Uncertainty Contributors in CTDI Benchmarking

Raman Rana, PhD, DABR; Bradie Frizzell, MS
The University of Oklahoma Health Sciences Center

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

INTRODUCTION

Computed Tomography Dose Index (CTDI) is the standard metric used to characterize radiation output from CT scanners and serves as the foundation for scanner acceptance testing, quality assurance (QA), accreditation, protocol optimization, and dose benchmarking.

Although CTDI measurement methodology is well standardized by national and international guidelines, practical implementation can vary between institutions and physicists.

Small differences in phantom positioning or measurement technique are often assumed to have negligible effects, yet these factors may introduce systematic errors into measured CTDI values and compromise the accuracy of scanner benchmarking.

Understanding these sources of variability is essential for ensuring reproducible measurements and meaningful comparison of CT performance across scanners and institutions.

This study investigates two practical sources of CTDI measurement uncertainty, namely phantom placement geometry and peripheral sampling strategy, and quantifies their impact on CTDI measurements under routine clinical conditions.

OBJECTIVE

To quantify the uncertainty introduced by phantom positioning and peripheral sampling strategy during CTDI benchmarking and evaluate their impact on measurement accuracy and reproducibility.

Acknowledgements:

The authors thank Dr. Jon Box and Claire Tran for their assistance with the initial data collection for this study.

METHODS AND MATERIALS

CTDI Measurements

- CTDI measurements of adult head and abdomen protocols were performed on multiple clinical CT scanners using a 16-cm head phantom and a 32-cm body phantom.
- A 100-mm pencil ionization chamber and calibrated electrometer were used following the standard CTDI measurement methodology.

Phantom Placement Study

Adult head CT protocols were measured using two phantom positioning methods:
- Manufacturer-supplied head holder
- Directly on the patient table

For each setup, CTDI measurements were obtained at:
- Center
- 12 o'clock
- 3 o'clock
- 6 o'clock
- 9 o'clock

Mean peripheral CTDI, $CTDI_w$, $CTDI_{vol}$, and DLP were calculated and compared.

Peripheral Sampling Study

To evaluate angular sampling uncertainty,
- Peripheral CTDI measurements from each individual position were analyzed independently.
- Results from each peripheral location were compared with the average of all four peripheral measurements.
- The effect of using a single peripheral measurement on CTDIw and CTDIvol was quantified.

