The Dependence of Helically Acquired CTDI on Beam Width and Pitch

Colin Schaeffer Ph.D.[1], Bethany McCurley[1], Lindsay DeWeese Ph.D.[1]
[1]Oregon Health & Science University

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INTRODUCTION

Helically acquired CTDI$_{vol}$ ($CTDI_{vol}^{H}$) has recently been proposed as an alternative to traditional axially acquired CTDI$_{vol}$ ($CTDI_{vol}^{A}$).[1] The two metrics have been shown, experimentally and through simulation, to agree well over the range of clinically used scan parameters.[1-3] These publications state that this agreement is independent of beam width and pitch. However, prior publications analyzed results for pitch and beam widths separately, while not controlling for the other.[1,2] This is problematic because, as we hypothesize, the dependence of $CTDI_{vol}^{H}$ on beam width and pitch is not direct, but indirectly due to overranging. Overranging is proportional to both pitch and beam width, therefore, one variable needs to be controlled while the other varies. Yang et al. did not model overranging in their simulation. Due to the limitations of these studies, a systematic analysis of the dependence of $CTDI_{vol}^{H}$ on beam width and pitch is warranted.

METHODS

Equipment: All measurements were taken on a clinically used Siemens SOMATOM FORCE CT scanner with a calibrated 100-mm RTI CT ionization chamber and Sun Nuclear 16 cm and 32 cm CTDI phantoms (Sun Nuclear 468-BH).

CTDI Measurements: Measurements were taken using the methodology of Leon et al.[1]

Acquisition Parameters: Scan parameters are summarized in Table 1. $CTDI_{vol}^{H}$ was measured using three nominal beam widths (19.2, 28.4, 57.6 mm) and seven pitch values (0.35, 0.60, 0.80, 1.00, 1.20, 1.35, 1.50).

Scan Length and Overranging: Due to pitch and beam width dependent helical overranging, each scan produced a different true scan length. The DICOM RDSR parameter "Exposed Range" was recorded and independently validated using CR plates placed at isocenter.

Analysis: To highlight how measurements vary with pitch, percent difference was calculated for each pitch/beam width combination in relation to the measurement with the same beam width and a pitch of 1. Percent differences were calculated for the center and periphery measurements individually, as well as combined calculated $CTDI_{vol}^{H}$. Percent difference from the pitch equals 1 measurement were plotted against both pitch and against exposed range, to show how increased overranging influences measurements.

Table 1: Scan techniques

	Body	Head
kVp	120	120
Rotation Time	0.5 s	1.0 s
mAs_{eff}	150	350
Beam Width (mm)	19.2 - 57.6	19.2 - 57.6
Pitch	0.35 - 1.5	0.35 - 1.5
Bowtie Filter	Standard	Standard
Scan Range	100 mm	100 mm

RESULTS

- Overranging distance correlated highly with the product of pitch and beam width ($\rho \times nT$) with an R^2 of 0.989. Overranging distances ranged from 13 mm (0.35 pitch / 19.2 mm beam width) to 46 mm (1.5 pitch / 57.6 mm beam width) past the prescribed scan range.
- Figure 1 shows percent difference from the pitch of 1 measurement plotted against overranging distance, while figures 2-4 show percent difference of the center, periphery, and $CTDI_{vol}^{H}$, plotted against pitch value.
- The central measurement in $CTDI_{vol}^{H}$ increases monotonically with pitch with percent differences ranging from -14.0% to 4.4% compared to a pitch of 1.
- The periphery measurement in $CTDI_{vol}^{H}$ increases monotonically for pitch values below 1.3 with percent differences ranging from -8.5% to 4.8% compared to a pitch of 1.
- A similar trend was observed in $CTDI_{vol}^{H}$ measurements with percent differences ranging from -9.6% to 3.9% compared to a pitch of 1.

