
<td>7463</td>
<td>12500</td>
<td>15625</td>
</tr>
<tr>
<td>neck</td>
<td>2941</td>
<td>4167</td>
<td>6454</td>
<td>6829</td>
</tr>
<tr>
<td>chest</td>
<td>1292</td>
<td>1923</td>
<td>2776</td>
<td>3846</td>
</tr>
<tr>
<td>abdomen/pelvis</td>
<td>1020</td>
<td>1667</td>
<td>2500</td>
<td>3333</td>
</tr>
<tr>
<td>trunk (L/A/P)</td>
<td>1136</td>
<td>1786</td>
<td>2692</td>
<td>3271</td>
</tr>
</tbody>
</table>

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<tr>
<td>neck</td>
<td>2941</td>
<td>4167</td>
<td>6454</td>
<td>6829</td>
</tr>
<tr>
<td>chest</td>
<td>557</td>
<td>836</td>
<td>1268</td>
<td>1858</td>
</tr>
<tr>
<td>abdomen/pelvis</td>
<td>444</td>
<td>725</td>
<td>1067</td>
<td>3333</td>
</tr>
<tr>
<td>trunk (L/A/P)</td>
<td>404</td>
<td>776</td>
<td>1244</td>
<td>3271</td>
</tr>
</tbody>
</table>
Conclusions

• Questions about individual patient doses should be referred to a Qualified Medical Physicist for calculation.
• Protocol review by a Qualified Medical Physicist is required for compliance with State of CA and accreditation bodies.

Organ Dose Threshold: 500 mSv

• Computed Tomography Dose Index (CTDI) as reported by the CT scanner represent dose to a cylindrical plastic phantom of a specific diameter. Therefore CTDI tends to overestimate dose to large patients and underestimate dose to a small patient.
• Thus organ doses can only be approximated from CTDI values when combined with specific knowledge about patient size and morphology (as well as the amount of organ in question is included within the extents of the scan range).
• While all of the above are required to make accurate estimates of organ dose, the total CTDIvol as reported by the scanner for a given body region can be used to provide an estimate for organ dose for the body region containing the scanned organ.

Organ Dose Threshold: 500 mSv <500 mGy>

• While organ doses can only be approximated from CTDI values and specific knowledge about patient size and morphology - as well as extent to which the organ in question is included within the extents of the scan range - are all required to make accurate estimates of organ dose, the total CTDIvol as reported by the scanner for a given body region can be used as a proxy for organ dose for the body region containing the scanned organ.
• Thus, if the cumulative CTDIvol for any given body part scanned exceeds 500 mSv there is a likelihood that an organ contained within that scan region may have also exceeded 500 mSv.

Organ Dose Threshold: 500 mSv

• The following situations may result in an organ dose exceeding the reporting threshold of 500 mSv:
  — Scans with table movement (any axial or helical scan)
    • For Pediatric, if the cumulative CTDIvol for any given body part exceeds 200 mGy
    • For Adult, if the cumulative CTDIvol for any given body part exceeds 250 mGy
  — Scans with NO table movement (e.g., neuroperfusion scan)
    • For Pediatric, if the cumulative CTDIvol for any given body part exceeds 650 mGy
    • For Adult, if the cumulative CTDIvol for any given body part exceeds 650 mGy
• Here “cumulative” CTDIvol means if the same anatomic region is scanned multiple times (e.g. pre- and post-contrast of the same region), then these CTDIvol should be added.
• NOTE: if different regions are scanned (e.g., pre-contrast abdomen, post-contrast thorax and pelvis), then the CTDIvol are not added.
Skin Dose Threshold: 500 mSv

• For dose to the skin, the immediate concern is potential for deterministic injury such as erythema (reddening), or hair loss (epilation), or more serious skin burns.
• In this case we want to identify what scans might result in a total PEAK skin dose that exceeds 500 mGy.
• In general, peak skin dose is greatest when the scan table is held stationary and multiple scan “slices” are performed in the same anatomical location.
• The principal scan where the table is held stationary and doses might result in skin injury are brain-perfusion scans.
• For these types of scans, Dose Length Product (DLP) tends to underestimate peak skin dose as a relatively small length of the body is actually being scanned.
• By definition CTDI_{vol} reports dose assuming multiple contiguous scan slices and considers scatter radiation from adjacent slices and thus overestimates peak skin dose for repeated scans in a fixed location.
• Measurement data for actual skin dose received from brain-perfusion scans indicates that CTDI_{vol} overestimates peak skin dose by approximately a factor of two.
• Thus, if the cumulative CTDI_{vol} for a head scan exceeds 1000mGy (1 Gy) there may be likelihood of deterministic injury to the skin.

