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Quantitative Evaluation of Vertical Off-Centering Effects on Dose Output and Image Quality across Modern CT Systems

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ABSTRACT

Vertical patient off-centering can alter CT automatic exposure control behavior, radiation output, and image quality. This work-in-progress study evaluated how three CT systems respond to vertical table-height offset using a LUNGMAN PH-1 anthropomorphic chest phantom scanned with and without added chest plates. The GE Discovery 750 HD protocol, using a clinical baseline Noise Index of 22, served as the initial reference condition. GE Revolution CT and Siemens SOMATOM Force were also analyzed.

For each scanner, DICOM metadata were extracted to evaluate tube current modulation (TCM). Computed tomography dose index volume (CTDIvol) and dose-length product (DLP) were recorded from scanner dose information, and image noise was measured using ROI standard deviation in the mediastinum/heart and abdomen/diaphragm regions. Preliminary results show scanner- and habitus-dependent CTDIvol and mean mA responses to vertical offset. Added chest plates generally amplified the dose and tube-current response, while regional noise changes were less uniform. Additional analysis is planned for Siemens NAEOTOM Alpha and Canon Aquilion ONE.

Introduction

Vertical patient centering is important in CT because off-centering can change how the scanner estimates attenuation and applies automatic exposure control. When a patient is positioned above or below isocenter, localizer geometry, bowtie filtration, and tube current modulation may be affected, potentially changing CTDIvol and image noise even when the same clinical protocol is used. Previous studies have shown that patient off-centering can alter AEC performance, radiation dose, and image quality in a scanner-dependent manner.

This is especially relevant for larger patients, who may require greater table-height adjustment to achieve centering. Using an anthropomorphic chest phantom with and without added chest plates, this study examines how vertical offset affects CTDIvol, tube current modulation, and ROI-based noise across GE Discovery 750 HD, GE Revolution CT, and Siemens SOMATOM Force systems. Additional scanners will be included as data collection continues.

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METHODS AND MATERIALS

A LUNGMAN PH-1 anthropomorphic chest phantom was scanned on three CT systems: GE Discovery 750 HD, GE Revolution CT, and Siemens SOMATOM Force. The GE Discovery 750 HD served as the initial reference scanner because it was the oldest clinical unit in the study and used a baseline Noise Index of 22. Comparable clinical chest CT protocols were used on the remaining scanners, with scanner-specific AEC settings recorded for comparison.

Scans were acquired at multiple vertical offsets relative to isocenter, with three repeats per offset when available. The phafntom was scanned under two habitus conditions: no added chest plates and chest plates added to simulate a larger patient habitus. The phantom materials include urethane-based resin soft tissue, density 1.06 g/cm³, and epoxy resin synthetic bone, density 1.31 g/cm³, with no metal parts or liquid structure.

Protocol summary: All systems used 120 kVp, 0.5 s rotation time, 2.5 mm slice thickness, 2.5 mm slice interval, and 350 mm FOV. GE Discovery and GE Revolution used Smart mA + Auto mA 3D with Noise Index-based AEC targets. Siemens SOMATOM Force used CARE Dose 4D with quality reference mAs. GE systems used helical acquisition with 40 mm beam collimation, while Siemens used helical single-source acquisition with 48 × 1.2 mm collimation. Reconstruction used standard soft-tissue kernels on GE and Br40/ADMIRE strength 3 on Siemens.

DICOM metadata were extracted using Python/pydicom, and images were reviewed in MicroDicom DICOM Viewer. Tube current, exposure, exposure time, table height, and image-position data were recorded for each reconstructed image series. CTDIvol and DLP were obtained from scanner dose information and merged with metadata by scanner, offset, plate condition, and repeat.

Image noise was measured using three ROIs in the mediastinum/heart region and three ROIs in the abdomen/diaphragm block. ROI standard deviation in HU was averaged by region. Tube current modulation profiles were generated by plotting tube current versus sorted image number.

