Best Practices Guidelines for CT-guided Interventional Procedures

A. Kyle Jones, PhD, FAAPM, Robert (Bob) Dixon, M.D., Jeremy Collins, MD, Eric Walser, MD, Boris Nikolic, MD

on behalf of the Society of Interventional Radiology Health and Safety Committee

Disclosure

- A. Kyle Jones, Ph.D. is President of FluoroSafety, a company that produces CME on quality and safety in medical imaging

- Neither FluoroSafety nor its products will be discussed in this talk

SIR Health and Safety Committee

- Now the “Safety and Professional Development Workgroup”
- Greatest hits include:
- *Guidelines for Patient Radiation Dose Management* J Vasc Interv Radiol **20**:S263-S273 (2009)
- *Occupational Radiation Protection of Pregnant or Potentially Pregnant Workers in IR: A Joint Guideline of the Society of Interventional Radiology and the Cardiovascular and Interventional Radiological Society of Europe* J Vasc Interv Radiol **26**:171-181 (2015)
- *Society of Interventional Radiology: Occupational Back and Neck Pain and the Interventional Radiologist* J Vasc Interv Radiol **28**:195-199 (2017).

Best Practices Guidelines

- Consensus document authored by content experts, including representatives from the parent SIR committee
- Reviewed by the parent committee, and goes through the standard review process at the *Journal of Vascular and Interventional Radiology*

CTBPG authors

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SIR support

- Debbie Katsarellis

Accessing the CTBPG

- The document was too long to be included in full in JVIR
- Instead, a brief executive summary was published with a link to the full CTBPG
- Open Access at JVIR


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A. Kyle Jones, PhD[a,*], Robert G. Dixon, MD[b], Jeremy D. Collins, MD[c], Eric M. Walser, MD[d], Boris Nikolic, MD, MBA[e] on behalf of the Society of Interventional Radiology Health and Safety Committee

PlumX Metrics

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Article Info

Abstract | Full Text | References | Supplemental Materials

Computed tomography (CT)–guided procedures performed by interventional radiology have increased in scope and number in part because of the imaging revolution sparked by advances in CT. Modern CT scanners feature wide detector arrays that enable increased coverage of patient anatomy in a single rotation. Considering advances in CT scanner technology and the increasing use of CT in interventional radiology, it is important that interventional radiologists observe best practices for CT-guided procedures, including acquiring images of only the quality necessary to safely and accurately access a target and participating in radiation management and monitoring efforts.

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Society of Interventional Radiology: Background and Necessity of the Best Practices Guidelines for CT-Guided Interventional Procedures is available online at www.jvir.org.

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J Vasc Interv Radiol **29**:518-519 (2018)

Accessing the CTBPG

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J Vasc Interv Radiol **29**:518-519 (2018)

Major content areas

- CT dose indices
- Documentation of CT guided procedures
- Minimum equipment requirements
- Phases of CT-guided procedures
- Determinants of image quality in CT
- Strategies for optimizing technical factors

Major content areas

- Ultrasound as an alternative/adjunct
- Radiation management
- Radiation protection
- Quality improvement
- Staffing levels for CT-guided procedures

