Common Technical Mistakes and How to Avoid Them: Lessons Learned from ACR CT Accreditation Program

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First Things First

Table 1

- Technical description of site's protocols for
  - **Adult Head**
    - for headaches or to exclude neoplasm, brain CT, top of the head. Use cerebrum technique for phantom
  - **High Resolution Chest**
    - HR Chest CT for evaluation of diffuse lung disease
  - **Adult Abdomen**:
    - Detection of possible liver metastases or lymphoma.
  - **Pediatric Abdomen**:
    - For blunt trauma, acute abdominal pain, or infection. **Assume 5-y/o patient.**

First Things First

Table 1

- Understand what site *really* does
- Make sure that lead radiologist and lead tech:
  - Understand importance of filling out correctly
  - Assist in filling out

First Things First

Table 1 - Common Mistakes

- For mA row – entering mAs, effective mAs or mAs/slice
- Help site understand difference between these
  - And that they are not all equivalent
  - mA ≠ mAs
  - mAs ≠ eff. mAs
  - mAs ≠ mAs/slice

First Things First

Siemens – eff. mAs (effective mAs)

$$Eff._mAs = \frac{mA * rot\_time}{Pitch} \Rightarrow mA = \frac{Eff._mAs * Pitch}{rot\_time}$$

Philips – mAs/Slice (similar definition to eff. mAs)

$$mAs/slice = \frac{mA * rot\_time}{Pitch} \Rightarrow mA = \frac{(mAs/Slice) * Pitch}{rot\_time}$$

Toshiba and GE use mA, time , Pitch as separate values.

First Things First

Common Mistakes include:

- Reporting mAs or eff. mAs or mAs/slice in Table 1
- Then using mAs or eff. mAs when performing CTDI measurements
  - Example: 200 eff. mAs, pitch .9, rot. time = 0.5 sec
    - In this case, mA = 360
    - Should perform CTDI measurement with 180 mAs
    - Spreadsheet will use pitch 0.9 and correct for values of effective mAs

First Things First

Common Mistakes include:

- If site does this incorrectly, spreadsheet will have incorrect values
  - If they perform acquisition with 200 mAs
  - And then use N,T and I such that a pitch of 0.9 results, then CTDIvol reported will be too high
  - If Pitch < 1, CTDIvol reported will be too high
  - If Pitch > 1, CTDIvol reported will be too low

First Things First

Common Mistakes - Reporting collimation incorrectly

- Admittedly this can be confusing for some scanners
- Example: Siemens Sensation 64
  - Scanner user interface says 64 x 0.6 mm
  - Scanner uses z-flying focal spot, which double samples on z-axis of anode to obtain 2X images.
  - Actual beam width is N=32, T = 0.6 mm
  - For Pitch 1.0, table travel will be 19.2 mm/rotation
  - Site sometimes list N=64, T=0.6mm, I= 38.4mm (-> Pitch 1)
  - In spreadsheet, this yields CTDIvol that is half what it should be

First Things First

Common Mistakes - Reporting collimation incorrectly

- Consult ACR CT Accreditation website for FAQs and clarifications
- http://www.acr.org/accreditation/computed/ct_faq.aspx

Other Lessons

Exceeding Dose Limits:

- Adult Head: 80 mGy
- Peds Abdomen: 25 mGy
- Adult Abdomen: 30 mGy

Exceeding Dose Limits

Adult Head (80 mGy limit) – Things to Check:

- Was protocol followed and scan done correctly?
  - Correct kVp, mAs, Collimation as in Table 1
- If yes and still > 80 mGy
  - Is site using cerebrum technique?
  - Is site using too high a kVp?
    - Can they use 120 kVp?
    - If they want to use 140 kVp, can they reduce the mAs?

Exceeding Dose Limits

Adult Head (80 mGy limit) – Things to Check:

- Was protocol followed and scan done correctly?
- If yes and still > 80 mGy
  - Is mA or rotation time very high? If so, why? (see below)
  - If helical scan, is a low pitch value being used?
    - Some mfrs recommend low pitch for helical head scans, but site should make sure that mAs is reduced to compensate
  - Is site using ***very thin slices***?
    - If so, the increased noise in thin slices may be driving them to increase mAs or decrease pitch

Exceeding Dose Limits

Peds Abdomen (25 mGy limit) – Things to Check:

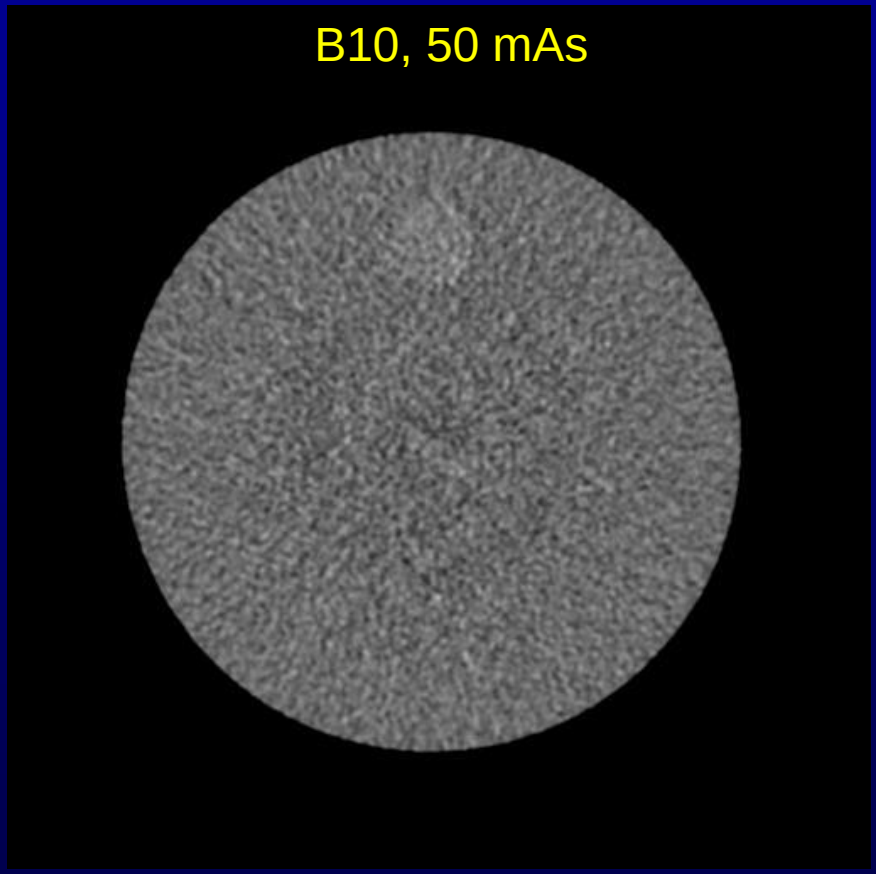
- Some sites lower mA , but also decrease pitch
  - Does not yield intended net dose reduction
- Some sites lower kVp (but keep mAs and pitch the same)
  - This will yield good dose savings

Other Potential Mistakes

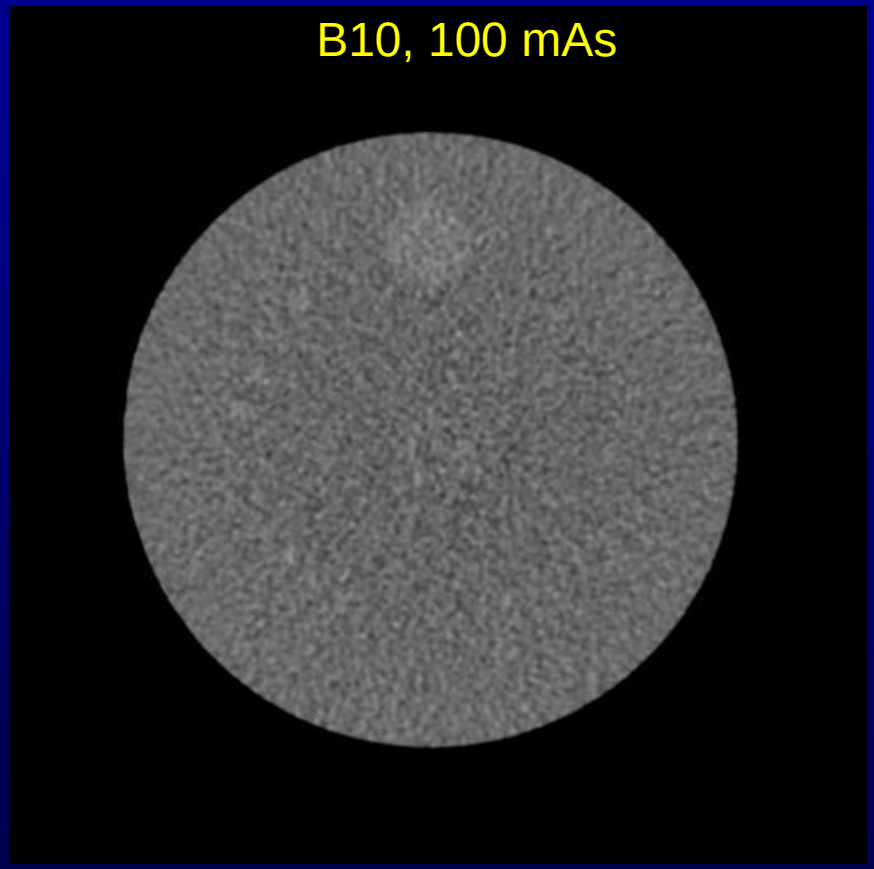
Low Contrast Resolution

- Passing is seeing all four 6 mm rods
- Common reason for failure
- In trying to reduce dose, site may go too far
  - Reduces technique, increases noise, cannot see 6 mm rod

