Feasibility study of direct helical acquisition method for $CTDI_{vol}$ measurement in dual energy CT

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Introduction

$CTDI_{vol}$ is the current standard measure of CT dosimetry However, modern scanners use helical protocols more than axial protocols, and it is tedious or sometimes problematic to convert helical protocols into equivalent axial protocols. A helical $CTDI_{vol}$ measurement method has been proposed and showed promising results to replace the current standard axial method. However, it which requires each measurement at a single axial scan. was unknown if the method can be utilized for dual energy CT helical acquisitions. In this study, the feasibility of the direct helical acquisition $CTDI_{vol}$ measurement method was evaluated with dual energy protocols.

Methods

Experiments were set up as helical scans with 16 and 32 cm diameter CTDI phantoms in two GE CT scanners (Discovery and Revolution). 21 Clinical dual energy protocols were selected from GSI (Gemstone Spectral Imaging) protocols for adult head, neck, chest, abdomen and extremity. Each protocol has its combination of pitches (0.508, 0.516, 0.984, 0.992, 0.969, 1.375,1.531), collimation widths (20, 40, 80 mm) and bowtie filters (small head, medium head, head, medium body, large body). The scan range was prescribed on the length of the Raysafe X2 CT ion chamber (Figure 1).

Air kerma readings from the ion chamber were used to calculate $CTDI_{vol}$. The formula to calculate $CTDI_{vol}$ is defined as:

$$CTDI_{vol} = (1/3M_{center} + 2/3M_{peripheral})$$

where M_{center} and $M_{peripheral}$ are air kerma readings from the CT ion chamber at center and peripheral regions of CTDI phantoms.

To evaluate the performance of the direct helical $CTDI_{vol}$ measurement method, the $CTDI_{vol}$ discrepancy and repeatability indices were defined as:

$$CTDI_{vol}\text{ discrepancy index} = (\text{measured} - \text{displayed}) / \text{displayed} * 100\%$$

$$CTDI_{vol}\text{ repeatability index} = (1 - \text{standard deviation} / \text{average}) * 100\%$$

where standard deviation and average are calculated from the 5 repeat measurements.

Finally, the methods of linear regression, Paired Student t-test, and correlation analysis were employed to assess the statistical significance.

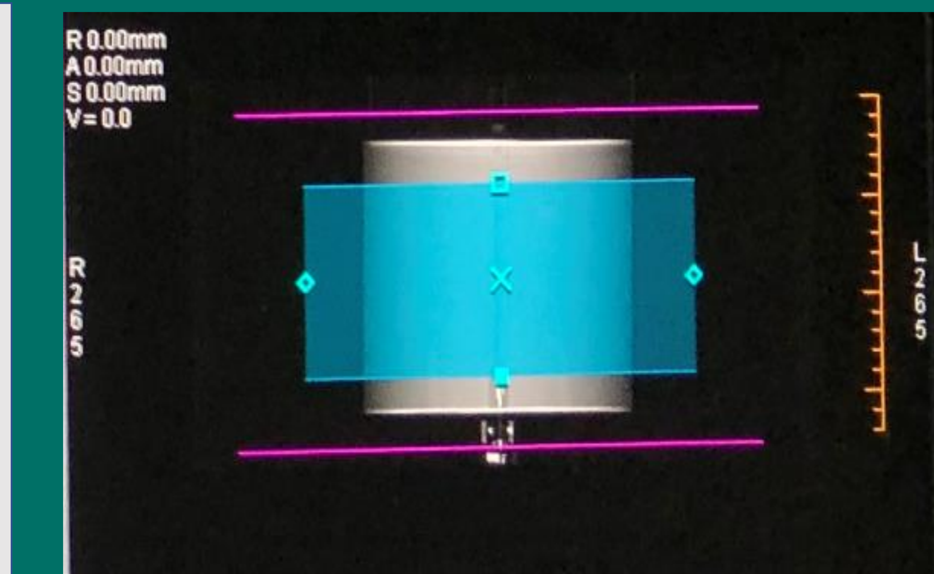

Figure 1. The prescribed scan range (the region with blue color, 10 cm length) on the 16 cm diameter phantom.

