Commissioning a Novel Single Photon Counting CT Simulator for Radiotherapy Planning

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Purpose

- To investigate the suitability, advantages, and disadvantages of a commercial single-photon counting computed tomography (SPCCT) for radiotherapy planning by commissioning a Siemens Naeotom Alpha scanner.

Background

- Siemens Naeotom Alpha SPCCT:
  - Dual X-ray tubes:
    - 90, 120, 140 kVp
  - CdTe photon-counting detectors
  - Spatial resolution:
    - 0.16×0.11×0.11 mm^3
  - Slice thickness:
    - 0.2-10 mm
  - Reconstructed image settings can be changed retrospectively regardless of acquisition settings
- SPCCT operates by replacing conventional energy-integrating detectors with photon-counting detectors

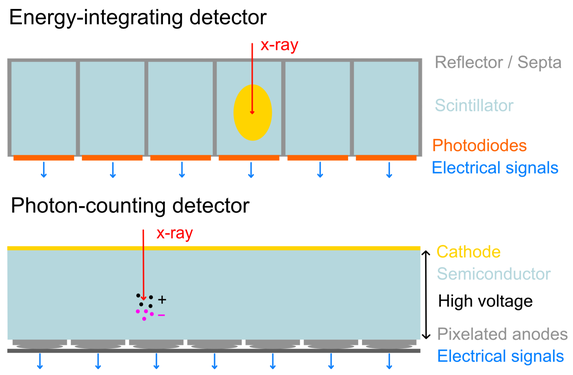

Figure 1: Detector cross-sections of an energy-integrating detector and a photon-counting detector.

Methods & Materials

- Commissioning followed AAPM Task Group 66 (TG-66) and the Canadian Partnership for Quality Radiotherapy (CPQR) guidelines:
  - Electromechanical
  - Image Quality
  - Radiation and Patient Safety
  - Additional testing from AAPM TG-233 and TG-299
- Relative electron density (RED) measurements were taken using the Advanced Electron Density phantom
- The extended Hounsfield Unit (HU) scale (-8,192 to +57,343 HU) was evaluated by including stainless steel and titanium measurements
- Iterative metal artifact reduction (iMAR) was investigated with stainless steel and titanium

Results

- Electromechanical evaluations were within expected tolerances.
- $CTDI_{vol}$ values differed from the manufacturer's specifications by 3.8% ± 4.6%
- Image quality metrics were baselined and showed expected trends with slice thickness, kernel type, mAs, and kVp
- Uniformity and CT number, among other metrics did show a difference based on phantom positioning but was not clinically significant
- Notable results for ring artifacts, metal artifact reduction, and relative electron density are seen in Figures 2-4

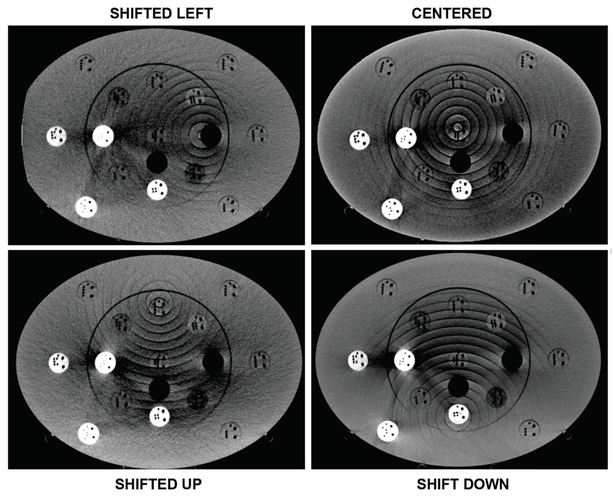

Figure 2: CT images illustrating extreme ring artifacts at the superior edge of the relative electron density phantom at various locations within the bore. 0.4 mm slice thickness, 140 kVp, Hr44 kernel. W/L = 400/40.

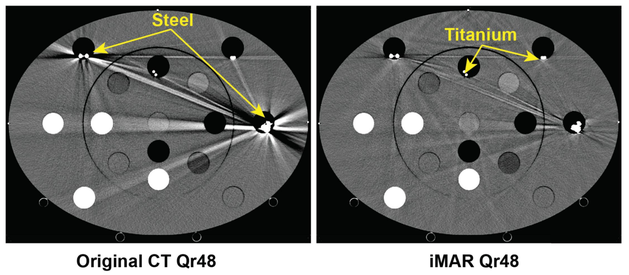

Figure 3: Uncorrected and iterative metal artifact reduction CT images with spinal fixation hardware inserted in the relative electron density phantom. 0.6 mm slice thickness, 140 kVp. W/L = 400/40.

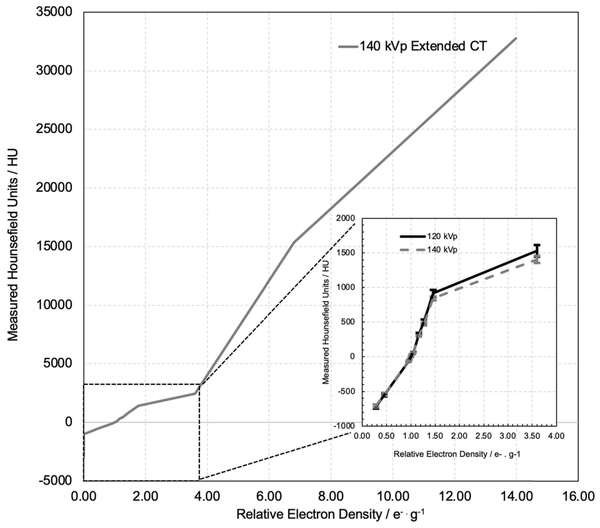

Figure 4: 140 kVp extended relative electron density curve for 140 kVp (averaged from multiple scans), including titanium and stainless steel. Inset shows both the 120 kVp and 140 kVp curves.

Conclusions

- The Siemens Naeotom Alpha SPCCT scanner satisfies the requirements for a radiotherapy simulator
- The work is under review at the Journal of Applied Clinical Medical Physics

References & Acknowledgements

1. Richtsmeier, D. *Exploration of applications of photon-counting detector computed tomography (CT) using a table-top CT system.* PhD Dissertation, University of Victoria, 2024. https://hdl.handle.net/1828/16363

Dr. Ian Porter, DVM, DACVR is kindly acknowledged for his assistance on the use of the Siemens Naeotom Alpha CT scanner.

This work is supported from a generous grant from the Cornell Riney Canine Health Foundation