Low Contrast Resolution



Low Contrast Resolution



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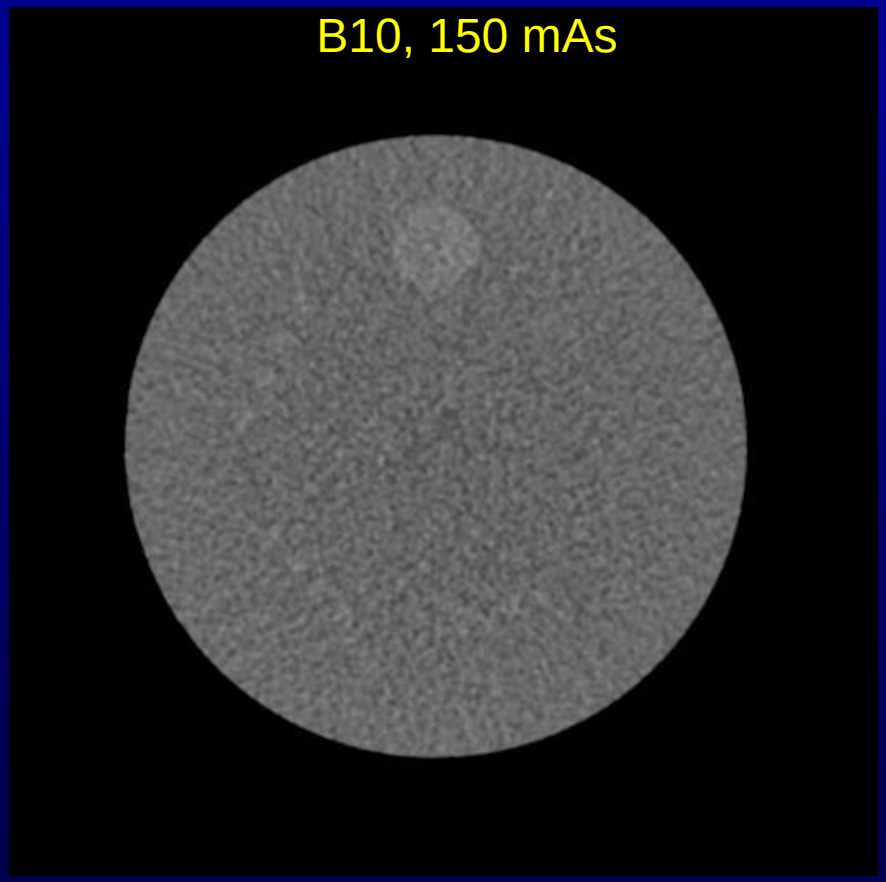

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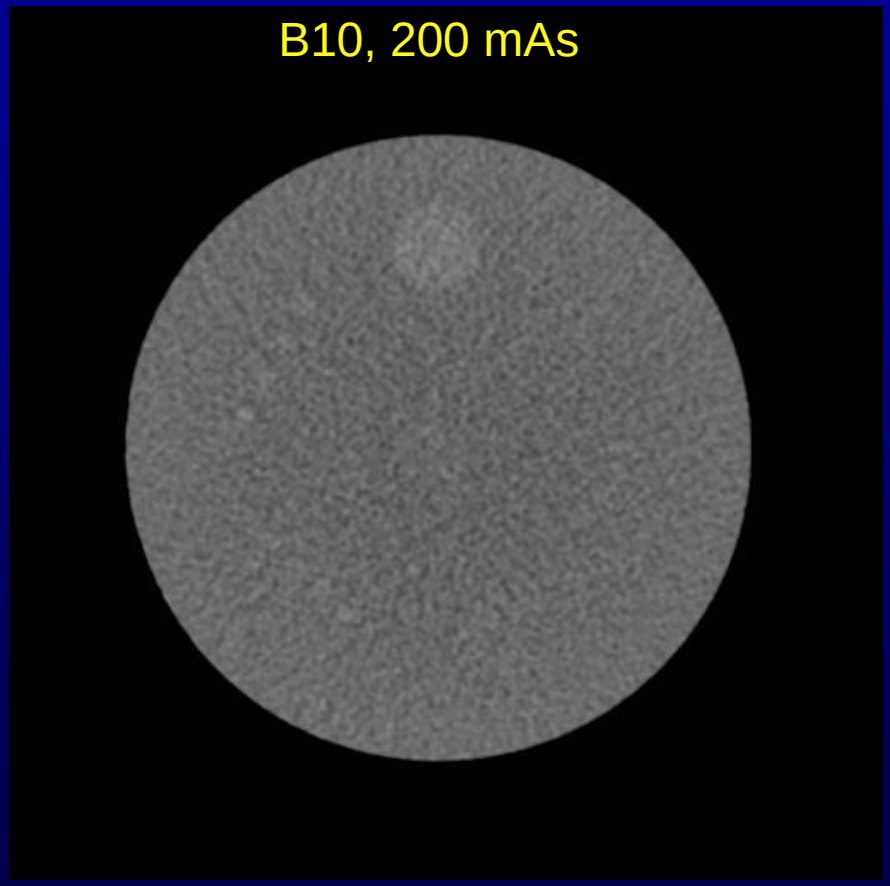

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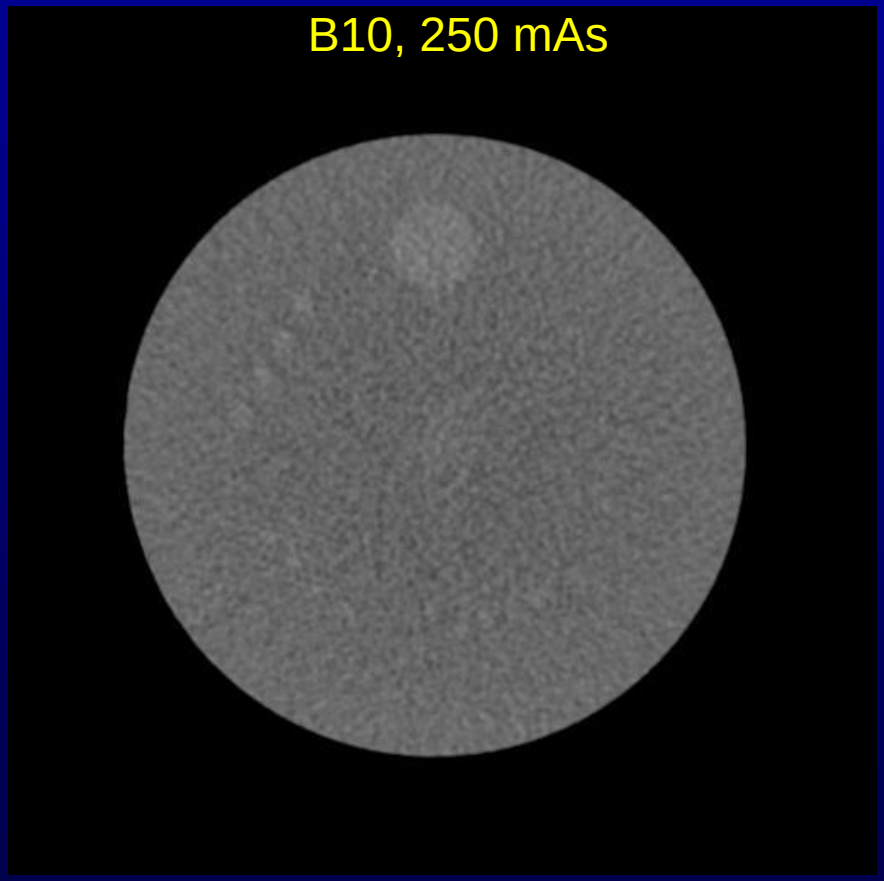