Skin Dose Threshold: 500 mSv

• For Pediatric, if the cumulative CTDI_{vol} for any given body part exceeds 650 mGy
• For Adult, if the cumulative CTDI_{vol} for any given body part exceeds 650 mGy
• Here “cumulative” CTDI_{vol} means if the same anatomic region is scanned multiple times (e.g., pre- and post-contrast of the same region), then these CTDI_{vol} may be added.
• NOTE: if different regions are scanned (e.g., pre-contrast abdomen, post-contrast thorax and pelvis), then the CTDI_{vol} are not added.

Skin Dose Threshold: 500 mSv

• It is unlikely in CT that skin dose averaged over entire organ will exceed 500 mSv.
• Rather for skin the immediate concern is potential for deterministic injury such as erythema (reddening), or hair loss (epilation), or more serious skin burns.
• In this case we want to identify what scans might result in a total PEAK skin dose that exceeds 500 mGy.
• In general, peak skin dose is greatest when the scan table is held stationary and multiple scan “slices” are performed in the same anatomical location.
• The principal scan where the table is held stationary and doses might result in a skin injury are neuro-perfusion scans.
• For these types of scans, Dose Length Product (DLP) tends to underestimate peak skin dose as a relatively small length of the body is actually being scanned.
• By definition CTDI_{vol} reports dose assuming multiple contiguous scan slices and considers scatter radiation from adjacent slices and thus overestimates peak skin dose for repeated scans in a fixed location.
• Data for skin dose received from neuro-perfusion scans indicates that CTDI_{vol} overestimates peak skin dose by 30 to 100%.
• Thus, the following situations may result in an skin dose exceeding the reporting threshold of 500 mSv:
  – Scans with NO table movement (e.g., neuroperfusion scan)
    • For Pediatric, if the cumulative CTDI_{vol} for any given body part exceeds 650 mGy
    • For Adult, if the cumulative CTDI_{vol} for any given body part exceeds 650 mGy
  – Scans with table movement (any axial or helical scan)
    • For Pediatric, if the cumulative CTDI_{vol} for any given body part exceeds 200 mGy
    • For Adult, if the cumulative CTDI_{vol} for any given body part exceeds 250 mGy
• Here “cumulative” CTDI_{vol} means if the same anatomic region is scanned multiple times (e.g., pre- and post-contrast of the same region), then these CTDI_{vol} may be added.
• NOTE: if regions outside of the abdomen/pelvis are scanned then the CTDI_{vol} are not added.

Fetal Dose Threshold: 50 mSv

• SB-1237 also requires that a CT or therapeutic dose to an embryo or fetus greater than 50 mSv (5 rem) dose equivalent be reported if dose delivered is to a known pregnant individual unless the fetal dose was specifically approved, in advance, by qualified physician.
• Exceeding the specified fetal dose threshold may occur in certain clinical scenarios.
• For CT the following situations may result in an embryo or fetal dose exceeding the reporting threshold of 50 mSv:
  – Scans with table movement (any axial or helical scan)
    • If the cumulative CTDI_{vol} for a scan of the abdomen/pelvis including the uterus exceeds 25 mGy
    • Scans with NO table movement (e.g., perfusion scan of abd/pelvis)
    • If the cumulative CTDI_{vol} for a scan including the abdomen/pelvis including the uterus exceeds 65 mGy
• Here “cumulative” CTDI_{vol} means if the uterine/abdomen region is scanned multiple times (e.g. pre- and post-contrast of the same region), then these CTDI_{vol} should be added.
• NOTE: if regions outside of the abdomen/pelvis are scanned then the CTDI_{vol} are not added.
Conclusions

• Questions about individual patient doses should be referred to a Qualified Medical Physicist for calculation.
• Protocol review by a Qualified Medical Physicist is required for compliance with State of CA and accreditation bodies

For Further Information

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Question # 1
CTD1vol for a single 1 cm slice is 10 mGy. What is the dose in mGy for 20 consecutive, non-overlapping slices?

