CT Dosimetry Challenges Encountered in the Field

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No conflicts of interest, but

30+ years of consulting physics work, with an average of 112 CTs tested annually over past decade

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CT Dosimetry Challenges Encountered in the Field

Before making any $CTDI_{vol}$ measurements, I am assuming that you have already:

1. Established appropriate technique factors for the 4 (AH, AA, PH, PA) ACR image quality scans *(figuring those out could be a stand-alone talk)*.
2. Performed the 4 (AH, AA, PH, PA) ACR image quality scans.
3. Centered the $CTDI_{vol}$ phantom at some easily known table position

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CT Dosimetry Challenges Encountered in the Field

- The process of creating an axial scan to make $CTDI_{vol}$ measurements will have one or more of the following challenges in properly:
  1. Creating the axial scan.
  2. Setting the mA.
  3. Setting the kVp.
  4. Setting the beam width.
  5. Setting the rotation time.

(Oh, no, not done yet)

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CT Dosimetry Challenges Encountered in the Field

6. Selecting the SFOV/bowtie filter.
7. Setting multiple scans in the same location.
8. Dealing with Dose Notification Warnings.
9. Dealing with dual x-ray tube systems.
10. Dealing with dual energy scans.
11. Curating the peripheral exposure measurements.

(not quite a dirty dozen, but close)

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Helical $CTDI_{vol}$ Challenges Encountered in the Field

1. Creating the axial scan
   - Canon/Toshiba – convert the helical to S&V
   - GE – convert the helical to axial
   - Siemens, Philips, United Imaging – open a new scan
     - Find an axial (sequence) protocol for adult head or adult abdomen

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Helical $CTDI_{vol}$ Challenges Encountered in the Field

2. Setting the correct mA
   - Canon/Toshiba – no change needed
   - GE – undo where GE *helpfully* adjusted the mA to *correct* for the change in pitch
   - Siemens, Philips, United Imaging – calculate the mAs from effective mAs, also calculate mA to enter into the ACR dosimetry spreadsheet

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

3. Setting the correct kVp
   - Canon/Toshiba – no change needed
   - GE – no change needed
   - Siemens, Philips, United Imaging – make sure the kVp of the new axial $CTDI_{vol}$ scan matches the IQ scan, especially during pediatric (non-standard kVp) scans.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

4. Setting the beam width
   - Canon/Toshiba – Change beam width from 0.5x4 or 1x4 to 2x4, 4x4, 5x4, 8x4, or 10x4.
     - Make sure that it matches the IQ scan.
   - Except! Aquilion ONE – the 40 mm helical beam is not available in S&V, only in a Volume scan – set start at 20, set end at -20 to get a 40 mm beam.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

4. Setting the beam width
   - GE – usually no change needed
   - Except! if initial slice width is 3.75 mm, for all but the oldest 4 slice Lightspeed systems, GE changes the beam width to the 10 or 20 mm beam when the 20 or 40 mm beam was used in the IQ scan

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

4. Setting the beam width
   - Siemens, Philips, United Imaging – make sure the beam width of the new axial $CTDI_{vol}$ scan matches the IQ scan.
   - Except! Siemens Sensation doesn't have the 16x1.2 mm beam available in sequence scans – set it at 12x1.2 mm and adjust the spreadsheet's values for N, T, and I until the pitch matches the IQ scan.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

5. Setting the rotation time
   - Canon/Toshiba – no change needed
   - GE – no change needed
   - Siemens, Philips, United Imaging – make sure the rotation time of the new axial $CTDI_{vol}$ scan matches the IQ scan.
     - Except! Siemens sequence scans don't match their fast rotation helical scan's rotation times.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

6. Selecting the proper SFOV/bowtie filter
   - Canon/Toshiba – change only if the S SFOV was used for AA, PA IQ scans.
   - GE – no change needed, assuming you didn't change the SFOV during the IQ scans.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

6. Selecting the proper SFOV/bowtie filter
   - Siemens, Philips, United Imaging – no change, assuming you selected the head or abdomen sequence protocol appropriately
   - Except! Siemens Definition AS Pediatric Abdomen – need to use Adult Abdomen Sequence, then correct the exposure measurements.