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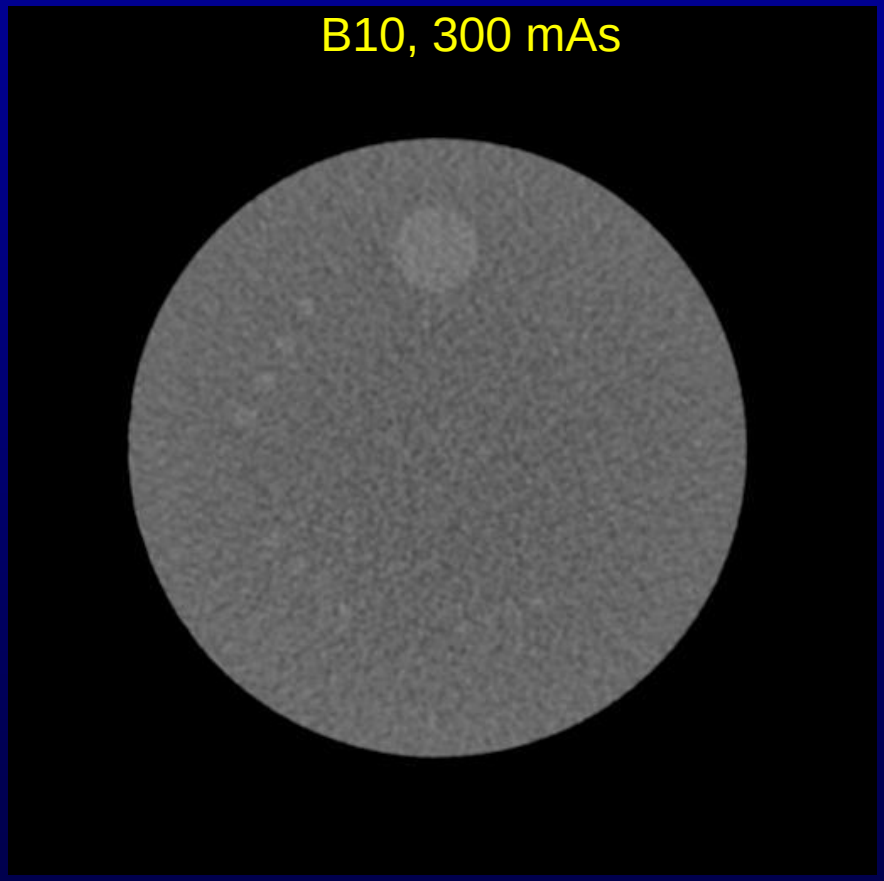

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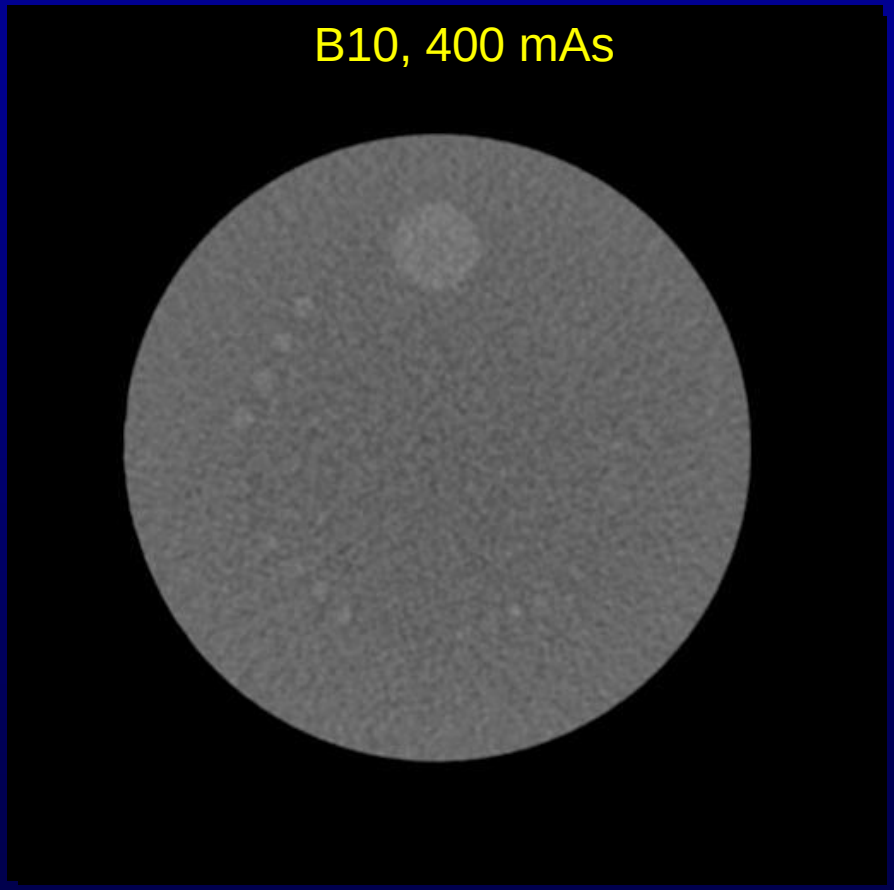

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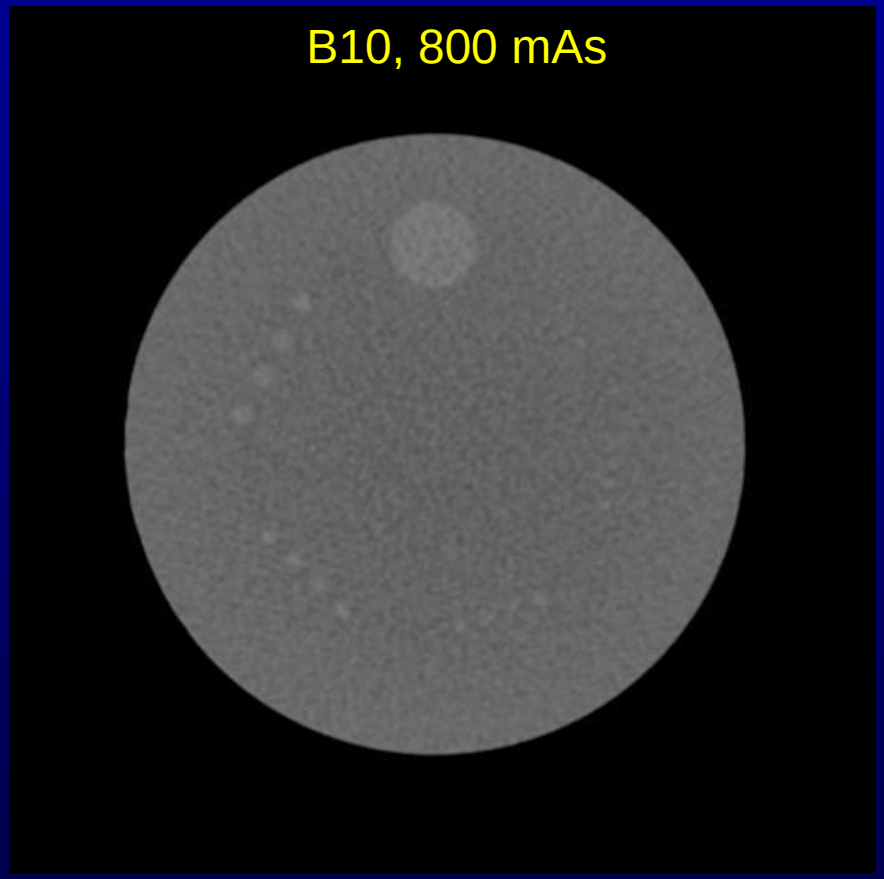

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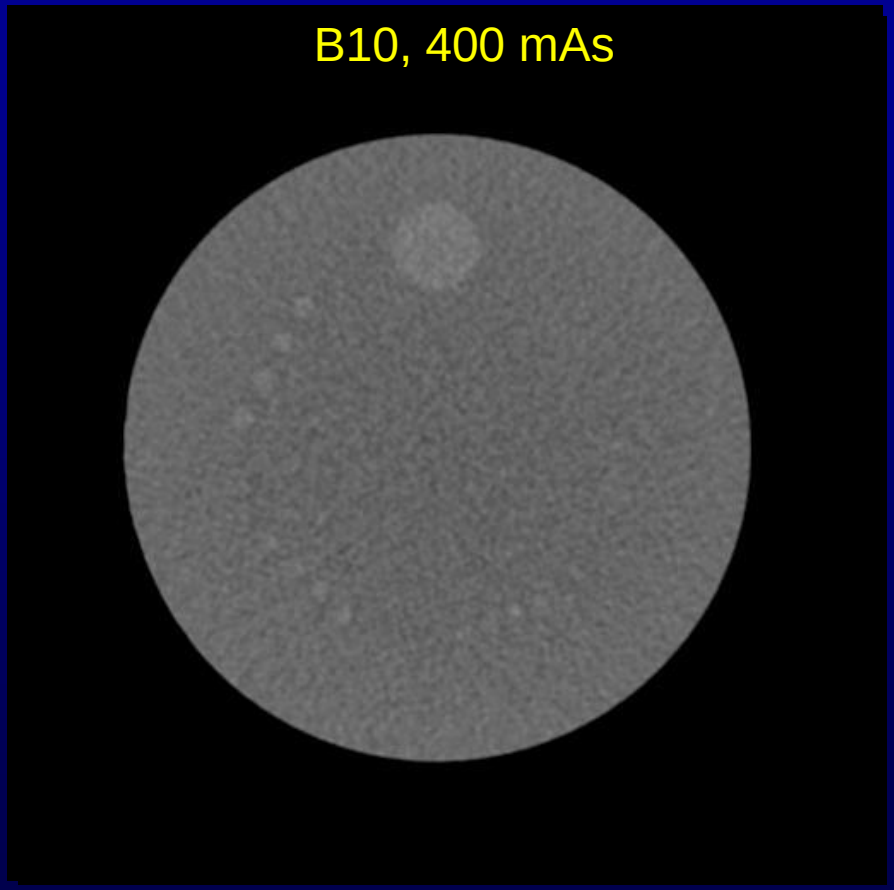

