Investigation of Partial-Arc CBCT Protocols for Imaging Extremities

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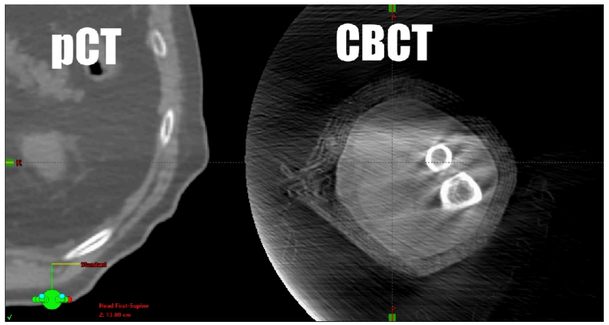
Introduction

In some cases of upper extremity IGRT where the treatment isocenter is laterally displaced from the torso, a CBCT acquired with a full rotation is not possible due to potential collision between one of the kV imaging arms and the patient. In most cases a partial-arc CBCT scan (∼200°) is feasible, however this scan technique has a smaller (<25 cm) FOV which can exclude a large volume of patient tissue, leading to image artifacts and low image quality.



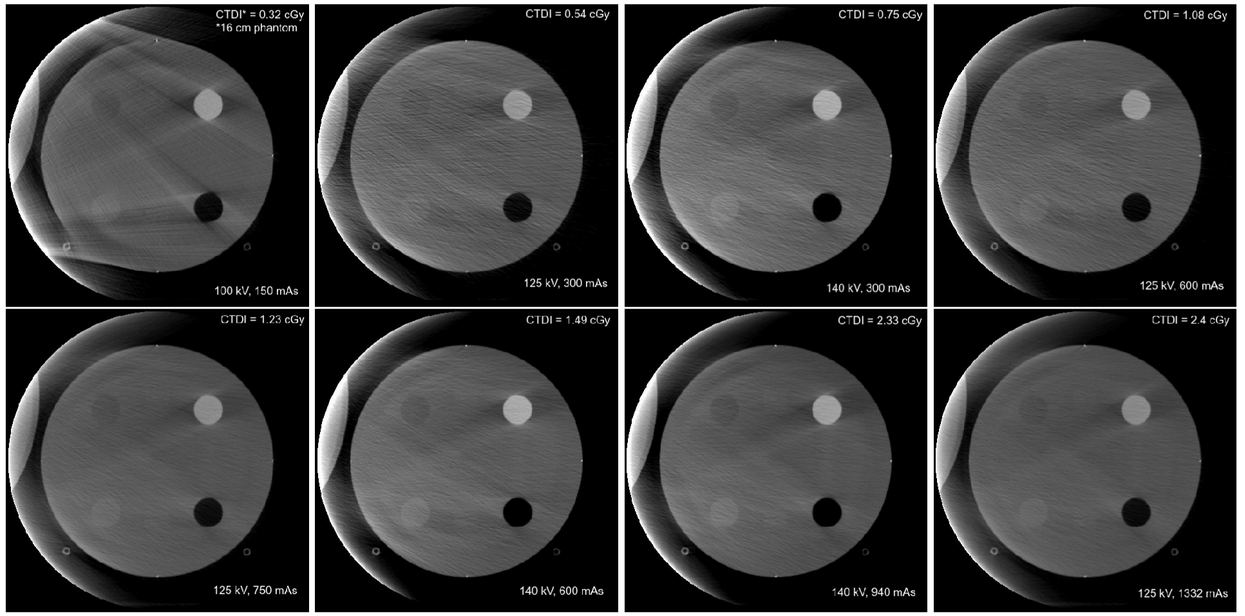
In the above example image, a patient being treated in the upper extremity has undergone a partial-arc CBCT scan. Compared with the planning CT image, the patient's torso is completely truncated by the CBCT FOV, creating significant artifacts.

The purpose of this study was to investigate CBCT partial-arc protocols where a significant volume is excluded from the FOV, as a function of kV, mAs, and CTDI. The goal was to determine the optimal imaging parameters to yield the best image quality as a function of CTDI.