Documentation of CT-guided procedures

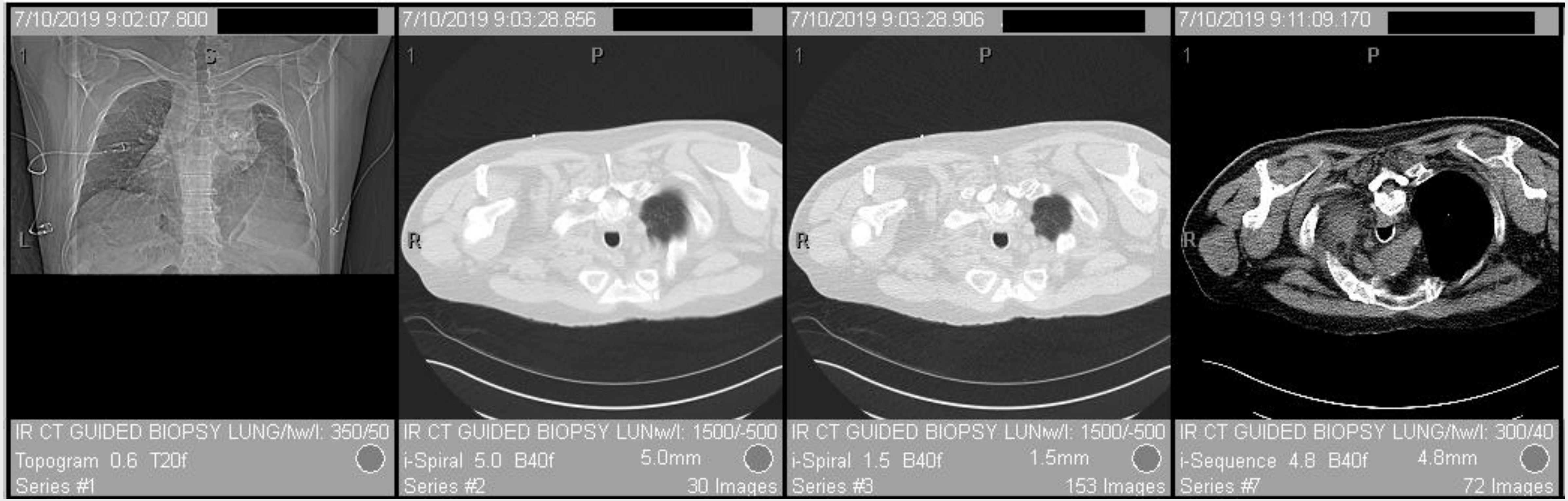
- Minimum requirements outlined in *ACR-SIR-SPR Practice Parameter for the Reporting and Archiving of Interventional Radiology Procedures*
- Considering that the marginal cost for storing additional images is essentially 0, may consider archiving all images
- Configuration options provided by manufacturers may be inflexible

Equipment

- Multidetector CT capable of covering an axial extent of at least 10 mm in a single rotation
- Can produce at least 3 images/rotation
- Basic dose reporting capabilities
  - Prospective display of $CTDI_{vol}$ and DLP
  - Itemization of scan parameters for each acquisition
  - Reporting of of total $CTDI_{vol}$ and DLP for the procedure
  - Capable of permanently archiving total procedural dose indices

Phases of CT-guided procedures

- Scout
- Pre-procedure planning scan (PPS)
- Intervention phase
- Post-procedure scan