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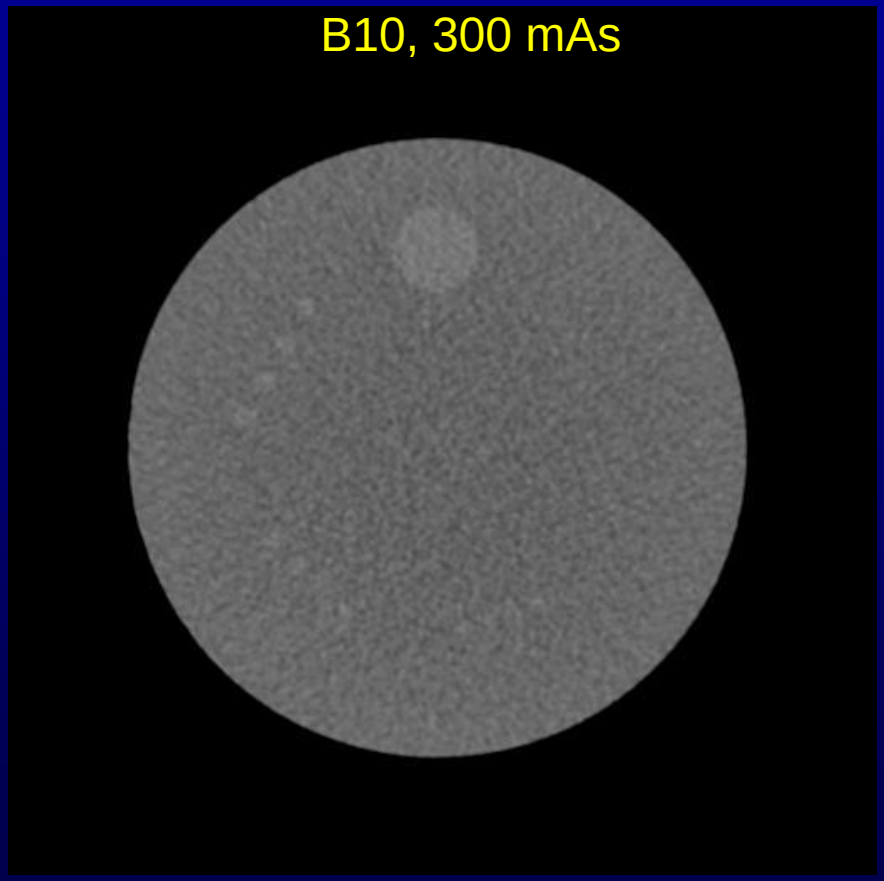

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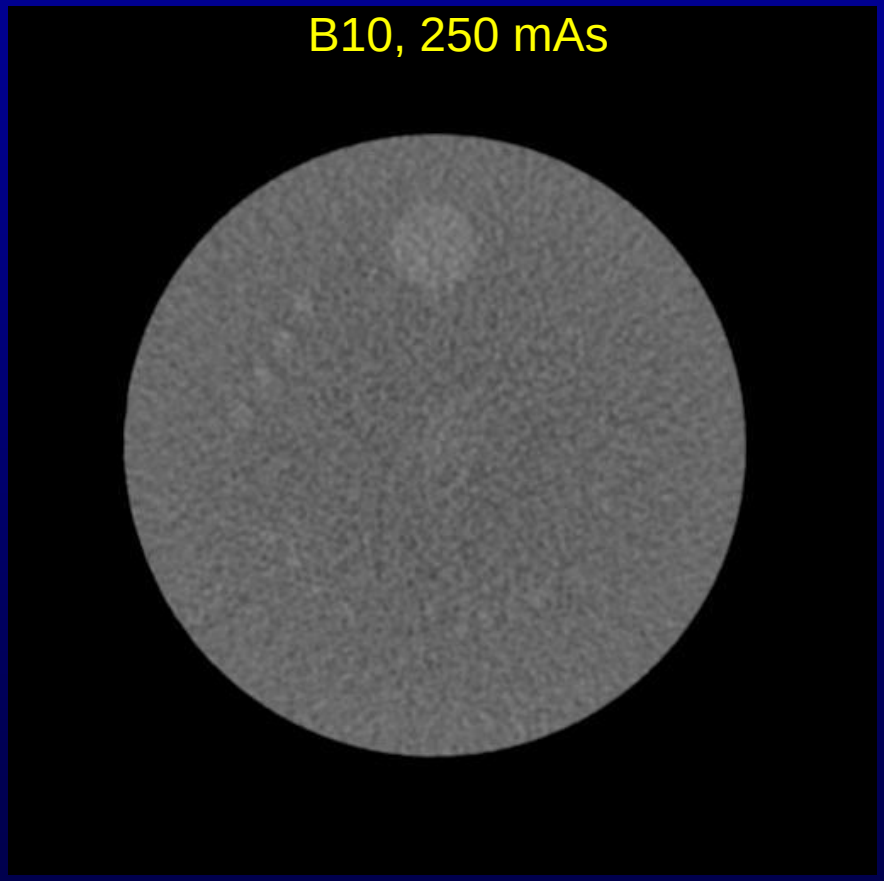

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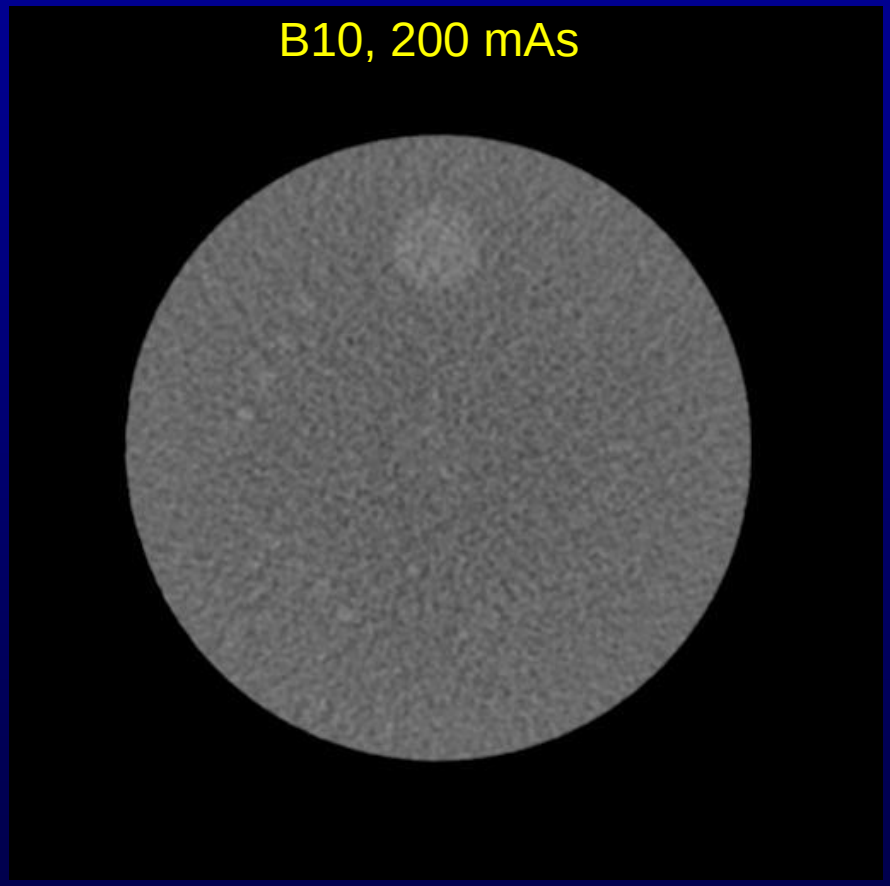