Methods and Materials

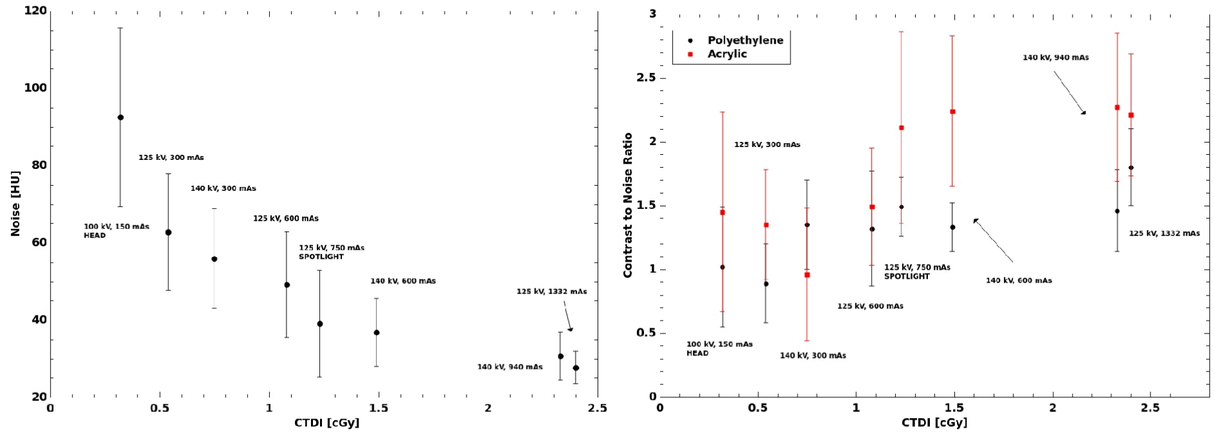
- Eight CBCT protocols (using 100 kV, 125 kV, and 140 kV) with CTDIs ranging from 0.32 to 2.4 cGy were studied on Varian TrueBeam CBCT systems.
- The $CTDI_w$ for each protocol was verified by performing measurements with a 32 cm CTDI body phantom and a 10 cm pencil ionization chamber.
- Image quality was assessed by scanning an ACR CT phantom, with a TomoTherapy "cheese" phantom (30 cm diameter SolidWater) placed laterally outside of the FOV to simulate the effect of the patient torso.
- The ACR CT phantom images were analysed for uniformity, noise, CNR, CT number accuracy, and spatial resolution.
- The study was performed on *six* TrueBeam CBCT systems to assess machine-to-machine variations. From the individual CBCT system image quality metrics, the mean and standard deviation of the measurements were calculated.

Image Quality vs kVp and mAs



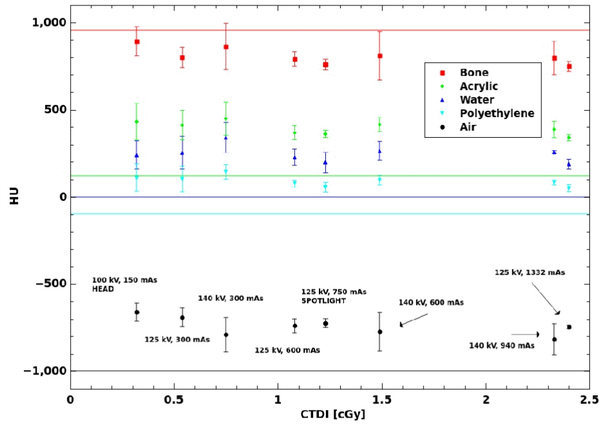
Example of ACR CT phantom CT number accuracy module images for the eight CBCT partial-arc protocols investigated (W=3000, L=600). A 30 cm diameter TomoTherapy phantom is placed just out of the FOV to simulate the effect of the patient torso.

Relationship between Noise, CNR, and CTDI



While image noise was found to decrease consistently with CTDI (left), the relationship between CNR and CTDI was less direct due to the influence of significant out-of-FOV artifacts (right). The CNR was calculated for two material inserts (polyethylene and acrylic).

CT Number Accuracy



The reconstructed CT numbers in all the investigated protocols were found to have poor accuracy compared with the theoretical values (solid lines), with no obvious dependence on CTDI.

Discussion

- Image uniformity was unaffected by the choice of kV and CTDI.
- Image noise was reduced as a function of CTDI, however there was no obvious increase in CNR with CTDI due to significant out-of-FOV image artifacts.
- Large CT number inaccuracies were observed for all protocols, with the 140 kV scans experiencing the greatest machine-to-machine variations.
- Limiting spatial resolution increased marginally with CTDI, from 5 lp/cm (CTDI=0.32 cGy) to 6.67 lp/cm (CTDI=2.4 cGy).
- Qualitatively, images acquired with larger CTDIs appeared to be less influenced by streaking artifacts.

Conclusion

- Partial-arc CBCT scans affected by large out-of-FOV artifacts are able to achieve image quality improvement by using a protocol with an increased CTDI (increased kV and/or mAs).
- However, due to the strong effect of these artifacts, the relationship between dose and image quality is not straightforward. Thus, the protocol with the greatest CTDI is not necessarily the most optimal.
- In clinical practice, the protocol with the lowest CTDI with acceptable image quality for the task should be used.