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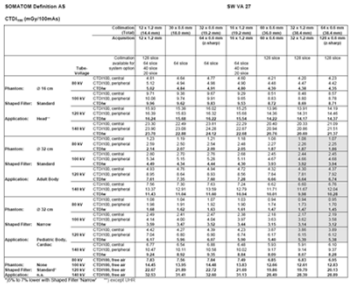
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

6. Siemens – Axial; Except! Pediatric Abdomen



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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

6. Siemens – Axial; Except! Pediatric Abdomen

		CTDIw	23.70	22.88	24.12	22.68	20.76	20.69	21.37
∅ 32 cm	80 kV	CTDI100, central	1.23	1.19	1.21	1.18	1.08	1.08	1.07
		CTDI100, peripheral	2.59	2.50	2.54	2.48	2.27	2.26	2.25
		CTDIw	2.14	2.07	2.09	2.05	1.87	1.87	1.86
Standard	100 kV	CTDI100, central	2.80	2.70	2.76	2.68	2.45	2.44	2.45
		CTDI100, peripheral	5.34	5.15	5.28	5.11	4.67	4.66	4.68
		CTDIw	4.49	4.34	4.44	4.30	3.93	3.92	3.94
Adult Body	120 kV	CTDI100, central	4.93	4.76	4.94	4.72	4.32	4.30	4.37
		CTDI100, peripheral	8.95	8.64	8.93	8.56	7.84	7.81	7.92
		CTDIw	7.61	7.35	7.66	7.28	6.66	6.64	6.74
	140 kV	CTDI100, central	7.56	7.30	7.63	7.24	6.62	6.60	6.76
		CTDI100, peripheral	13.37	12.91	13.59	12.79	11.71	11.67	12.04
		CTDIw	11.43	11.04	11.60	10.94	10.01	9.98	10.26
∅ 32 cm	80 kV	CTDI100, central	1.08	1.04	1.07	1.03	0.94	0.94	0.95
		CTDI100, peripheral	1.98	1.91	1.92	1.90	1.74	1.73	1.70
		CTDIw	1.68	1.62	1.63	1.61	1.47	1.47	1.45
Narrow	100 kV	CTDI100, central	2.49	2.41	2.47	2.38	2.18	2.17	2.19
		CTDI100, peripheral	4.14	4.00	4.04	3.97	3.63	3.62	3.58
		CTDIw	3.59	3.47	3.52	3.44	3.15	3.14	3.12
Pediatric Body, Cardiac	120 kV	CTDI100, central	4.42	4.27	4.39	4.23	3.87	3.86	3.89
		CTDI100, peripheral	7.04	6.80	6.90	6.74	6.17	6.15	6.12
		CTDIw	6.17	5.96	6.07	5.90	5.40	5.39	5.38
	140 kV	CTDI100, central	6.77	6.54	6.88	6.48	5.93	5.91	6.10
		CTDI100, peripheral	10.47	10.11	10.58	10.02	9.17	9.14	9.37
		CTDIw	9.24	8.92	9.35	8.84	8.09	8.07	8.28

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

6. Siemens; Except! Pediatric Abdomen

   For example: at 100 kVp, center:

   narrow bowtie = 2.17

   standard bowtie = 2.44

   So, multiply each of your center position readings by 2.17/2.44 = 0.889 to get the correct Ped Abd exposure

   Then, repeat similarly for the peripheral measurements.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

7. Setting multiple scans in the same location
   - Canon/Toshiba – set movement to 0.0 mm, set start location at 0.0, copy scans 2x to get 3 scans, set wait time, accept the warning.
   - GE – set interval to 0.0, set start/end location to bracket 0.0, set number of images to 3 x images/rotation to get 3 scans, set inter-scan delay time, accept the warning.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