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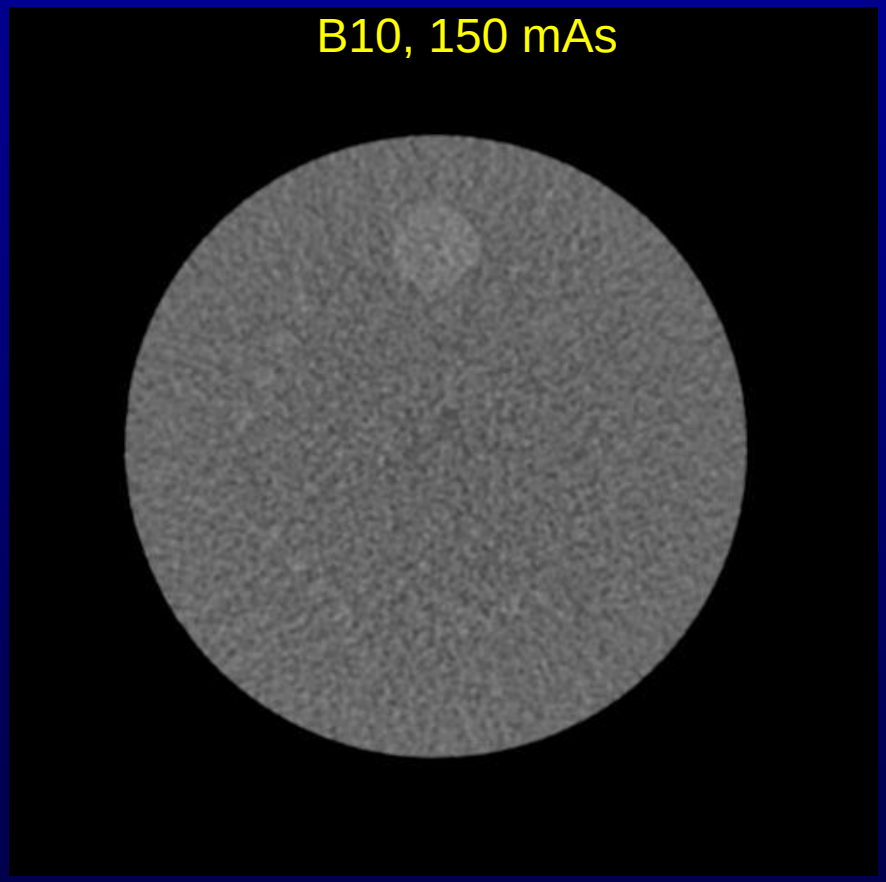

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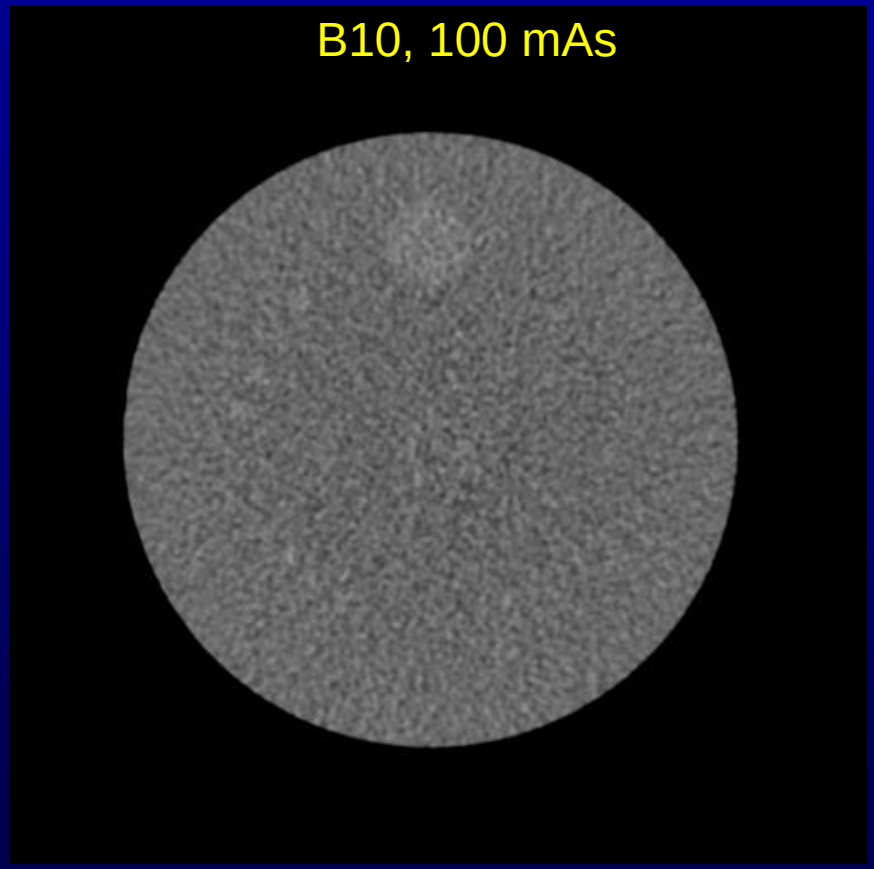

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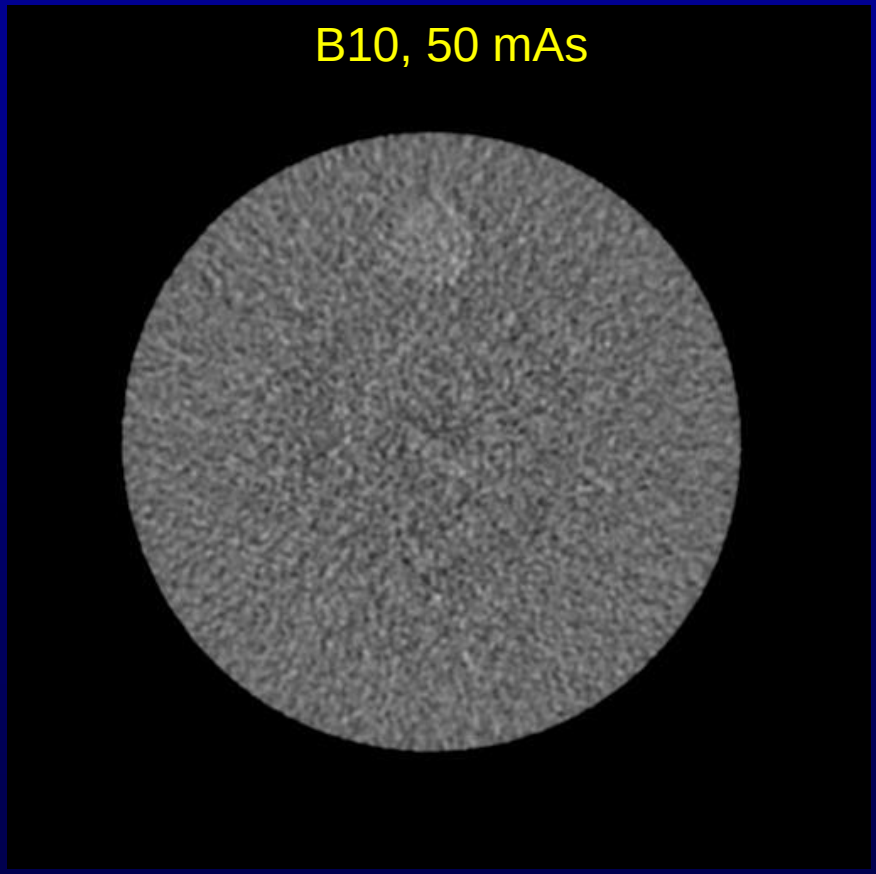


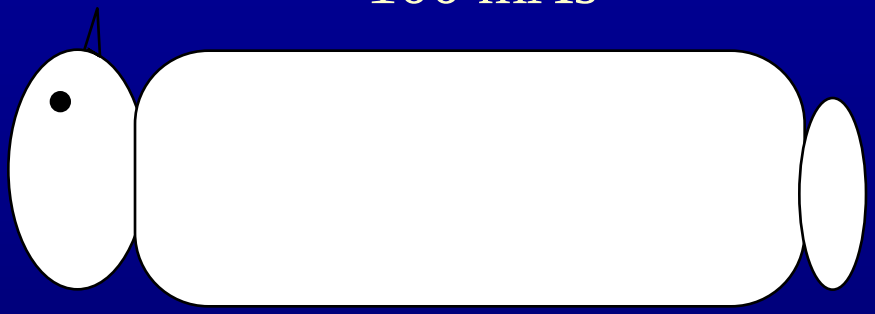
$CTDI_{vol}$ and DLP

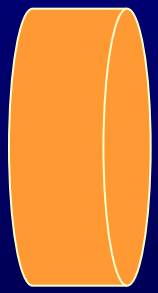
- $CTDI_{vol}$ currently reported on the scanner
  - (though not required in US)
- Is Dose to one of two phantoms
  - (16 or 32 cm diameter)
- Is NOT dose to a specific patient
- Does not tell you whether scan was done "correctly" or "Alara" without other information (such as body region or patient size)
- MAY be used as an index to patient dose with some additional information (later)

