Comprehensive Multi-platform Characterization of an Advanced Linac-based Cone-beam CT Imaging System

Department of Radiation Medicine
UNIVERSITY OF WISCONSIN
SCHOOL OF MEDICINE AND PUBLIC HEALTH

Jennie Crosby, Ian Morton, Gemma Davies, and Carri Glide-Hurst

Department of Radiation Medicine, School of Medicine and Public Health, University of Wisconsin-Madison

Purpose

To use CBCTs for simulation-free or adaptive planning workflows, high-quality scans are essential.

Recent advances in CBCT technology have provided:

- Extended field of view
- Advanced iterative reconstruction methods
- Metal artifact reduction

To use CBCTs for accurate dose calculation we need:

- CT-like Hounsfield Units (HU)
- HU accuracy
- Minimal HU variability across several units
- HU repeatability over time

Goal

To use CBCTs for simulation-free and adaptive treatment planning, HU accuracy and stability across platforms must be established.

Methods

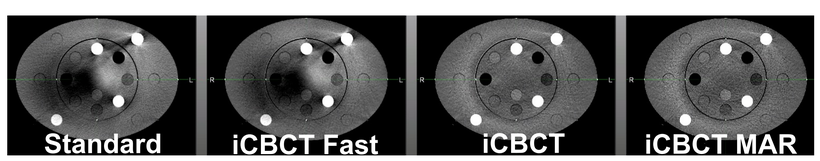
Five linear accelerators with iterative CBCT reconstruction algorithms were used for this work.

- Ranging in age from 1 to 8 years old
- 4 Varian TrueBeams
- 1 Varian Edge

Three head configurations and two body configurations of an electron density phantom were scanned with Pelvis, Pelvis Large, Head, FSRT Head, and Image Gently protocols.

Then reconstructed with 4 algorithms:

- Standard
- Iterative CBCT (iCBCT)
- Iterative CBCT Fast
- Iterative CBCT Metal Artifact Reduction (MAR)



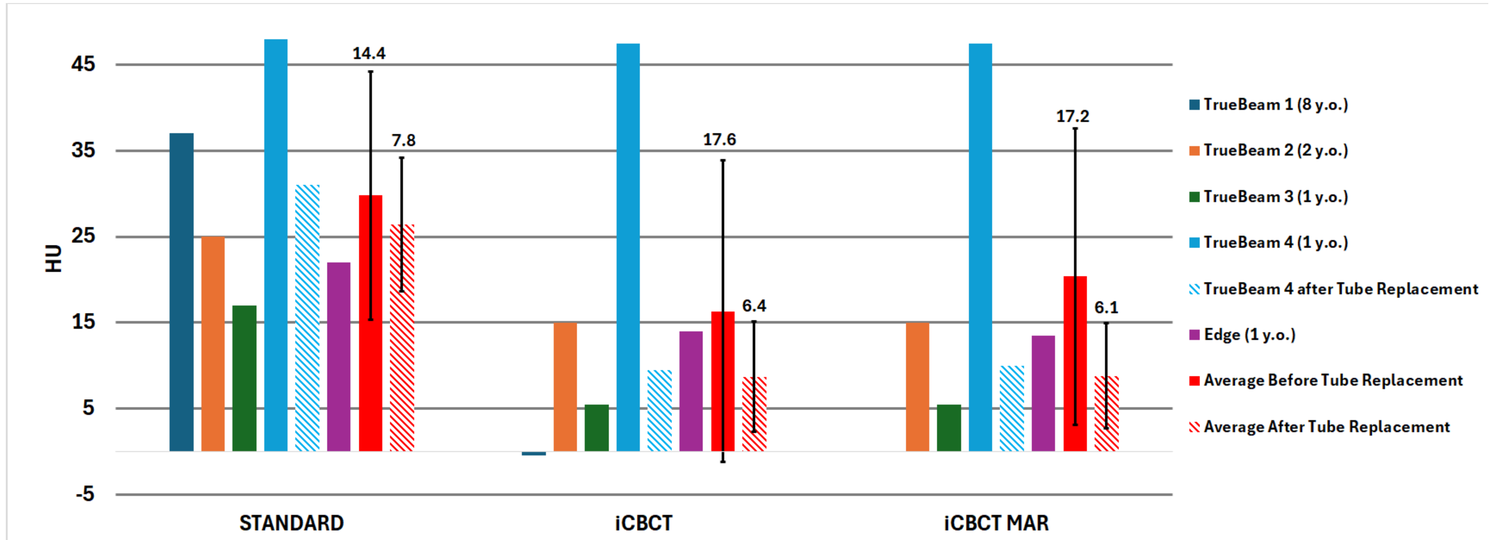
Acquired over 4 months to evaluate HU repeatability.