7. Setting multiple scans in the same location
   - Philips - set increment to 0.0, graphically set start/end location to bracket 0.0, set number of cycles = 3, set cycle time, accept the warning.
   - United Imaging – set start location, set # of cycles = 1, repeat scan three times
     - because my meter won't reset in the unchangeable 6.0 second cycle time.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

7. Setting multiple scans in the same location
   - Siemens – depends on software version
     - Older: set Feed = 0, set # of scans = 3, set cycle time, accept the warning.
     - Newer: can't set Feed = 0, so must repeat each scan manually three times

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

8. Dealing with Dose Notification Warnings
   - Canon/Toshiba, GE – type in reason, accept
     - doesn't stop anything, just a pain
   - Siemens, Philips, United Imaging – no problem, assuming the head or abdomen sequence CTDIvol protocol doesn't have a DNV programmed

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

9. Dealing with dual x-ray tube systems
   - Only Siemens FLASH systems
     - Only Tube A fires during Sequence scans
     - Assign the total mAs from both tubes to Tube A when calculating mA for spreadsheet.
     - Assumes that the output of Tube B is the same as Tube A's is.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

10. Dealing with dual energy scans
    - Canon/Toshiba - two Volume scans in rapid succession
      - should be able to measure like Cone Beam CT
      - personally, never done it
    - GE – rapid switching of kVp within one rotation
      - should be able to measure like axial scan
      - personally, never done it

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

10. Dealing with dual energy scans
    - Philips - two layer detector
      - measure like axial scan
    - United Imaging – if they have dual energy, I'm unaware of it.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

10. Dealing with dual energy systems
    - Siemens FLASH systems
      - Can't be done because only Tube A fires during Sequence scans
      - Maybe if you repeated two Sequence scans with appropriate kVp and mAs and summed the exposures, but still assuming Tube A = Tube B.

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Helical $CTDI_{vol}$ Challenges
Encountered in the Field

11. Curating the peripheral exposure measurements
    - **All** systems
      - Lead edge of the fan beam overlaps with the trail edge of the fan beam in a single rotation causing a falsely high exposure if that overlap occurs where the peripheral ion chamber is positioned.

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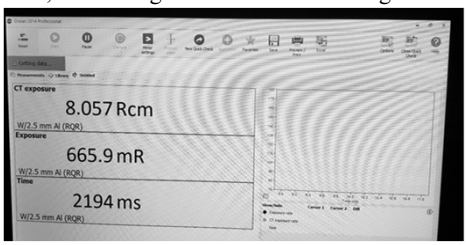
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

- So, what is a good result? Is this one good?



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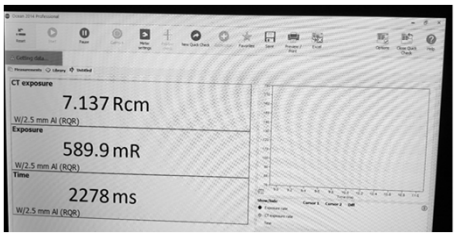
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

- How about this next one?



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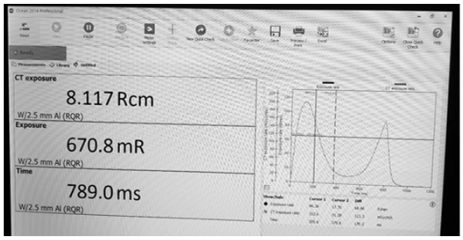
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

- Some additional info will help.



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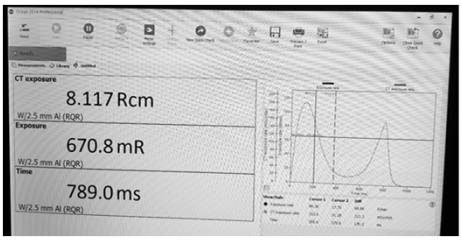
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

- So, that's a NO!