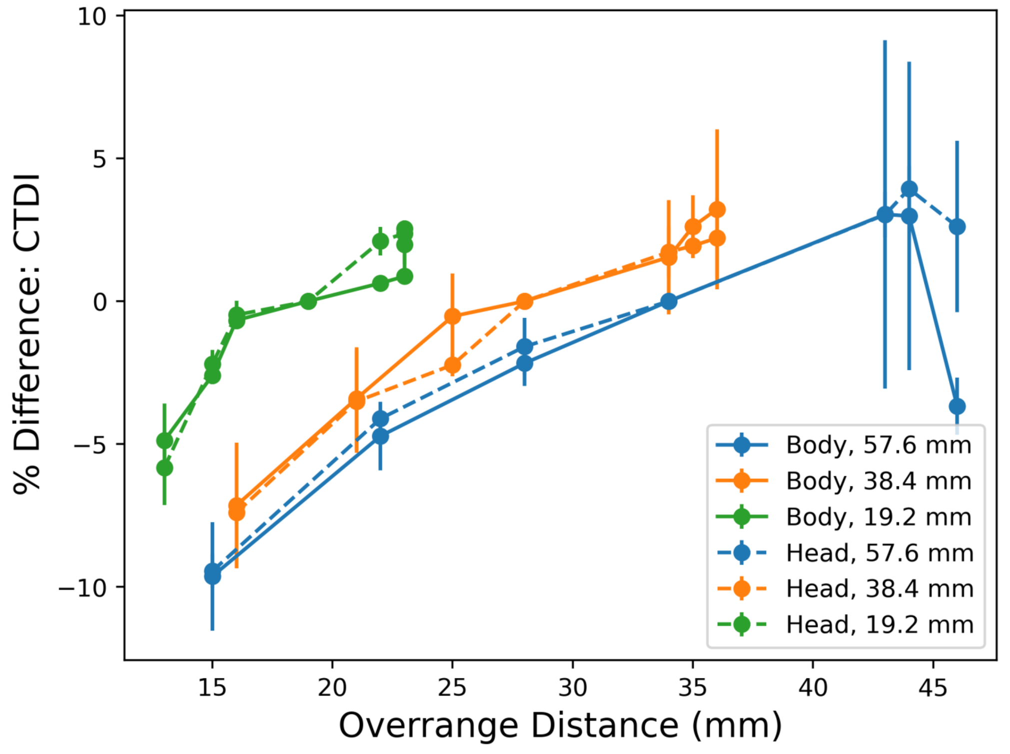

Figure 1: Percent difference of $CTDI_{vol}^{H}$ normalized to a pitch of 1 plotted against overrange distance