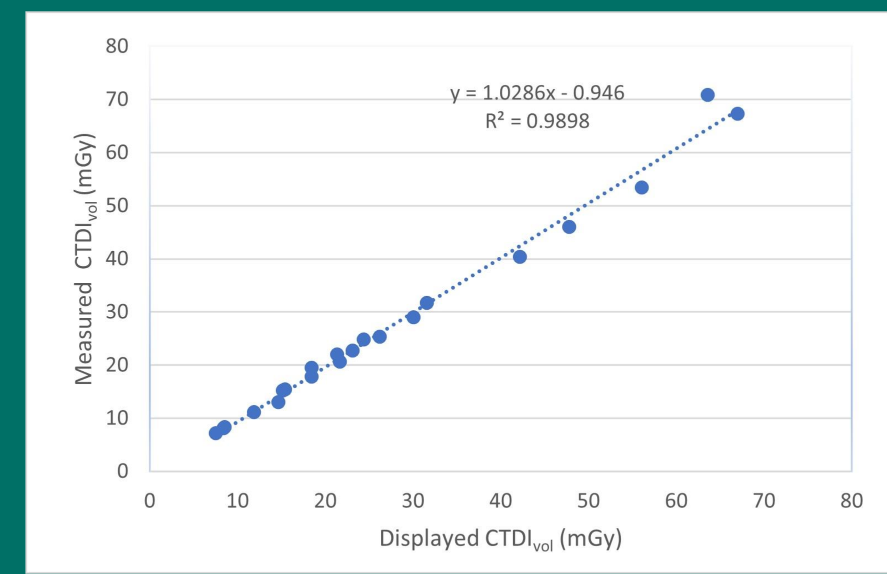

Figure 2. The linear regression between measured and displayed $CTDI_{vol}$.

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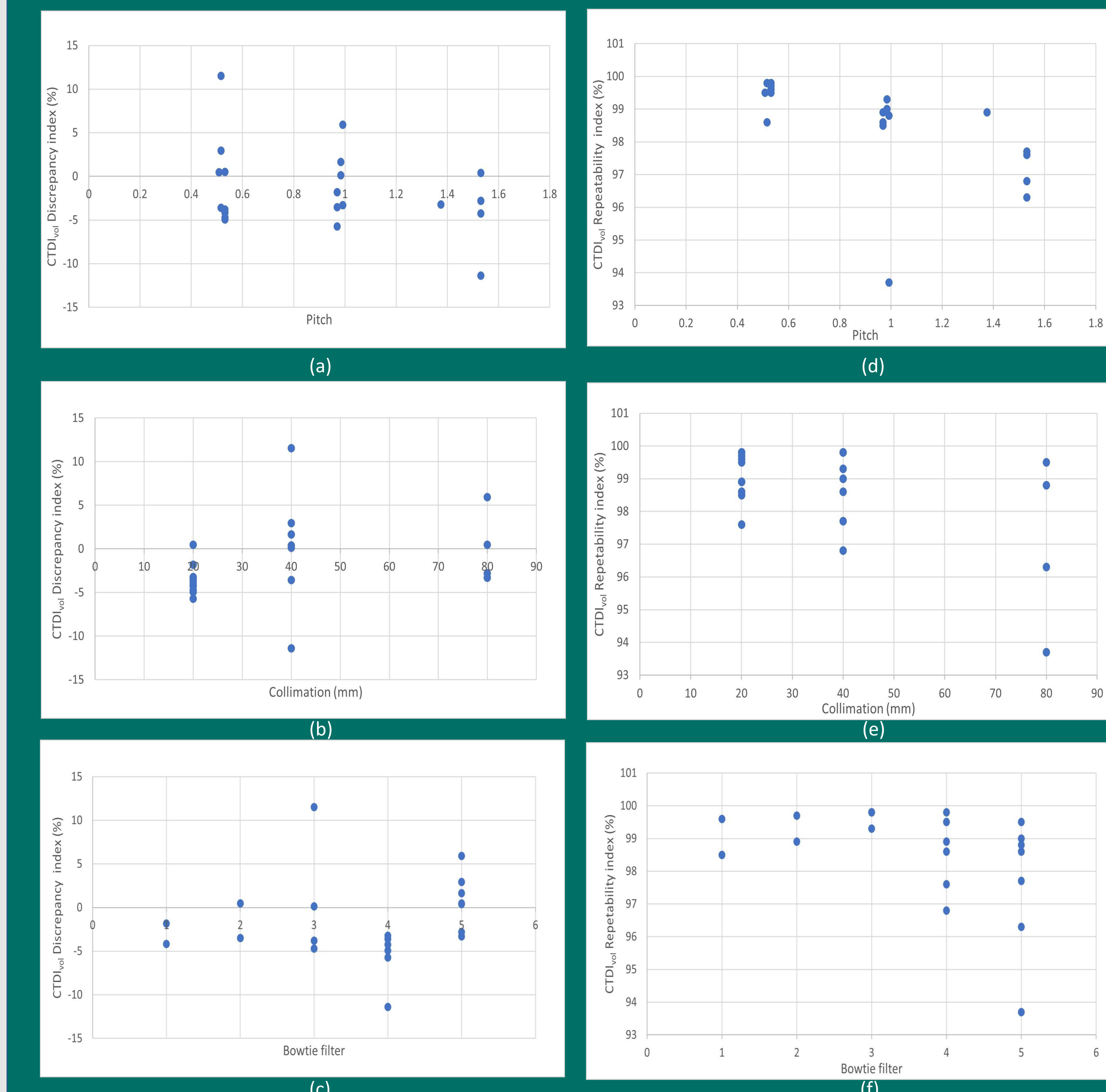