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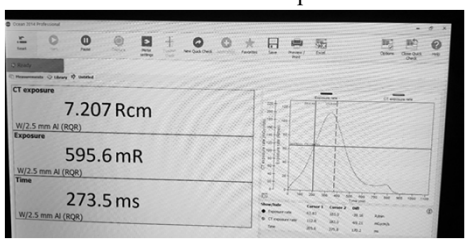
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

- Some additional info will help.



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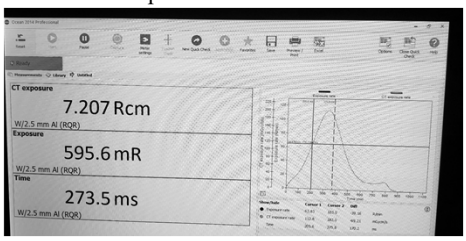
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

- That's a keeper!



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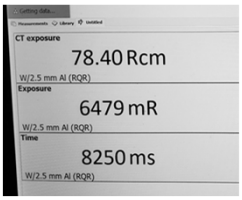
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

- Now, helical. Which of these two measurements is the correct peripheral result?



or

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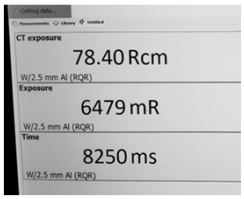
Helical $CTDI_{vol}$ Dosimetry
Is Easier!

- That was a trick question, but answerable without additional waveform information.



or

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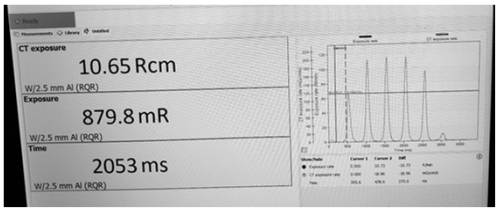
Helical $CTDI_{vol}$ Challenges
Encountered in the Field

- Example of why that happened
  - Different techniques, with 5 revolutions instead of 10.



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Helical $CTDI_{vol}$ Dosimetry
Is Easier!

Scoreboard (low score wins)

	Helical Steps	Axial Steps
Canon/Toshiba	6	10 or 11
GE	6	15
Philips	5	19
United Imaging	5	14
Siemens	6	16, 18, 19, 22, or #$%!

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Helical $CTDI_{vol}$ Dosimetry
It Reduces Potential Errors!

- Canon/Toshiba (repeated ACR scan) – we can err during axial scans by:
  1. Incorrect beam width
  2. Incorrect scan field of view (bowtie)
  3. Movement not zero
  4. Inappropriate peripheral exposure curating

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Helical $CTDI_{vol}$ Dosimetry
It Reduces Potential Errors!

- GE (repeated ACR scan) – we can err by:
  1. Incorrect mA
     (after GE *helpfully* adjusted the mA to *correct* for the change in pitch)
  2. Incorrect beam width
     (if initial helical slice width is 3.75 mm)
  3. Inappropriate peripheral exposure curating

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Helical $CTDI_{vol}$ Dosimetry
It Reduces Potential Errors!

- Philips (non-repeated ACR scan) – we can err by:
  1. Incorrect beam width
  2. Incorrect scan field of view (bowtie)
  3. Incorrect mAs / DoseRight left ON
  4. Incorrect rotation time
  5. Scan increment not set at zero
  6. Inappropriate peripheral exposure curating

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Helical $CTDI_{vol}$ Dosimetry
It Reduces Potential Errors!

- United (non-repeated ACR scan) – we can err by:
  1. Incorrect beam width
  2. Incorrect scan field of view (bowtie)
  3. Incorrect mAs / U-Dose left ON
  4. Incorrect rotation time
  5. Scan increment not set at zero
  6. Inappropriate peripheral exposure curating

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Helical $CTDI_{vol}$ Dosimetry
It Reduces Potential Errors!