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L
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Topogram 0.6 T20f
Series #1
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R
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5.0mm
Series #2
30 Images
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i-Spiral 1.5 B40f
1.5mm
Series #3
153 Images
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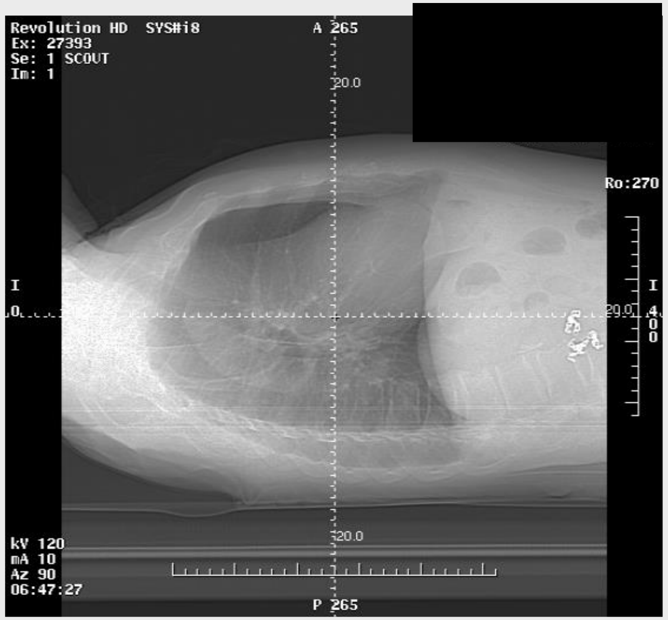
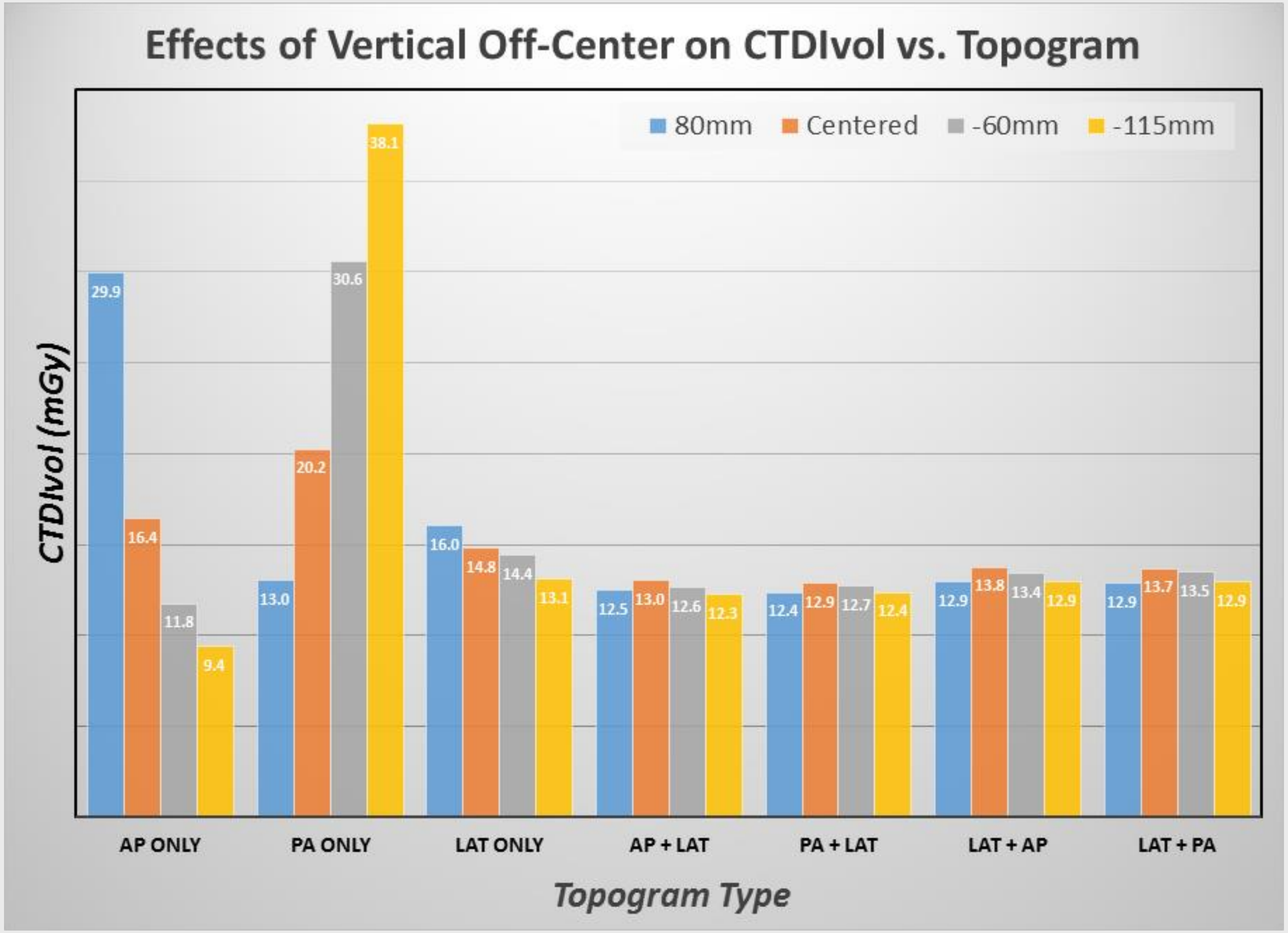
P
R
IR CT GUIDED BIOPSY LUNG/w/l: 300/40
i-Sequence 4.8 B40f
4.8mm
Series #7
72 Images

Scout

- Very minor impact on patient dose
- Should include sufficient extent to identify necessary landmarks
- Center the patient to the extent possible
- Often good practice to perform 2 scouts (AP and lateral) to ensure appropriate operation of tube current modulation (TCM)