Figure 3. Performance of the helical $CTDI_{vol}$ method with pitch, collimation and bowtie filter. (a-c) plot the $CTDI_{vol}$ discrepancy indices; (d-f) depict the $CTDI_{vol}$ repeatability indices. In (c) and (f), the horizonal axis denotes different bowtie filters: 1: small head, 2: medium head, 3:head, 4:medium body, and 5:large body bowtie filter.

Results

Paired Student t-test shows the direct helical measurement has no statistically significant difference with the manufacturer reported $CTDI_{vol}$ (p=0.51), exhibiting the absolute discrepancy of -0.12±0.93 (mGy) (mean±standard deviation), discrepancy index of 1.5±3.7 (%) and repeatability index of 98.5±1.5 (%). Direct helical $CTDI_{vol}$ measurement results demonstrate excellent agreement with manufacturer reported $CTDI_{vol}$ values with a fitted linear equation of y=1.0286x-0.946 (y-measured, x-displayed) and $R2$ =0.9898, as shown in Figure 2. No correlation is found between $CTDI_{vol}$ discrepancy/repeatability and pitch, or collimation width, or bowtie filter (p>0.05) (as shown in Figure 3), indicating the method is independent from scan pitch, collimation width and bowtie filter.

Discussion

The previous study showed promising results that the values of direct helical $CTDI_{vol}$ measurement agreed well with axial and manufacturer reported $CTDI_{vol}$ values for routine single energy clinical protocols (1). This study extended the testing protocols with dual energy GE CT scanners. The result supports the conclusion that direct helical $CTDI_{vol}$ measurement method is an acceptable alternative for axial $CTDI_{vol}$ measurement method. The direct helical $CTDI_{vol}$ measurement method has the advantage of removing the current inefficiency in finding or converting into equivalent axial acquisition protocols during routine quality assurance (QC) testing. This makes it possible that helical CTDI phantom acquisition protocols during QC testing are always identical to clinical helical acquisition protocols. This study suggests that the direct helical $CTDI_{vol}$ measurement method is a more robust approach for dual energy CT dosimetry evaluation in QC testing. Further studies will include more CT scanners and protocols from other vendors.

Conclusion

The result suggests that the direct helical $CTDI_{vol}$ measurement method is a good alternative for the axial $CTDI_{vol}$ method in evaluating $CTDI_{vol}$ of dual energy CT scanners during quality assurance testing.

Reference

1. Leon SM, Kobistek RJ, Olguin EA, Zhang Z, Barreto IL, Schwarz BC. The helically-acquired CTDIvol as an alternative to traditional methodology. J Appl Clin Med Phys 2020;21(8):263-271. doi: 10.1002/acm2.12944