*Scenario 1: **No adjustment** in technical factors for patient size*

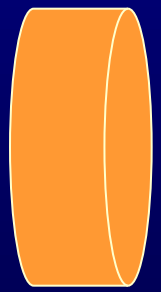
100 mAs

100 mAs





32 cm phantom



32 cm phantom

$CTDI_{vol}$ = 20 mGy

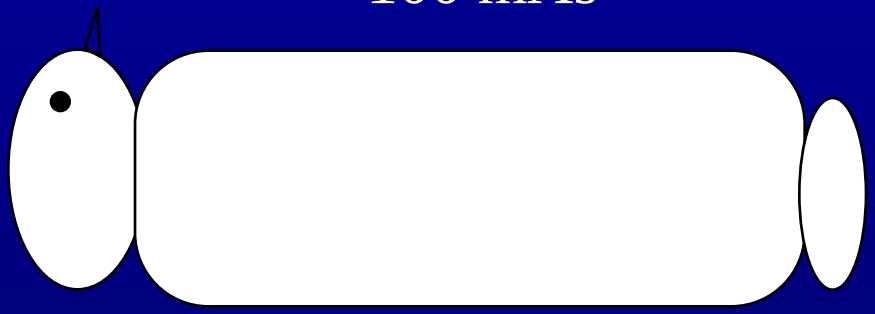
$CTDI_{vol}$ = 20 mGy

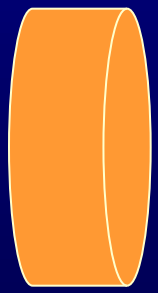
The $CTDI_{vol}$ (dose to phantom) for these two would be the same

*Scenario 2: **Adjustment** in technical factors for patient size*

50 mAs

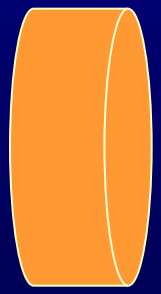
100 mAs





32 cm phantom

$CTDI_{vol}$ = 10 mGy



32 cm phantom

$CTDI_{vol}$ = 20 mGy

The $CTDI_{vol}$ (dose to phantom) indicates larger patient received 2X dose

Did Patient Dose Really Increase ?

For same tech. factors, smaller patient absorbs more dose

- Scenario 1: CTDI is same but smaller patient's dose is higher
- Scenario 2: CTDI is smaller for smaller patient, but patient dose is closer to equal for both.

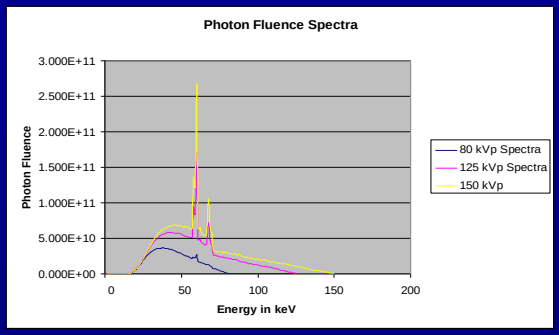
$CTDI_{vol}$

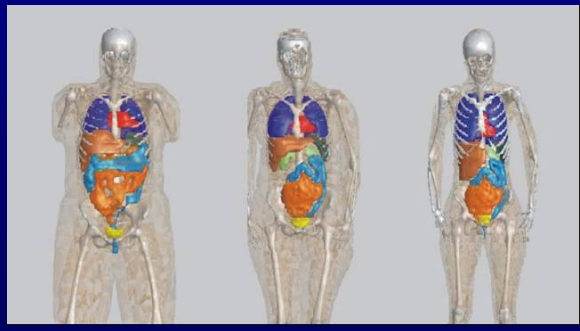
- Not patient Dose
- By itself can be misleading

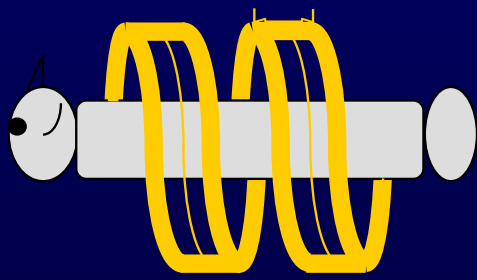
- $CTDI_{vol}$ should be recorded with:
  - Description of phantom size (clarify 16 or 32 cm diameter)
  - Description of patient size (lat. Width, perimeter, height/weight, BMI)
  - Description of anatomic region

Monte Carlo Simulation Techniques (Monte Carlo Based Patient Radiation Dose From CT)

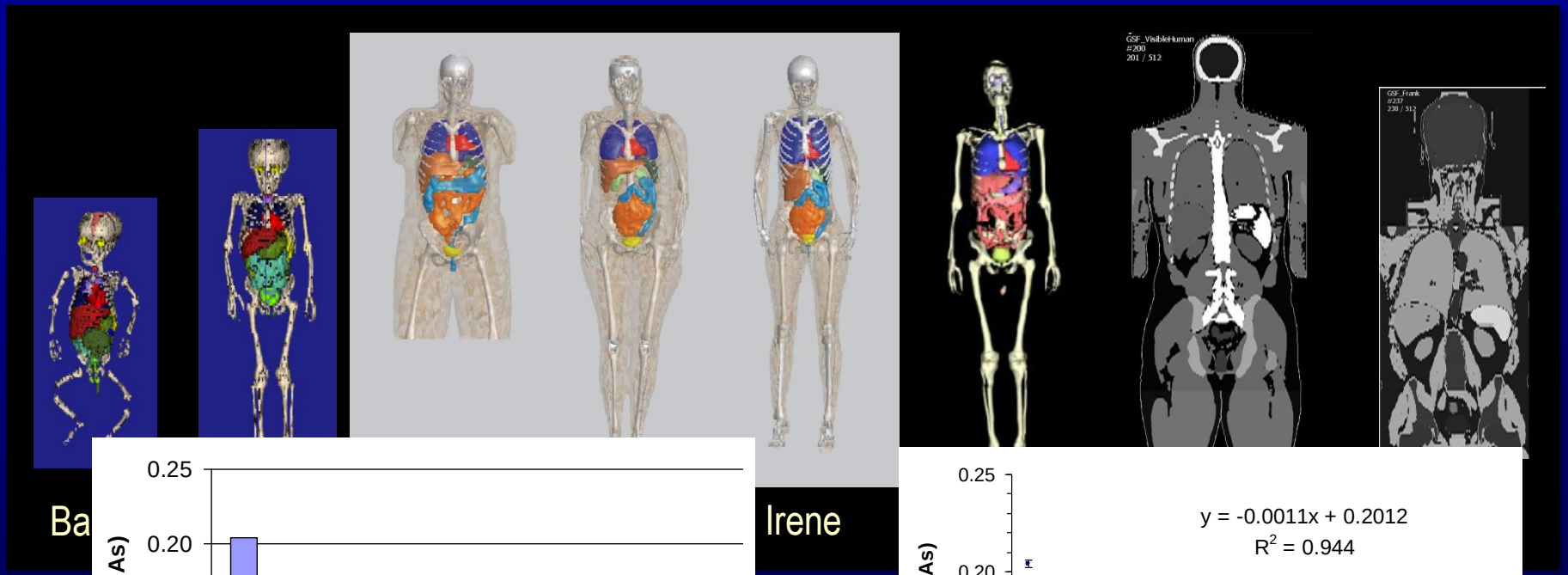
- Model MDCT scanner in detail
- Model patient in detail
- Simulate CT scan
  - Movement of X-ray source
  - Simulate photon interactions with patient
- Tally radiation dose absorbed at a location
  - e.g. organ such as glandular breast tissue