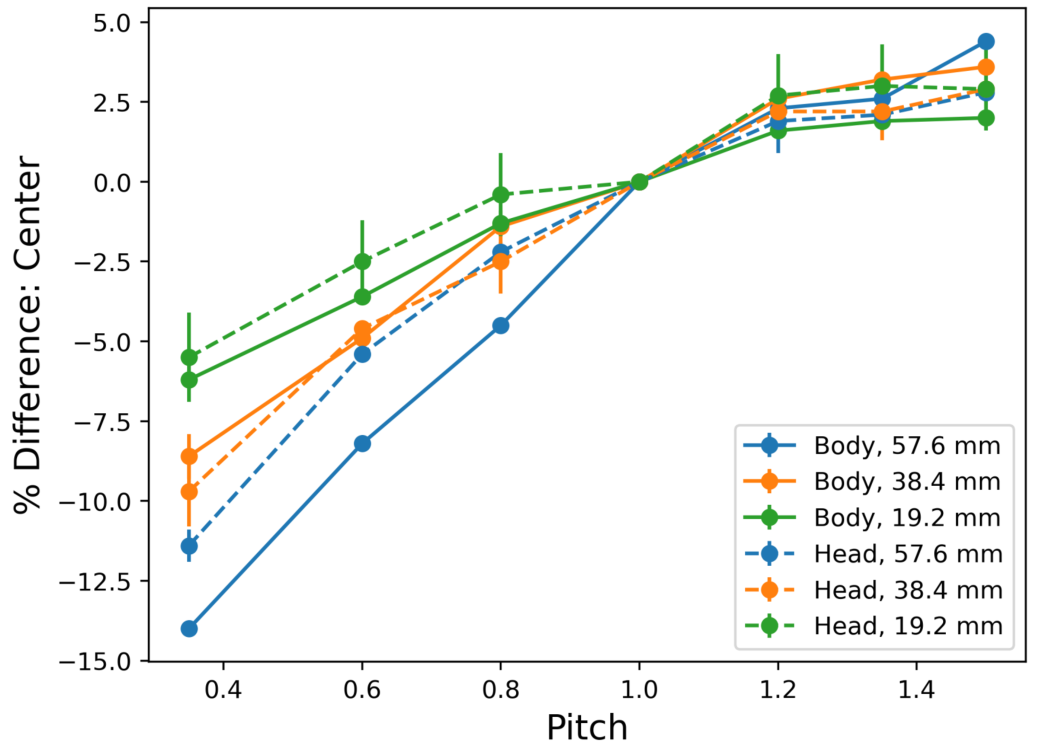

Figure 2: Percent difference of the center measurement normalized to a pitch of 1 plotted against pitch

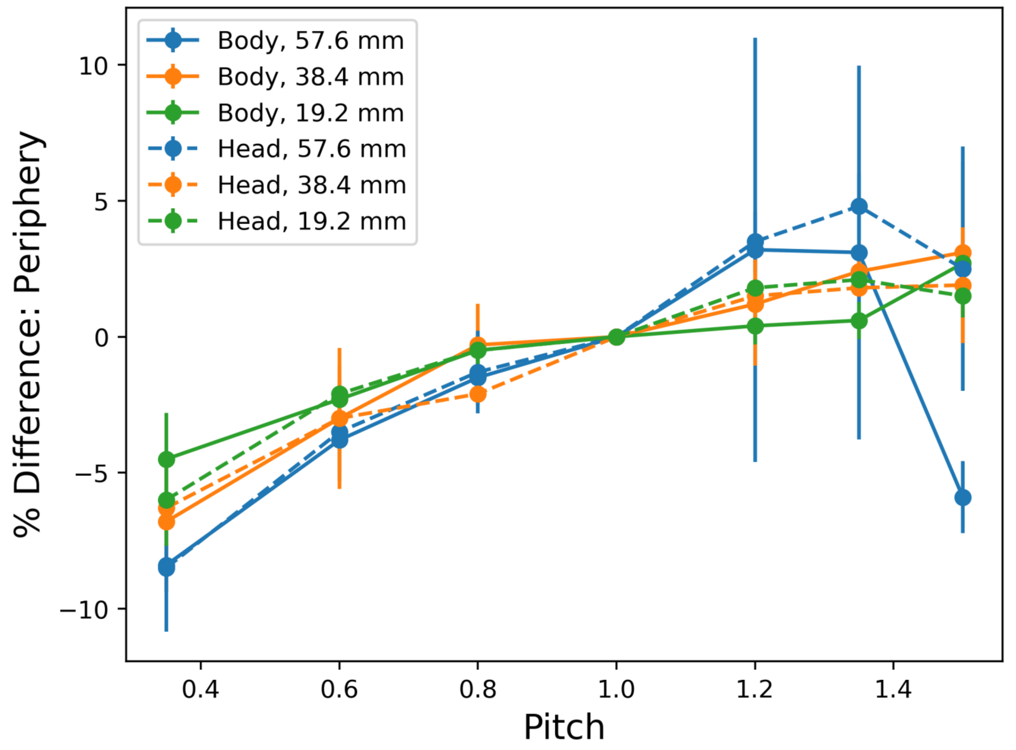

Figure 3: Percent difference of the periphery measurement normalized to a pitch of 1 plotted against pitch