Effects of Vertical Off-Center on CTDIvol vs. Topogram
80mm
Centered
-60mm
-115mm
CTDIvol (mGy)
29.9
16.4
11.8
9.4
13.0
20.2
30.6
38.1
16.0
14.8
14.4
13.1
12.5
13.0
12.6
12.3
12.4
12.9
12.7
12.4
12.9
13.8
13.4
12.9
12.9
13.7
13.5
12.9
AP ONLY
PA ONLY
LAT ONLY
AP + LAT
PA + LAT
LAT + AP
LAT + PA
Topogram Type

Pre-procedure planning scan (PPS)

- Typically helical
- Extent should be limited (e.g., 75 mm) – lesion location is known from prior imaging and landmarks are included in the scout
- Techniques should be adapted to indication and patient size
- Should contribute no more than 50% of total procedural dose-length product (DLP)

Technical factor selection

- Technical factors should be adapted to indication and patient size, as they are for diagnostic CT

- Different implementations of interventional CT present different challenges

Indication	qref mAs
Lung biopsy	50
Abdomen/pelvis biopsy	100
Solid organ biopsy	150
Solid organ ablation	200

Intervention phase

- May be done using axial, helical, or CT fluoroscopy
  - If helical, scan range should be limited to that used for the PPS or less

- Techniques should again be adapted to patient size
  - Automatically (may not be possible, depending on manufacturer and mode)
  - Manually (can also match to TCM-selected techniques from PPS)

- Dose accumulation can be monitored by observing total $CTDI_{vol}$

Post-procedure scan

- Not always acquired, used to verify therapeutic endpoint or to identify complications
  - May use iodine contrast, timing considerations

- Should be performed similarly to PPS, although a longer scan range may be necessary

Monitoring and managing radiation dose (intra-procedure)

- Relies primarily on scanner-reported dose indices

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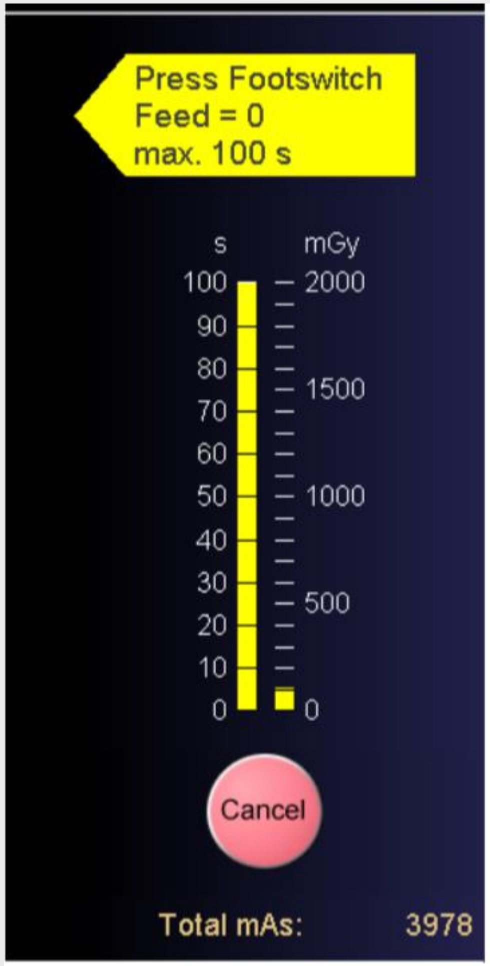
- Some rudimentary tools are provided by manufacturers



Monitoring and managing radiation dose (intra-procedure)

- Relies primarily on scanner-reported dose indices
- Some rudimentary tools are provided by manufacturers
- Model for estimating skin dose from $CTDI_{vol}$