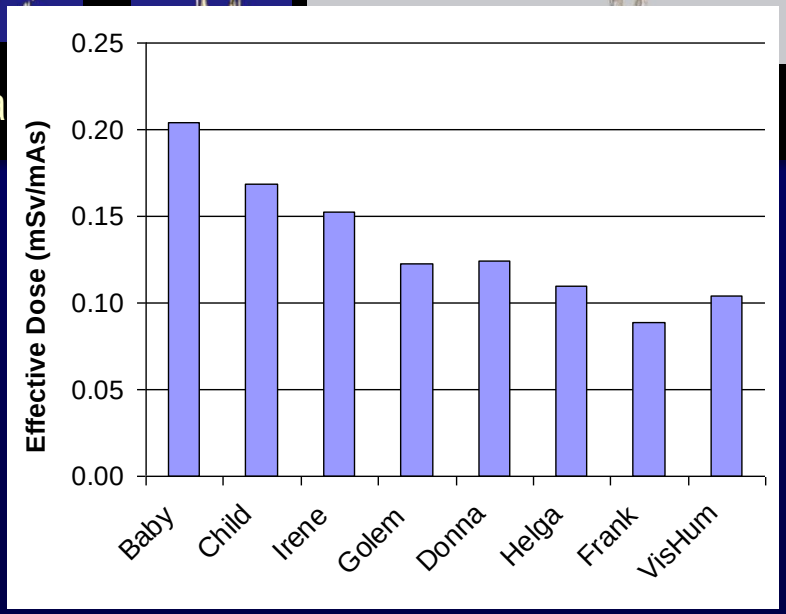


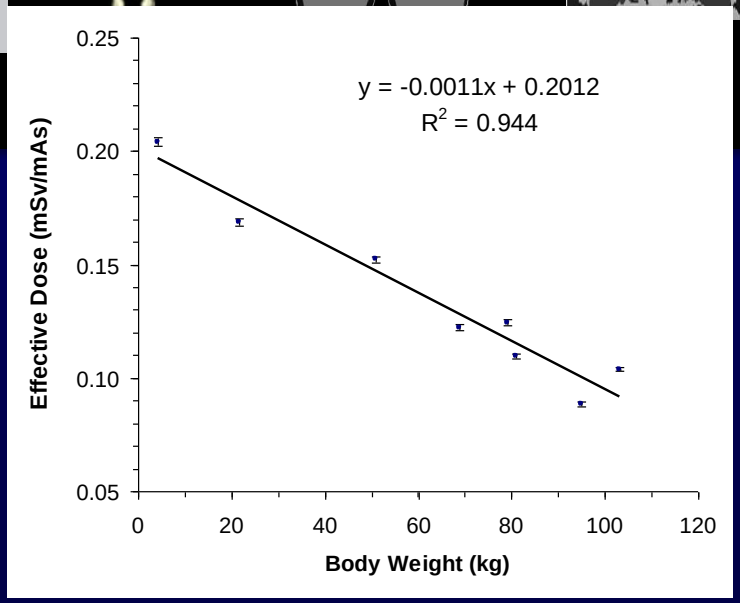




What Really Happened to Patient Dose ?



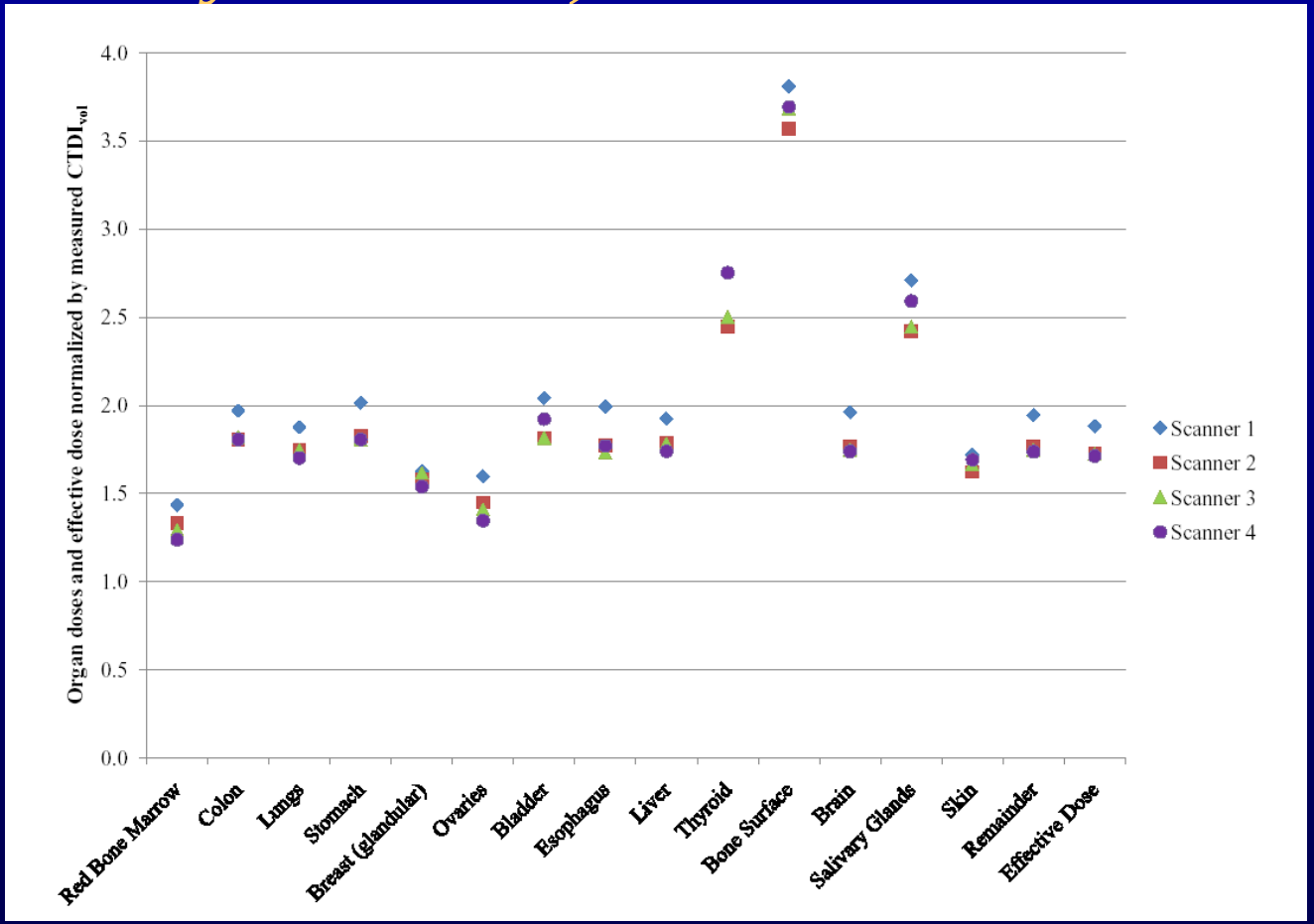




Turner et al, RSNA 2008 (Med Phys in Press)

- How does organ dose vary across scanners of different CT manufacturers when:
  - Using comparable scanners (64 row)
  - Using same technical factors (kVp, mA, etc.)
  - Using same anatomy of one reference patient model (Irene)

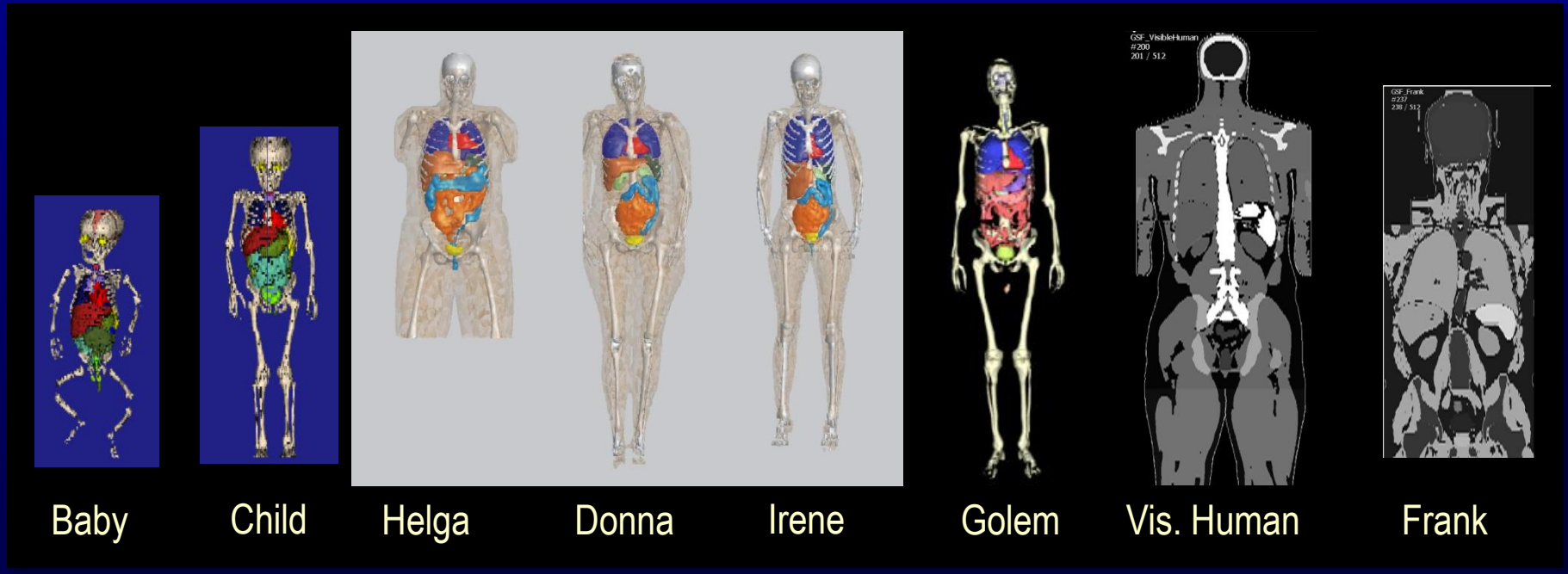
Turner et al, RSNA 2008 (Med Phys in Press)