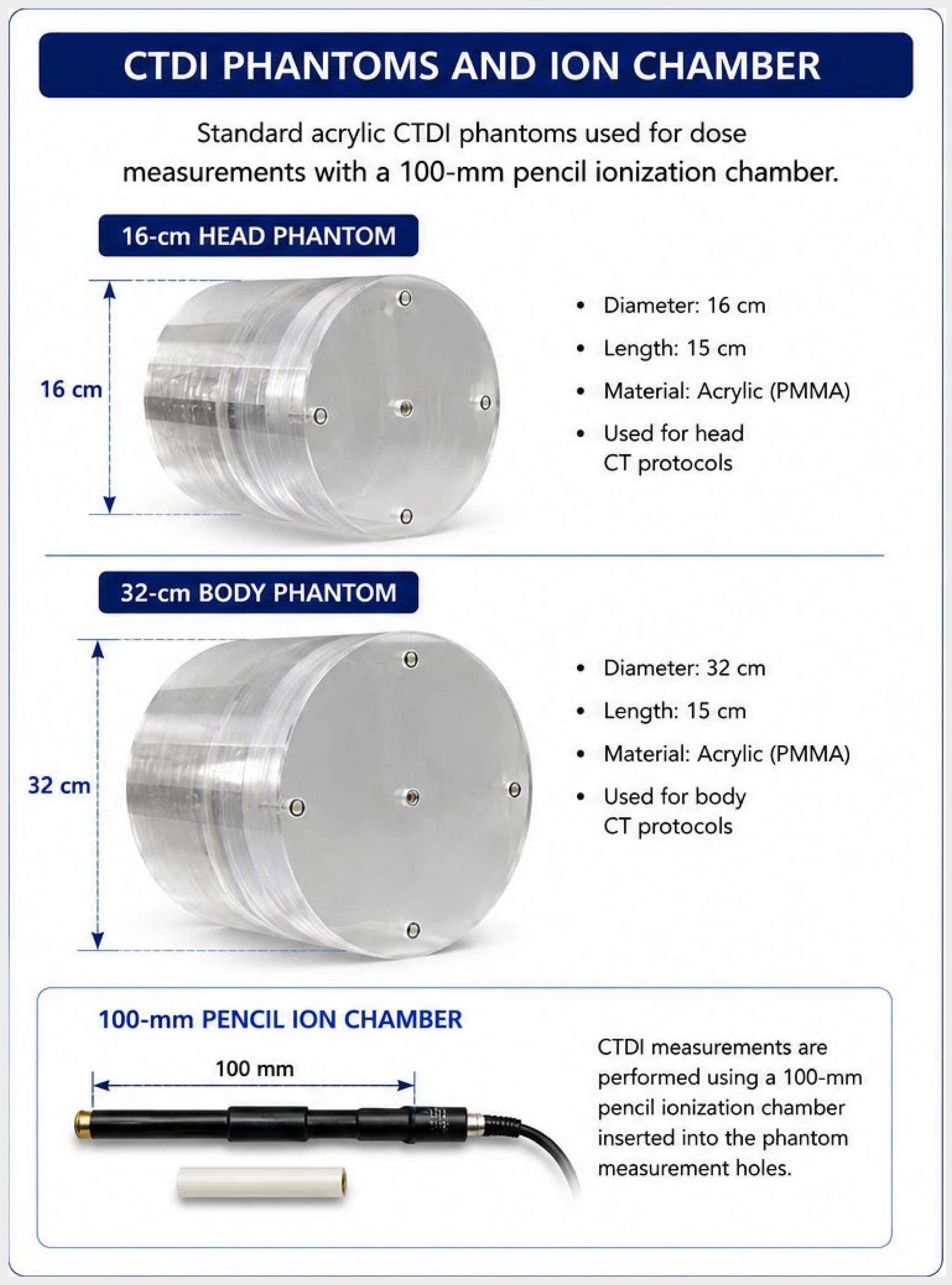

Figure 1. Standard CTDI phantoms and 100-mm pencil ionization chamber used for CT dose measurements. A 16-cm diameter head phantom and a 32-cm diameter body phantom composed of polymethyl methacrylate (PMMA) were used to perform CTDI measurements following the standard CTDI methodology. A calibrated 100-mm pencil ionization chamber was inserted into the phantom measurement holes to acquire CTDI data.