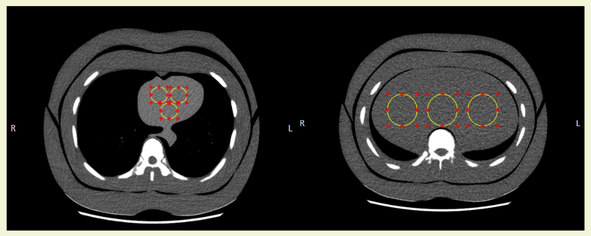

Figure 1A. ROIs in heart. **Figure 1B.** ROIs in abdomen.

Figure 1. ROI placement for regional image-noise analysis. Three ROIs were placed in the mediastinum/heart region (A) and abdomen/diaphragm block (B) to measure HU standard deviation. Heart ROIs were approximately 500 mm², while abdomen/diaphragm ROIs were approximately 2,000 mm². ROI slices were separated by 28 images to maintain consistent anatomical sampling across scanners.

RESULTS

CTDIvol and mean mA responses to vertical off-centering were strongly scanner and habitus dependent. At +6 cm, CTDIvol increased by approximately +51.1% for GE Discovery 750 HD with chest plates, +60.5% for Siemens SOMATOM Force without chest plates, and +31% for Siemens SOMATOM Force with chest plates, relative to 0 cm. GE Revolution CT without chest plates showed minimal CTDIvol change, remaining nearly constant at 3.47–3.48 mGy.

Mean mA generally followed CTDIvol trends. GE Discovery 750 HD with chest plates increased from approximately 313 mA at 0 cm to 473 mA at +6 cm (+51.1%), while Siemens SOMATOM Force without chest plates increased from approximately 87 mA to 143 mA (+64.2%). GE Revolution CT showed a smaller response, increasing from approximately 105 mA to 125 mA with chest plates (+18.2%) and remaining nearly flat without chest plates.

TCM profiles showed scanner-specific AEC behavior. GE Discovery 750 HD and Siemens SOMATOM Force demonstrated larger profile shifts with positive offset, while GE Revolution CT without chest plates appeared to operate near a low-current floor. ROI noise trends were more variable than dose and mA trends, suggesting that increased radiation output did not always produce proportional noise reduction across anatomical regions.

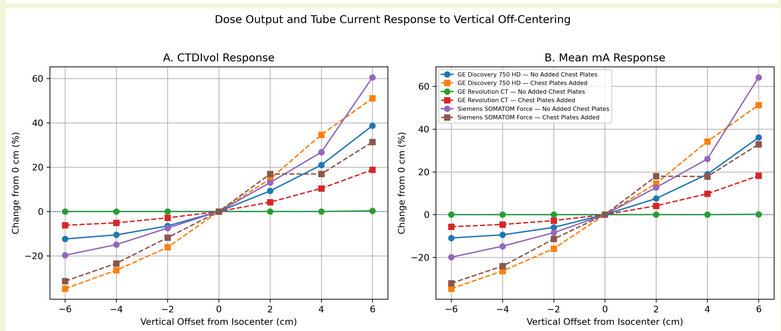

Figure 2. CTDIvol and mean mA response. Percent change from 0 cm shows scanner- and habitus-dependent AEC response to vertical off-centering.

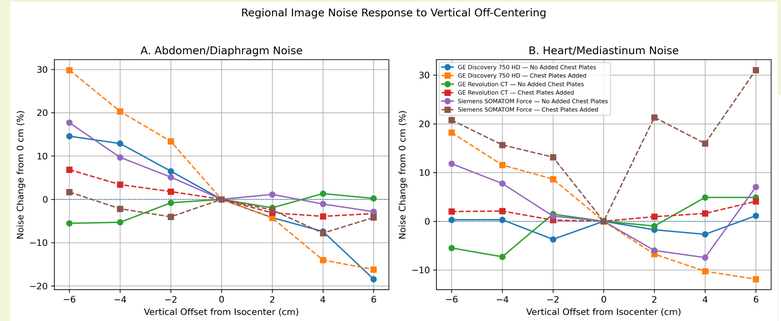

Figure 3. ROI noise response. Mean HU standard deviation varied by scanner, offset, phantom habitus, and anatomical ROI region.