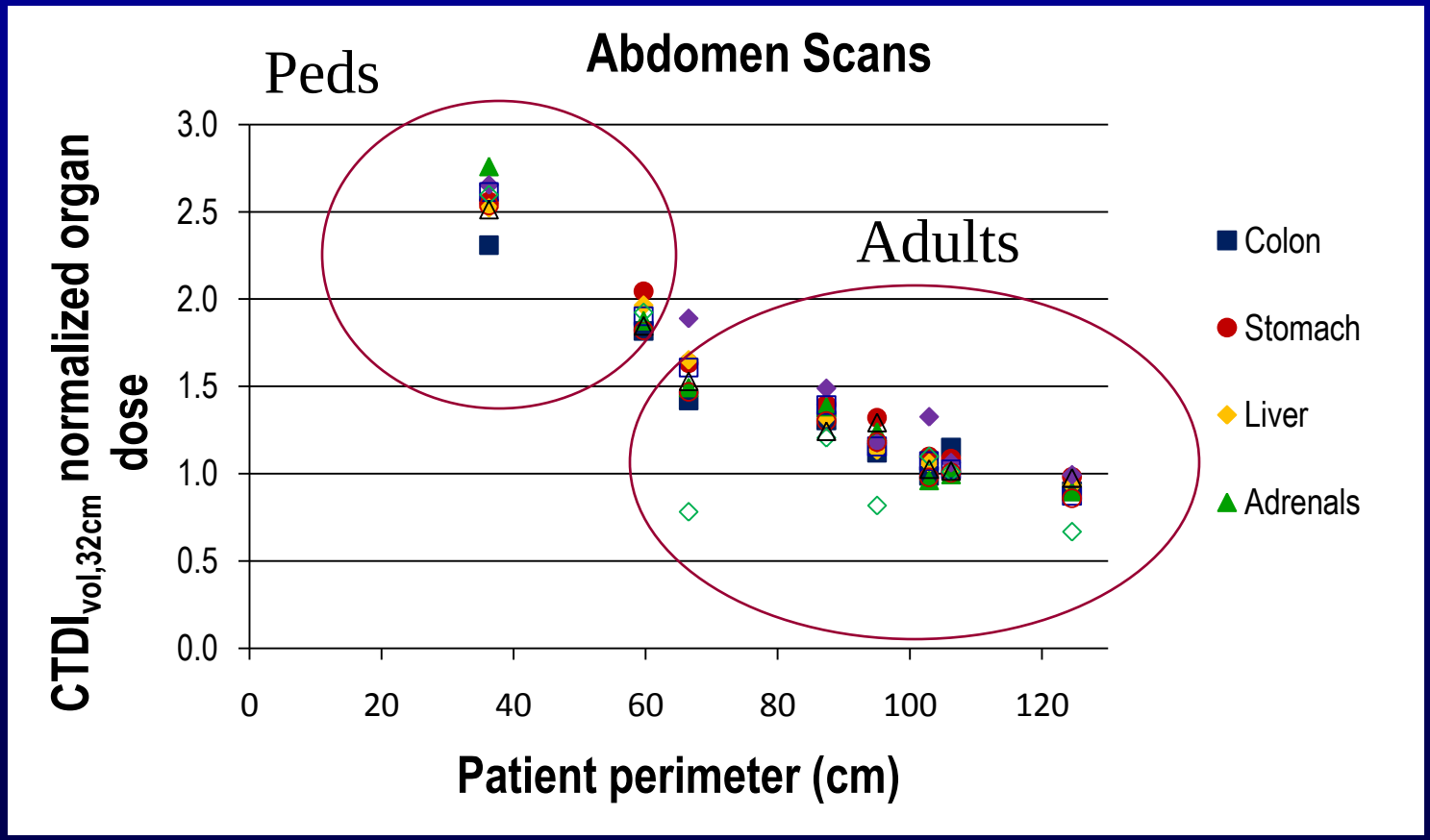
HOWEVER, Organ Dose Normalized by $CTDI_{vol}$ is essentially scanner independent; BUT NOT = 1.0!!!

Turner et al, RSNA 2009

How does Organ Dose change with Patient Size?



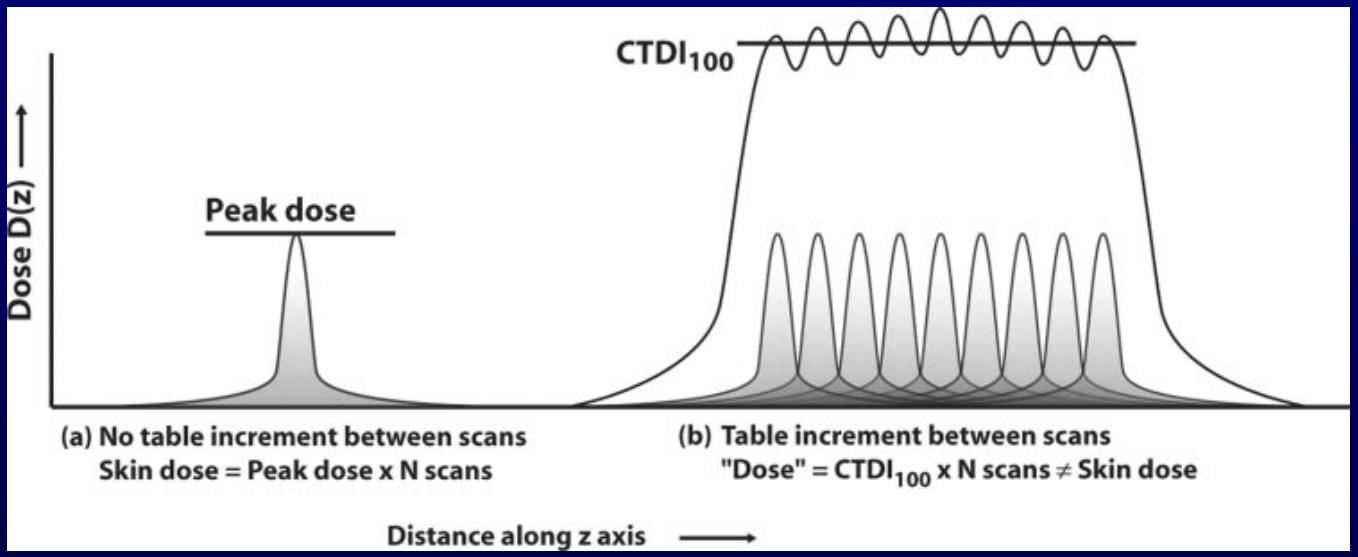
Turner et al, RSNA 2009 (32 cm diam reference)



Organ Dose – normalized by $CTDI_{vol}$ – is a pretty smooth exponential curve fit to patient size (here perimeter)

Does $CTDI_{vol}$ Indicate Peak Dose?

- $CTDI_{vol}$ is a weighted average of measurements made at periphery and center of cylindrical phantom
- Defined to reflect dose from a series of scans performed w/table movement

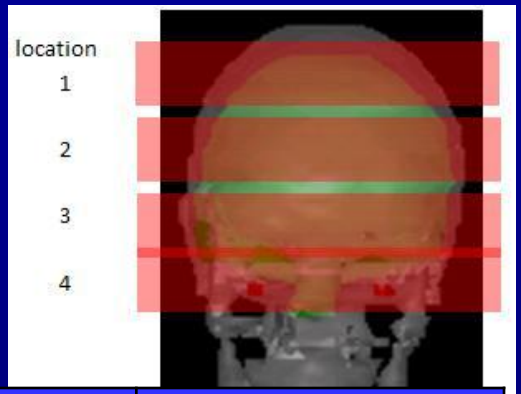


Does $CTDI_{vol}$ Indicate Peak Dose?

- $CTDI_{vol}$ is a weighted average of measurements made at periphery and center of cylindrical phantom
- Defined to reflect dose from a series of scans performed w/table movement
- Is not patient dose (not even skin dose)
- Typically OVERestimates skin dose in cases where scan is performed with no table movement (e.g. perfusion scans)

- BTW, AAPM TG 111 dose metric will do a better job here (specifically defines a measure with no table motion);
  - But still not patient dose (Dose to phantom)

Simulated Neuro Perfusion Scan (One location, No Table Movement)



	2Gy eye lens dose		$CTDI_{vol}$ predicted dose		2Gy skin dose		CTDIvol predicted dose	
	Total mAs	# rotations	Eye lens	%over	Total mAs	# rotations	Skin	%over
Loc4, 80kVp, 170mAs	87,900	517	3.4 Gy	70%	69,000	406	2.6Gy	30%
Loc1, 80kVp, 170mAs	9,694,300	57,026	372 Gy	18,500%	67,900	399	2.6Gy	30%
Loc4, 120kVp, 300mAs	22,400	75	3.1 Gy	55%	19,000	112	2.6Gy	30%

Summary of CTDI portion

- Summary of CTDIvol
  - Is not patient dose
  - Is dose to a reference sized phantom (reference can vary from Peds to Adult or it might be same)
  - Underestimates dose to small patients
  - Overestimates dose to very large patients

  - Is not skin dose (overestimates skin dose for perfusion scans)
  - TG 111 measurements (small chamber) will do a better job when that is standardized