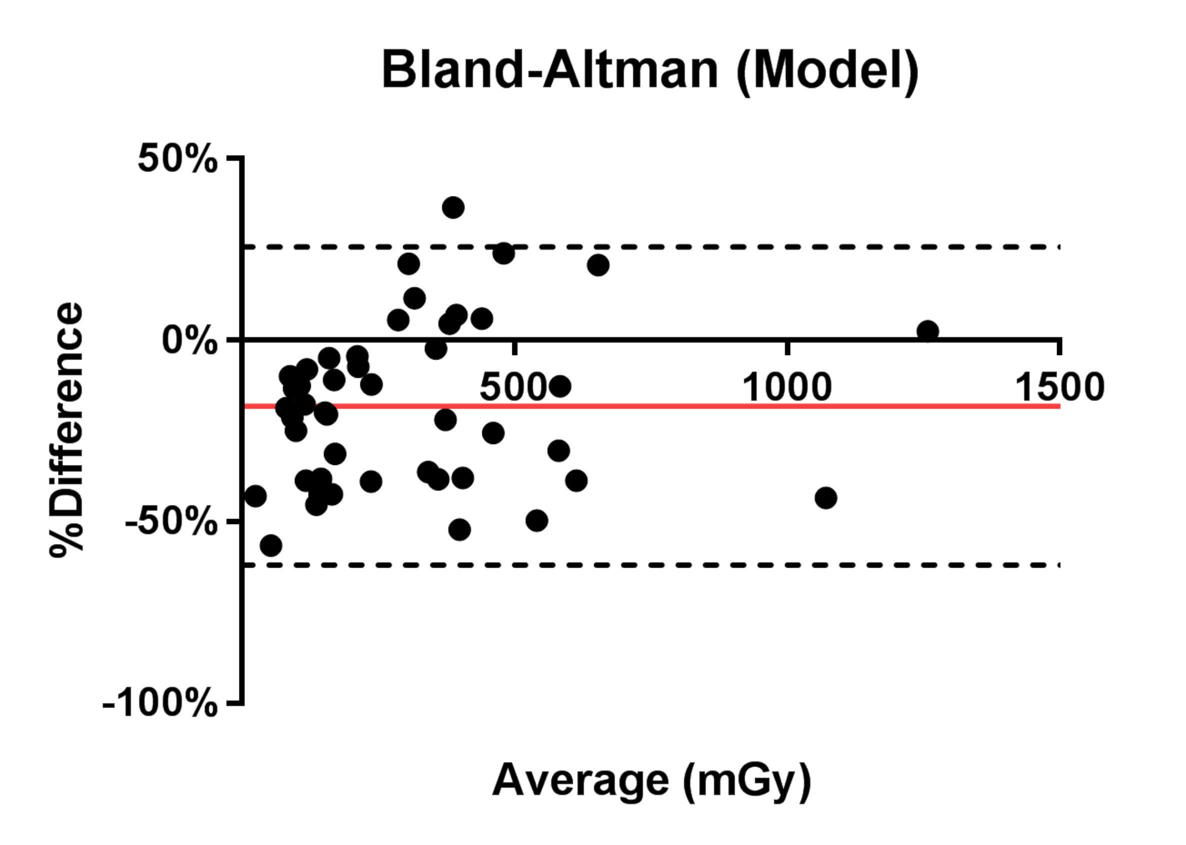
$$CTDI_{vol} = CTDI_w / pitch$$

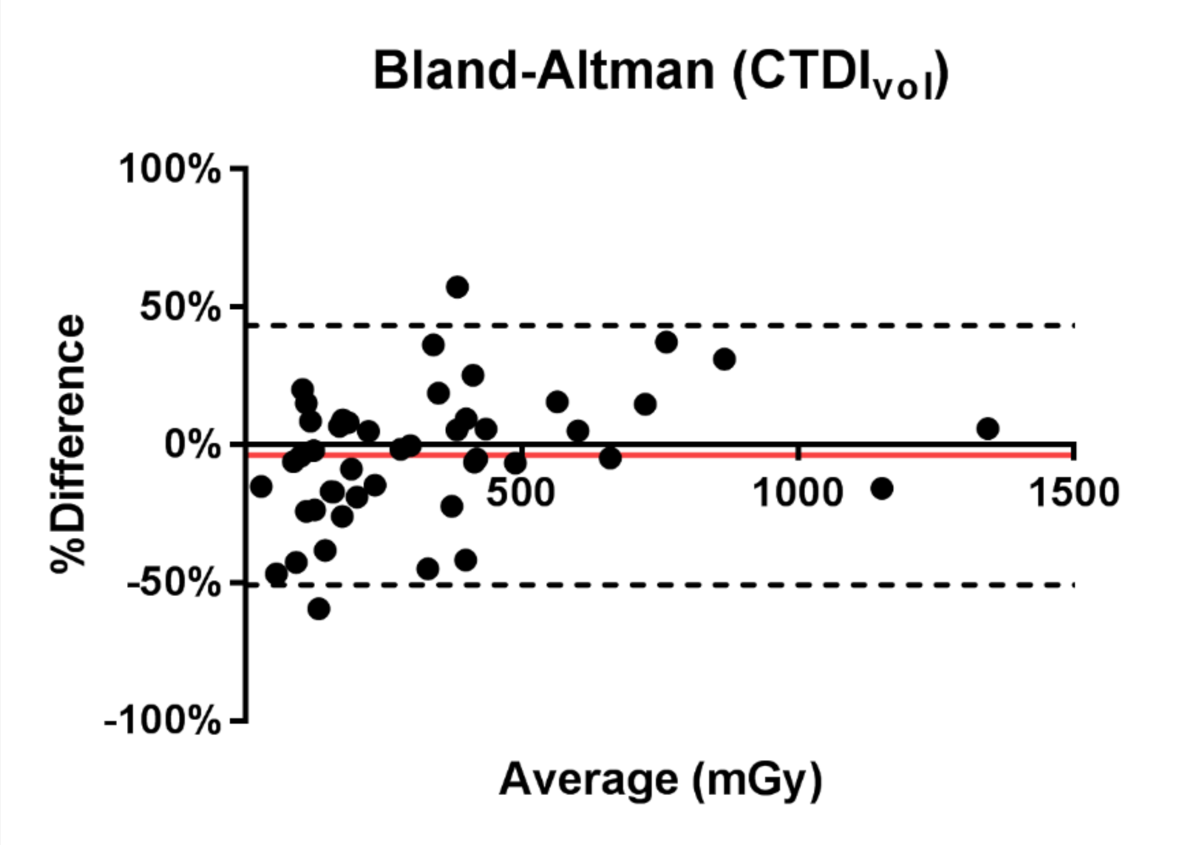
$$CTDI_w = \frac{1}{3} CTDI_{center} + \frac{2}{3} CTDI_{peripheral}$$

$$\text{skin dose} = \begin{cases} CTDI_{peripheral} & \text{helical mode} \\ 0.5 \times CTDI_{peripheral} & \text{intermittent mode} \end{cases}$$

$$\text{skin dose} = \begin{cases} 1.2 \times CTDI_{vol} & \text{helical mode} \\ 0.6 \times CTDI_{vol} & \text{intermittent mode} \end{cases}$$

Leng S et al. *Am J Roentgenol* **197**:W97-W103 (2011)


Bland-Altman (Model)
50%
0%
-50%
-100%
%Difference
500
1000
1500
Average (mGy)


Bland-Altman (CTDIvol)
100%
50%
0%
-50%
-100%
%Difference
500
1000
1500
Average (mGy)