METHOD AND MATERIALS

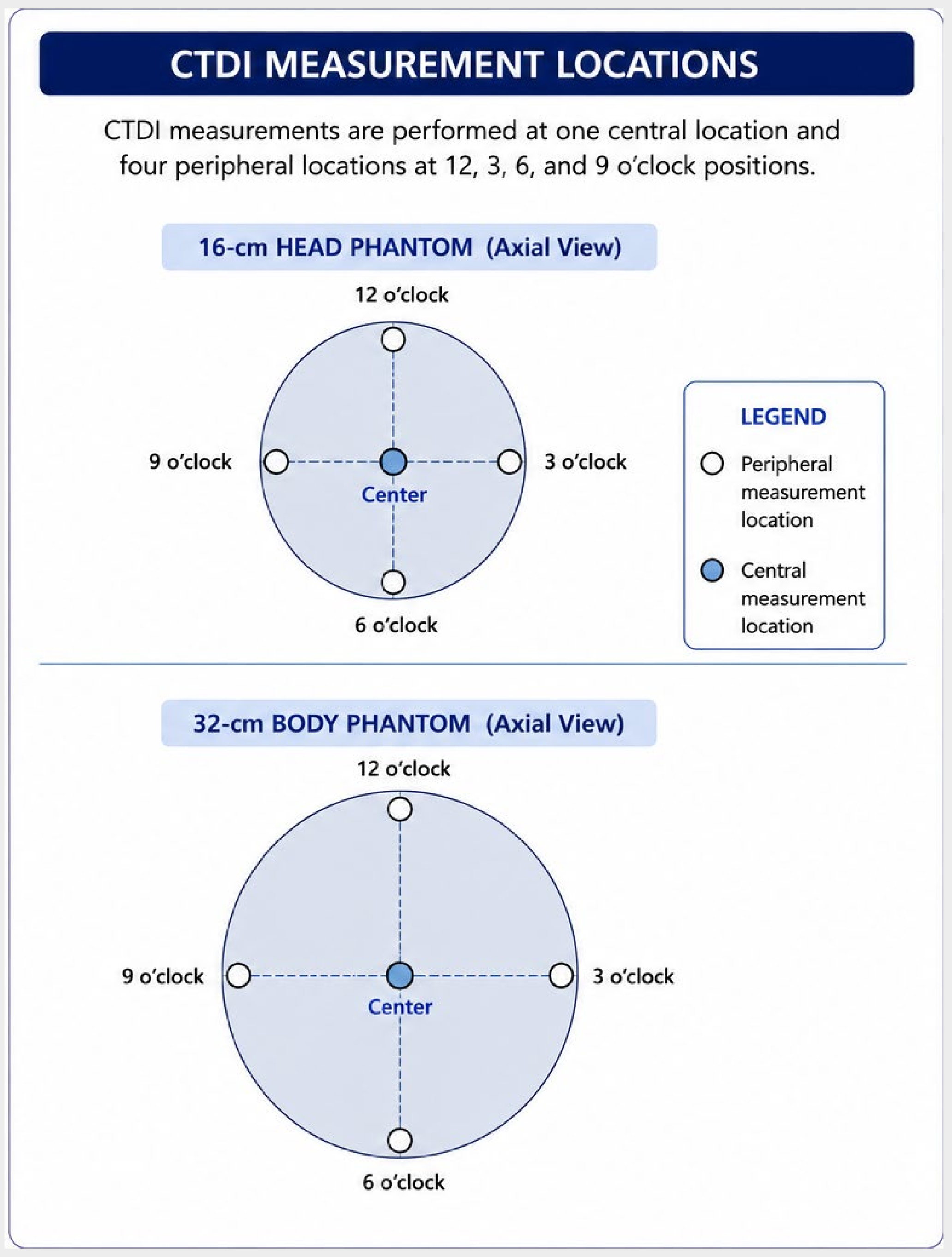

Figure 2. Standard CTDI measurement geometry showing the center and four peripheral measurement locations (12, 3, 6, and 9 o'clock) for the 16-cm head and 32-cm body CTDI phantoms. CTDI measurements were obtained at all five locations, and the average peripheral measurements were used for calculations.