Compared across all 5 machines to evaluate inter-machine variability.

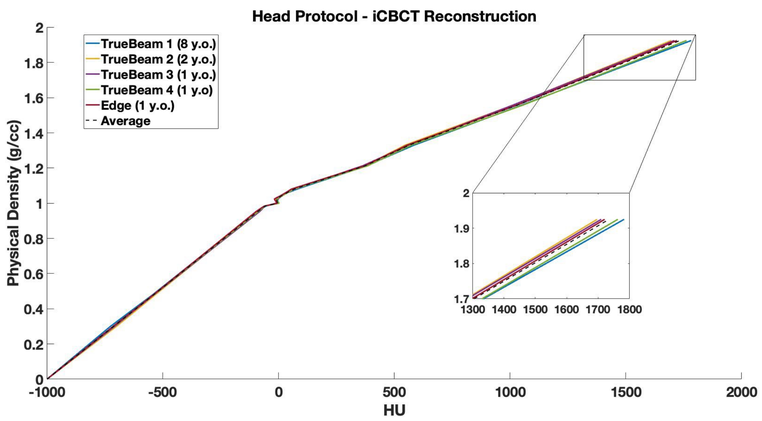
Scans reacquired after major kV system service events.

Results

TrueBeam 4 was an outlier compared to the other machines.
Following a kV tube replacement, it returned to alignment with the other platforms.

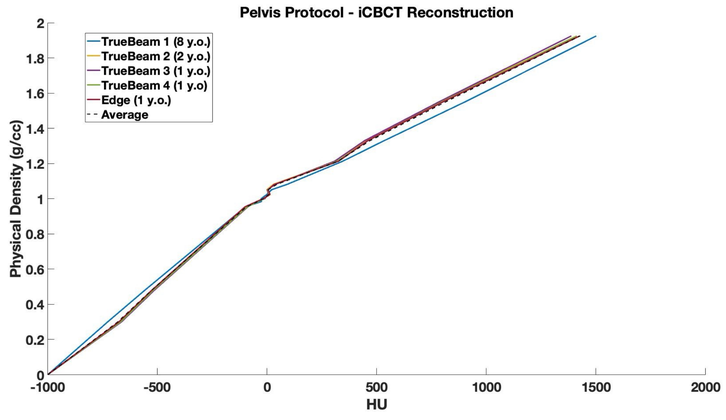


HU Values across machines and reconstructions for the solid water density rod.
The error bars represent the standard deviation across machines.



HU versus physical density for the Head protocol with the iterative CBCT reconstruction.

The inset shows the discrepancy between machines at higher densities.



HU versus physical density for the Pelvis protocol with the iCBCT reconstruction.

TrueBeam 1 is an outlier across most of the densities investigated; it is equipped with a different imaging panel which may account for the discrepancy.

Repeat scans found a maximum variability of 40 HU (2.7%) for body phantom and 44 HU (2.5%) for head phantom

Inter-machine variability (33 HU) exceeds published HU tolerances for water ($\pm$5 HU) for Pelvis and Pelvis Large protocols.

Conclusions

Protocol-specific deviations were observed among platforms exceeding 1 standard deviation from the mean of machines, suggesting a need to consider protocol and machine-specific HU-density curves.

The next step is to evaluate the dosimetric impact of the HU variabilities quantified in this work.

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Contact the presenting author at: jennie.crosby@wisc.edu