$p < 0.0001$

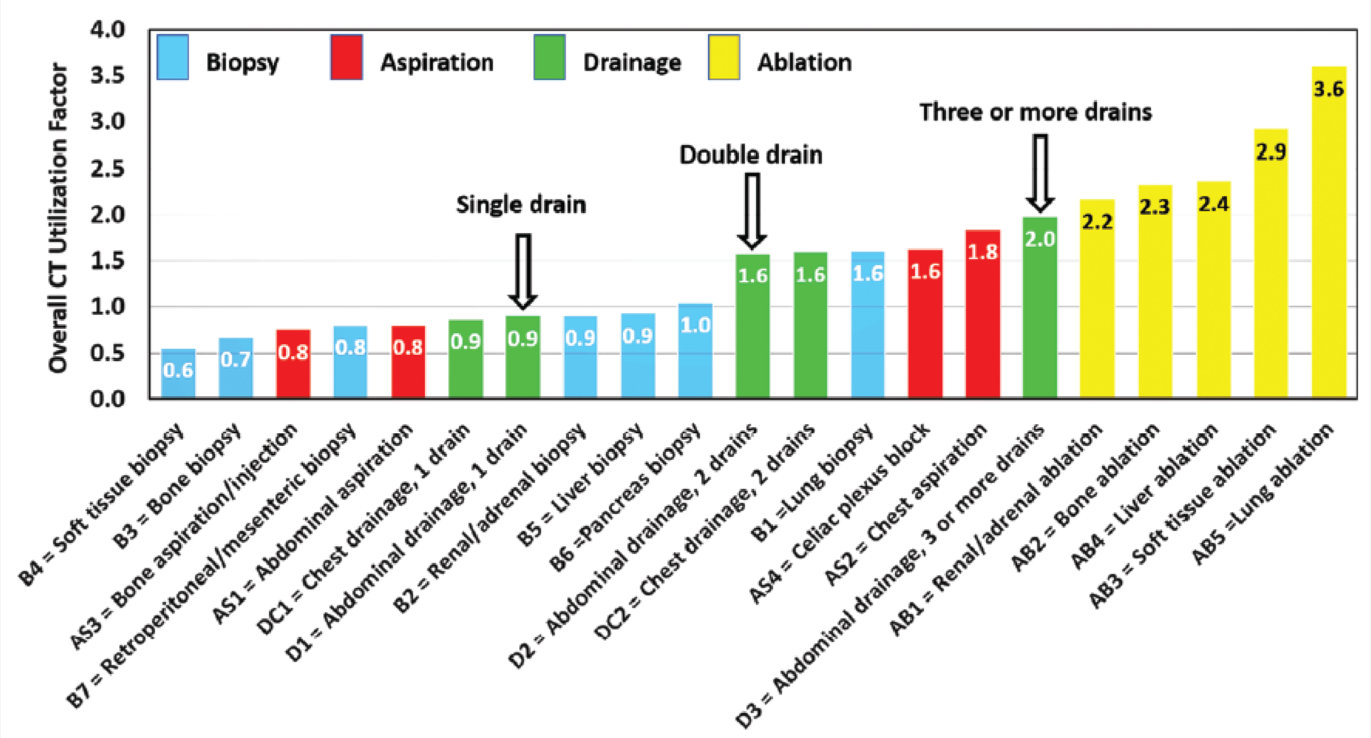
$p = 0.29$

CT dose indices

CT dose metric	Describes	Fluoro analog	Use
$CTDI_{vol}$	Scanner output	$K_{a,r}$	Notification levels
DLP	Total energy imparted	P_{KA}	Total radiation burden to patient, proportional to scatter (i.e., operator dose)

Monitoring and managing radiation dose (across procedures)

- Different problem than diagnostic CT
  - Procedures are not as "standard", although there is some standardization



Yang K et al. *Radiology* **289**:150-157 (2018)