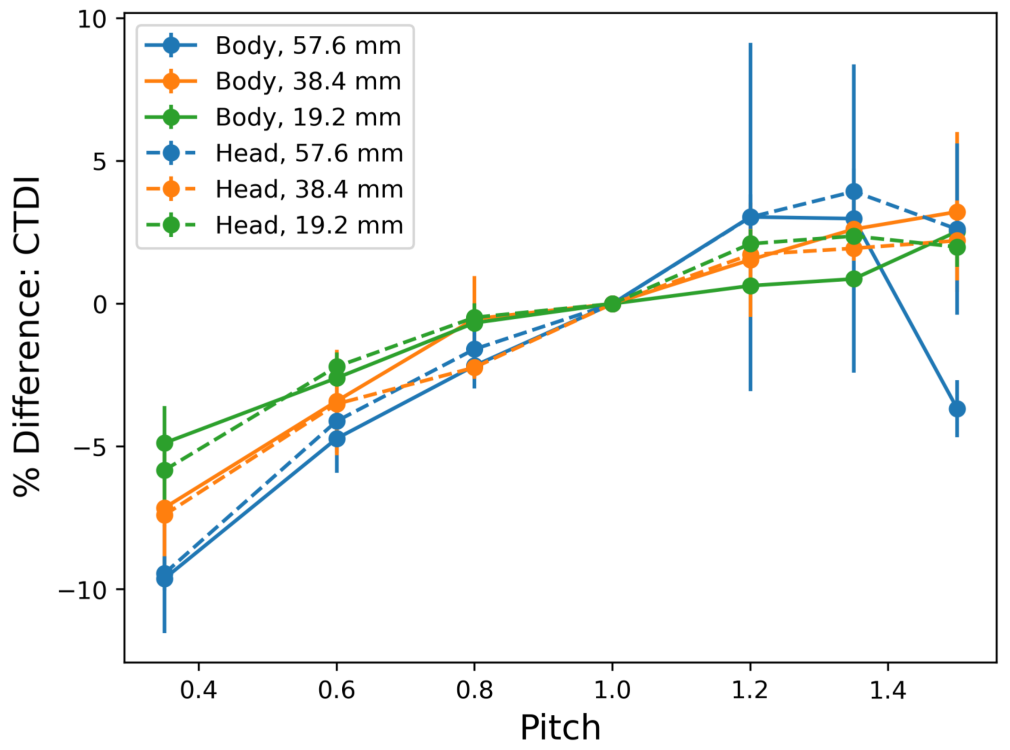

Figure 4: Percent difference of $CTDI_{vol}^{H}$ normalized to a pitch of 1 plotted against pitch

DISCUSSION

- There are two competing effects observed: 1) increase in measurement with increasing pitch due to larger overranging distances, and 2) steep decline in periphery measurements with large pitch/beam width combinations due to large gaps in the peripheral dose distribution.
- The added dose due to overranging has real dosimetric impact on clinical scans. The fact that helical measurements account for this may be an advantage over traditional axial measurements. However, we feel it is important to understand these dependencies and possible limitations before widespread adoption.

CONCLUSION

$CTDI_{vol}^{H}$ measurements are influenced by overranging and therefore show a dependence on both beam width and pitch. Despite a constant mAs_{eff} and scanner reported $CTDI$, we observed that $CTDI_{vol}^{H}$ can vary by up to 20% depending on pitch value. This dependency on beam width and pitch is important to keep in mind if such a metric is to be widely adopted as a surrogate for $CTDI_{vol}^{A}$.

REFERENCES

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CONTACT INFORMATION

Colin Schaeffer, Ph.D.
Diagnostic Radiology
Oregon Health & Science University
schaeffer@ohsu.edu