Correct Answer: 1

Question # 2
Cancer risk from diagnostic radiation exposure is best categorized as:

1. A stochastic risk
2. Thought to have no absolutely safe threshold for radiation inducement
3. Risk of occurrence increases linearly with dose
4. Risk is very small compared to normal risk of cancer
5. All of the above

Correct Answer: 5


Question # 3
Hair loss and/or skin burns from X-Ray:

1. Can only occur with therapeutic or interventional studies
2. Have a probability of occurring at any dose
3. Become more severe as dose increases
4. Are potential risks for CT technologists
5. Will occur immediately after exposure

Correct Answer: 3

Question # 4
Which of the following are not deterministic effects of CT doses that may be observed due to high radiation exposures?

- 1. Skin burns
- 2. Cataracts
- 3. Reproduction Problems
- 4. Genetic Effects

Correct Answer: 4


Question # 5
The Effective Dose (ED) from a CT of the abdomen/pelvis to approximately equivalent to:

- 1. 10 mSv
- 2. 1 rem
- 3. 3 years of background radiation
- 4. 20% of a radiation worker’s annual limit
- 5. All of the above

Correct Answer: 5

Ref: RadiologyInfo.org website (2011)
Question # 6
Which of the following scans would you expect to have the highest DLP?

1. A head scan at 120 kVp and 350 effective mAs
2. An abdomen/pelvis at 120 kVp and 200 effective mAs
3. A three phase abdomen at 120 kVp and 200 effective mAs
4. A neuroperfusion scan at 120 kVp, 150mA, 45 seconds

Correct Answer: 3


Question # 7
Which of the following values best represents cancer risk from a CT scan?

1. Exposure
2. Dose
3. CTDI vol (mGy)
4. Dose Length Product
5. Effective Dose

Correct Answer: 5

Question # 8
Which of the following studies has the highest presumed cancer risk?

1. A head scan at 120 kVp and 350 Effective mAs
2. An abdomen/pelvis at 120 kVp and 200 effective mAs on an adult
3. An abdomen/pelvis at 120 kVp and 100 effective mAs on a one year old
4. A neuroperfusion scan at 120 kVp, 150 mA, 45 seconds (6750 mAs) that encompasses a 28.8 mm swath

Correct Answer: 3

Question # 9
Senate Bill 127 in California requires reporting of CT exposures that result in unanticipated permanent functional damage to an organ or physiological system, hair loss, or erythema, as determined by a qualified physician. In which of the following circumstances would the reporting not be required when erythema is observed?

1. The patient received instructions concerning the risks and potential consequences of the procedure and consented to the procedure.
2. The patient received no instructions concerning the risks and potential consequences of the procedure and consented to the procedure.
3. The patient spent the day following the CT scan at the beach without sunscreen.
4. The patient developed hair loss at six months following the CT scan

Correct Answer: 2
Ref: Senate Bill Number 1237, CA Health and Safety Code Section 115113, October 4, 2010 and Information Notice Regarding Senate Bill 1237 posted 1/14/2011 on CA RHB website.
Question # 10

Under Senate Bill 1237 in California regarding repetition of a CT scan, repetition of the CT Scan due to “patient movement or interference” means all of the following except:

1. Repetition of a CT scan due to abnormal patient anatomy
2. Repetition of a CT scan due to interference from the patient's family
3. Repetition of a CT scan due to involuntary movement of the patient
4. Repetition of a CT scan due to malfunction of the contrast injector

Corresponding percentages:
- 7% for option 1
- 67% for option 2
- 17% for option 3
- 10% for option 4

Correct Answer: 4

Ref: Senate Bill Number 1237, CA Health and Safety Code Section 115113, October 4, 2010 and Information Notice Regarding Senate Bill 1237 posted 1/14/2011 on CA RHB website.