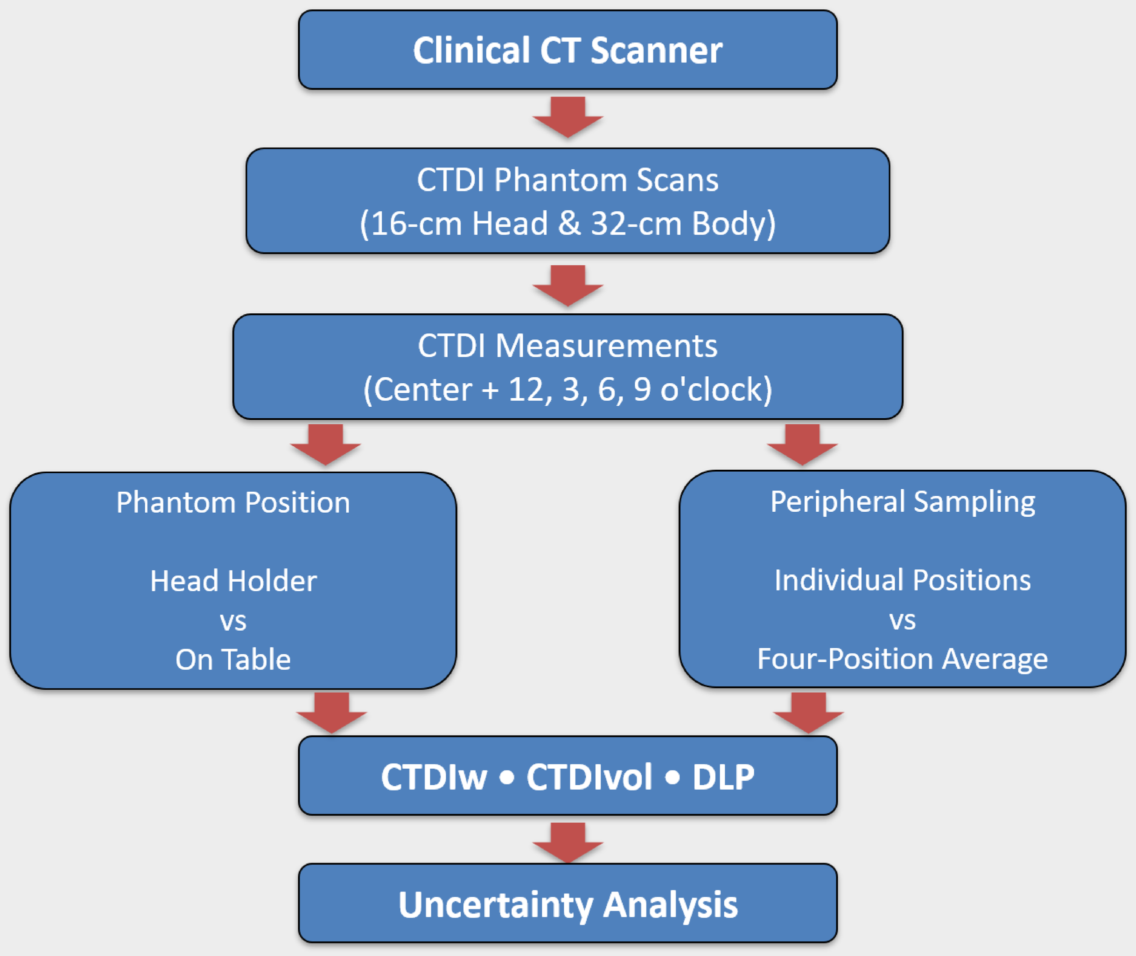

Figure 3. Experimental workflow illustrating the CTDI measurement procedure and subsequent evaluation of phantom placement and peripheral sampling on CTDI uncertainty.

RESULTS

Metric	Head Holder	On Table	Percent Difference
Mean Peripheral CTDI (mGy)	24.52	23.33	-5.1%
CTDIvol (mGy)	24.53	23.39	-4.9%
DLP (mGy.cm)	429.3	409.2	-4.9%

Table 1. Effect of 16-cm head phantom placement on CTDI metrics - head holder vs table.

Peripheral measurement position	Peripheral $CTDI_W$ (mGy)	Calculated $CTDI_{vol}$ (mGy)	% difference from scanner displayed $CTDI_{vol}$
12 o'clock	652.1	23.2	7.35
9 o'clock	609.9	20.8	3.81
6 o'clock	491.2	17.3	19.76
3 o'clock	603.3	20.6	4.69

Table 2. $CTDI_w$ measurements (for one of the scanners) made at different peripheral positions in the 32-cm body phantom, demonstrating, for each measurement, the discrepancies compared to the scanner's displayed $CTDI_{vol}$.

RESULTS

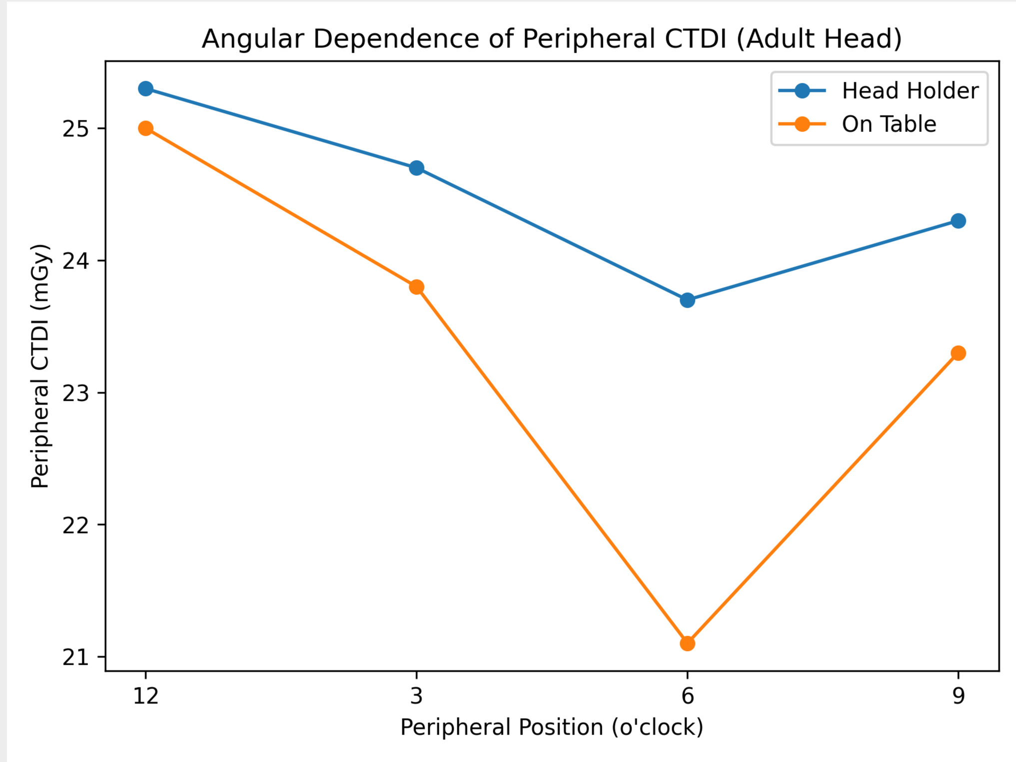

Figure 3. Angular dependence of Peripheral CTDI.