Table 2: Procedure-specific Dose Metric Distributions

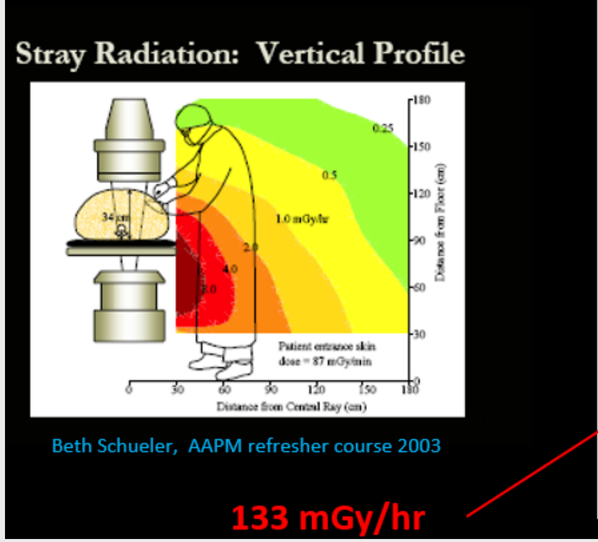
Category	No. of Procedures	DLP (mGy · cm) 25th Percentile	DLP (mGy · cm) 50th Percentile	DLP (mGy · cm) 75th Percentile	$CTDI_{sw}$ (mGy) 25th Percentile	$CTDI_{sw}$ (mGy) 50th Percentile	$CTDI_{sw}$ (mGy) 75th Percentile	Scan-length-weighted SSDE (mGy) 25th Percentile	Scan-length-weighted SSDE (mGy) 50th Percentile	Scan-length-weighted SSDE (mGy) 75th Percentile
Ablation										
AB1	187	1678	2364	3594	9.8	10.8	15.5	11.6	13.1	17.6
AB2	43	817	1987	3472	9.8	12.6	19.0	12.9	18.1	22.8
AB3	28	2239	2788	4293	9.7	11.2	14.0	12.1	13.7	16.6
AB4	394	1612	2351	3405	9.8	10.3	12.9	11.7	12.9	15.9
AB5	27	791	1446	2088	5.9	6.7	8.4	7.6	9.1	11.0
Aspiration										
AS1	145	721	1103	1769	9.8	14.9	20.3	12.6	17.1	23.7
AS2	282	488	657	929	4.8	6.1	8.7	6.8	8.9	12.0
AS3	257	573	923	1471	14.3	19.9	25.1	19.1	25.0	32.6
AS4	60	719	1377	2107	9.8	12.3	14.5	13.3	15.7	19.2
Biopsy										
B1	884	443	569	801	4.8	6.4	8.3	7.0	8.8	12.0
B2	547	762	1167	1758	9.8	13.1	19.9	11.5	15.2	22.7
B3	760	462	733	1086	14.2	18.3	23.3	19.5	25.3	31.1
B4	253	452	683	1038	12.2	18.3	23.3	17.1	23.6	32.5
B5	997	771	1175	1903	9.8	12.3	18.5	12.5	15.7	23.2
B6	25	785	1199	1713	9.8	10.9	14.3	11.9	13.9	18.3
B7	959	685	1029	1542	9.8	13.0	19.7	12.4	16.0	23.4
Drainage										
D1	1571	748	1125	1866	9.8	11.7	19.0	12.0	14.8	22.8
D2	279	1514	2233	3442	9.8	15.9	22.0	12.7	18.3	25.4
D3	127	1813	2777	4281	9.8	13.2	21.6	11.4	15.6	24.8
DC1	354	697	1043	1686	9.8	9.8	18.2	11.6	14.3	22.8
DC2	34	1276	2282	3684	9.8	12.0	20.0	11.7	14.7	24.8
Overall	8213	643	1043	1798	9.8	11.6	18.8	11.5	14.9	23.2

Note.—Category definitions are provided in Table 1. $CTDI_{sw}$ = scan-length-weighted CT dose index, DLP = dose-length product, SSDE = size-specific dose estimate.

Yang K et al. *Radiology* **289**:150-157 (2018)

Operator dose

- Proportional to procedural DLP
- Can be really close to zero depending on how you practice
  - Although you may be surprised if you evaluate the scatter distribution in the room – each situation is rather unique
- NVLAP-accredited daily-read dosimeters are now on the market



	1.5 m	1.0 m	0.5 m	0.0 m	0.5 m	1.0 m	1.5 m
1.5 m	0.015	0.038	0.047	0.051	0.045	0.038	0.014
1.0 m	0.004	0.029	0.094	0.115	0.090	0.032	0.004
0.5 m	0.002	0.004	0.207	0.423	0.194	0.004	0.002
0.0 m	0.002						0.002
0.5 m	0.005	0.031	0.253	0.513	0.176	0.037	0.006
1.0 m	0.036	0.064	0.102	0.125	0.100	0.067	0.033
1.5 m	0.031	0.039	0.050	0.053	0.048	0.041	0.029
2.0 m	0.022	0.025	0.029	0.030	0.028	0.027	0.022
2.5 m	0.016	0.018	0.019	0.019	0.018	0.018	0.016
3.0 m	0.012	0.012	0.014	0.013	0.013	0.013	0.012