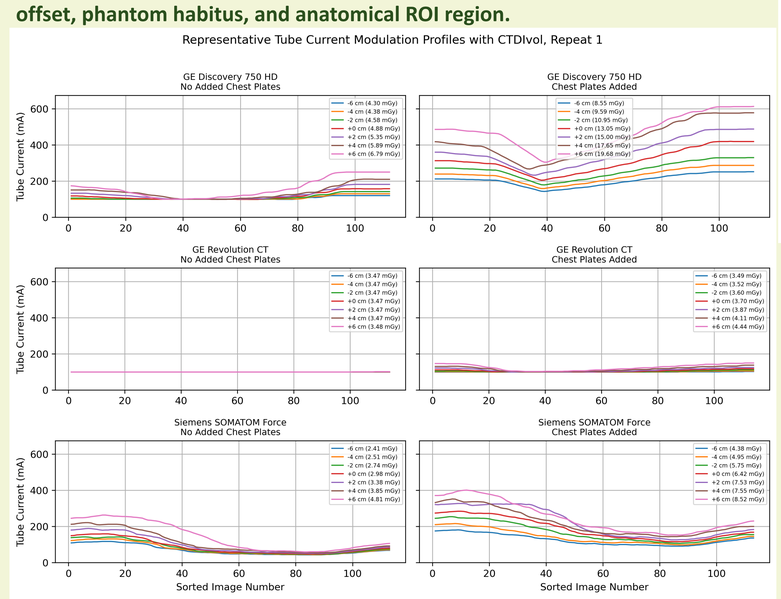

Figure 4. TCM profiles. Representative Repeat 1 tube current modulation profiles show slice-by-slice scanner-specific AEC behavior with CTDIvol labeled by offset.

DISCUSSION

Vertical off-centering produced scanner-specific changes in dose output, tube current behavior, and regional image noise. The strongest CTDIvol and mean mA increases occurred at positive offsets, particularly for GE Discovery 750 HD and Siemens SOMATOM Force. GE Revolution CT showed minimal change without chest plates, suggesting that under this phantom condition the system may have operated near a low-current/output floor.

Added chest plates generally amplified the dose and tube-current response, supporting the idea that larger habitus conditions make accurate centering more consequential. This is clinically relevant because larger patients may require greater table-height adjustment to position the anatomy near isocenter. If the patient is vertically mis-centered, the scanner may interpret attenuation differently through the localizer image, bowtie filter geometry, and AEC algorithm.

ROI noise trends were less monotonic than CTDIvol and mean mA trends. In some cases, increased dose output was associated with reduced regional noise; however, this relationship was not uniform across scanners or anatomical ROI locations. This likely reflects scanner-specific AEC behavior, reconstruction methods, and regional phantom composition.

Because GE Discovery 750 HD served as the oldest clinical reference system with a baseline NI of 22, these results should be interpreted as scanner-specific comparisons rather than fully equivalent protocol matching across vendors. Ongoing work will expand the analysis to Siemens NAEOTOM Alpha and Canon Aquilion ONE and further evaluate scanner-specific protocol matching.

CONCLUSIONS

Vertical patient off-centering altered CTDIvol and tube current modulation in a scanner- and habitus-dependent manner. Positive table-height offsets produced the largest dose and mA increases, especially with added chest plates, suggesting that larger habitus conditions may increase sensitivity to centering errors.

Regional image noise varied by scanner and anatomical ROI region and did not always scale directly with dose output. These preliminary findings support careful patient centering and scanner-specific evaluation of AEC behavior, particularly for larger patient habitus conditions. Additional scanner analysis is ongoing to determine whether these trends persist across newer CT platforms.

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