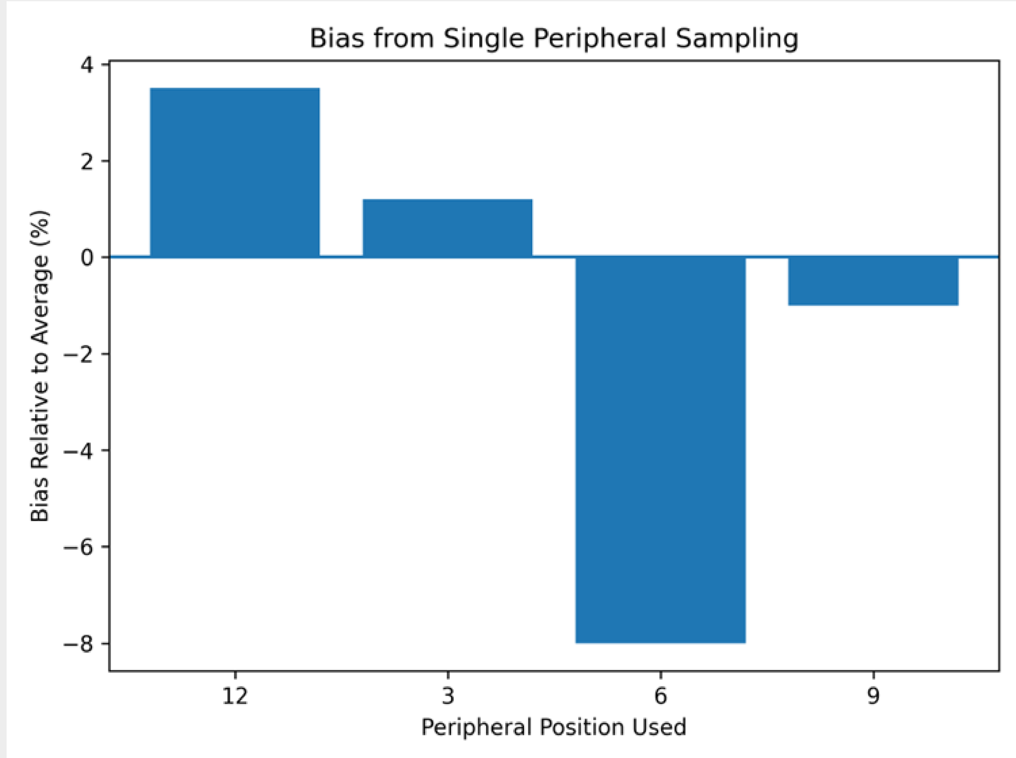

Figure 4. Bias Introduced by single peripheral sampling.

KEY FINDINGS & CONCLUSIONS

- Phantom placement directly on the patient table underestimated $CTDI_{vol}$ and DLP by approximately 5%.
- The 6 o'clock peripheral position consistently measured the lowest CTDI because of attenuation by the patient table.
- Individual peripheral measurements introduced systematic angular bias and should not be used as a substitute for averaging all four peripheral locations.
- The combined effects of phantom placement and simplified peripheral sampling can introduce measurement uncertainties exceeding 10% during CTDI benchmarking.

TAKE-HOME MESSAGE

- Consistent phantom positioning and complete four-point peripheral averaging are critical for minimizing uncertainty and ensuring reliable CTDI benchmarking across clinical CT systems.

REFERENCES

1. McCollough CH, Cody DD, Edyvean S, et al. The Measurement, Reporting, and Management of Radiation Dose in CT. AAPM Report No. 96; 2008.
2. Boone JM. The trouble with CTDI100. Med Phys. 2007;34:1364–1371.
3. IEC 60601-2-44. Medical Electrical Equipment—Part 2-44: Particular Requirements for the Basic Safety and Essential Performance of X-ray Equipment for Computed Tomography. International Electrotechnical Commission.