- Siemens (non-repeated ACR scan) – we can err by:
  1. Incorrect beam width
  2. Incorrect scan field of view (bowtie)
  3. Incorrect mAs / CAREdose still ON
  4. Incorrect rotation time
  5. Feed not set at zero
  6. Tube B not matching Tube A
  7. Inappropriate peripheral exposure curating

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Helical $CTDI_{vol}$ Dosimetry
It Reduces Potential Errors!

- All helical scans – we can err by:

1. Incorrect beam location
2. Incorrect Scan Field of View (if the clinical SFOV was adjusted to fit the ACR phantom)

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Helical $CTDI_{vol}$ Dosimetry
It Reduces Potential Errors!

Scoreboard (low score wins)	Helical Errors	Potential Axial Errors
Canon/Toshiba	2	4
GE	2	3
Philips	2	6
United Imaging	2	6
Siemens	2	7

(I'd say those 2 helical errors are either rare or easy to avoid)

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Helical $CTDI_{vol}$ Dosimetry
It Works!

- Agrees with my axial $CTDI_{vol}$ measurements (46 scanners, 5 manuf., 18 models, 140 protocols)
  - 136 of 140 Helical $CTDI_{vol}$ are within 10% of the Axial $CTDI_{vol}$
  - 93 of 140 Helical $CTDI_{vol}$ are within 5% of the Axial $CTDI_{vol}$
  - Worst was 17.6% different (FLASH, pitch = 3), where the helical $CTDI_{vol}$ looked more accurate

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Helical $CTDI_{vol}$ Dosimetry
It Works!

- Agrees with manufacturer's $CTDI_{vol}$ predictions
  - Of the 47 Helical CTDIvol that varied more than 5% from the Axial $CTDI_{vol}$:
    - 20 Helical $CTDI_{vol}$ were closer to the prediction.
    - 23 Axial $CTDI_{vol}$ were closer to the prediction.

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Helical $CTDI_{vol}$ Dosimetry
It has better reproducibility!

- Helical measurement's variation from average
  - C/T: <0.9% (center), <0.9% (periphery)
  - GE: <1.8% (center), <4.0% (periphery)
  - Philips: <1.4% (center), <1.6% (periphery)
  - Siemens: <1.6% (center), <7.7% (periphery)
  - United: <0.6% (center), <0.6% (periphery)

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Helical $CTDI_{vol}$ Dosimetry
It has better reproducibility!

- Curated Axial measurement's variation from average
  - C/T: <3.0% (center), <3.0% (periphery)
  - GE: <1.8% (center), <2.0% (periphery)
  - Philips: <1.2% (center), <2.4% (periphery)
  - Siemens: <2.9% (center), <2.1% (periphery)
  - United: <0.5% (center), <1.9% (periphery)

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Helical CTDIvol Dosimetry
It has better reproducibility!

- What does this mean?
  - Whereas: the overall reproducibility of uncurated exposure measurements in the helical mode is slightly better than curated measurements in the axial mode
  - Whereas: the helical methodology is already acquiring data from 3 to 21 revolutions of the tube (>= axial)

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Helical $CTDI_{vol}$ Dosimetry
It has better reproducibility!

- What does this mean?
  - Whereas: performing 24 helical scans in short succession does cause significant tube heating (a problem primarily with older, wimpier systems)
  - Whereas: performing $CTDI_{vol}$ measurements currently takes 30 to 45 minutes per scanner

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Helical $CTDI_{vol}$ Dosimetry
It has better reproducibility!

- What does this mean?
  - I Propose: Performing only two helical acquisitions (one center, one peripheral) is sufficient to make an acceptably accurate $CTDI_{vol}$ measurement.
    - You can say, I heard it here first!

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CT Dosimetry Challenges Encountered in the Field

Summary: for $CTDI_{vol}$ measurements:

I. Is easier? Winner = Helical
II. Reduces potential errors? Winner = Helical
III. Works? I'd call it a Tie
IV. Is more reproducible? Winner = Helical

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CT Dosimetry Challenges Encountered in the Field

- Questions?
  - Other than, why haven't we implemented the helical $CTDI_{vol}$ dosimetry methodology yet?

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