Quantitative evaluation of relative electron density to HU calibration stability in Ethos HyperSight CBCT for adaptive radiotherapy

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INTRODUCTION

Adaptive radiotherapy relies on CBCT imaging not only for target localization and contour propagation, but also dose calculation. It is therefore critical to not only assess image quality for these CBCT systems, but also the relative electron density (RED) to Hounsfield unit (HU) calibration for various acquisition parameters. This study provides a systematic evaluation of RED to HU calibration for the Varian Ethos HyperSight CBCT system, examining tube potential, mAs, and reconstruction algorithms (FDK, iCBCT, iCBCT Acuros, and iCBCT-MAR).

The main purpose is to characterize the dependence of RED to HU calibration accuracy on acquisition and reconstruction settings on the Varian Ethos HyperSight CBCT to assess implications for adaptive radiotherapy dose calculation.

METHODS AND MATERIALS

A commercial RED phantom containing eight inserts was imaged using the Ethos HyperSight CBCT using clinically relevant acquisition modes at 100 kV (head), 125 kV (pelvis), and 140 kV (large pelvis). Reconstruction algorithms included filtered back-projection (FDK), iterative CBCT (iCBCT), iCBCT Acuros, and iCBCT with metal artifact reduction (iCBCT-MAR). Inserts include air, lung exhale, lung inhale, adipose, solid water, liver, bone, and cortical bone with densities of 0.0, 0.29, 0.5, 0.945, 1.019, 1.093, 1.152, 1.824 g/cm^3, respectively.

Tube current was also examined at the preset low, middle, and high mAs settings at each tube potential. Mean HU and HU standard deviation (SD) were measured for each insert in MIM software, and the dependency on tube potential, reconstruction algorithm, mAs, and material composition was examined.

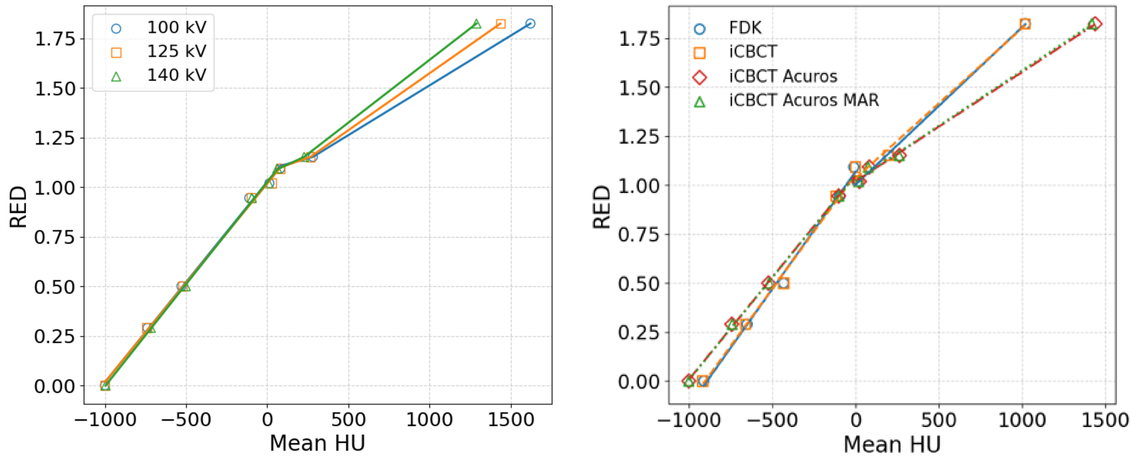

Figure 1. RED to HU calibration curves for different tube potentials for auto mAs and the iCBCT Acuros reconstruction algorithm (left), and for different reconstruction algorithms at tube potential 125 kV and middle mAs (right)

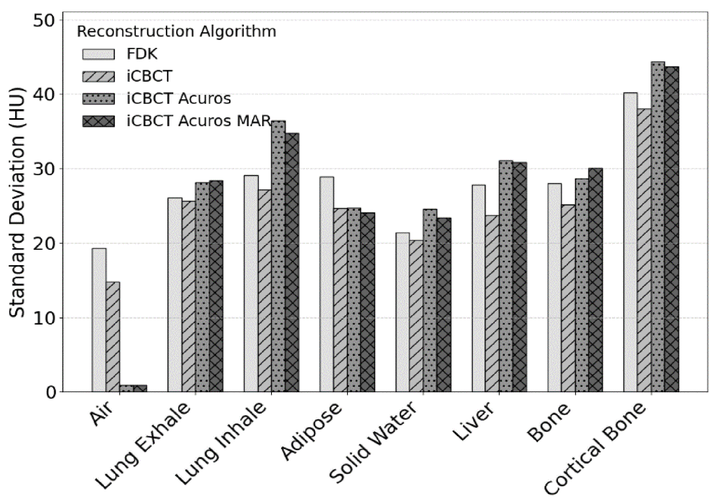

Figure 2. HU SD for different reconstruction algorithms across various materials at tube potential at 125 kV and middle mAs.

HU SD was dominantly material-dependent with limited dependency on reconstruction algorithm and tube voltage beyond 100 kV (not shown here).

REFERENCES

1- Assessing HyperSight iterative CBCT for dose calculation in online adaptive radiotherapy for pelvis and breast patients compared to synthetic CT. JACMP, 2026

2- Feasibility of HyperSight CBCT for adaptive radiotherapy benchmark study of dose calculation accuracy and delivery verification on the Halcyon. JACMP, 2025

RESULTS

All acquisitions demonstrated the expected bi-linear RED-HU relationship. Tube potential minimally influenced low-density materials, but did induce systematic HU scaling in higher-density inserts. For cortical bone, the mean HU exhibited a range of 333 HU between 100 and 140 kV. FDK and iCBCT yielded comparable RED–HU relationships, as did iCBCT Acuros and iCBCT-MAR, but a maximum difference of 419 HU was found between them for cortical bone. RED-HU relationships were unchanged with increasing mAs, but as expected, HU SD decreased with increasing mAs, plateauing beyond the middle setting.

Figure 1 shows the RED to HU relationship for different tube potentials and reconstruction algorithms. Figure 2 illustrates HU standard deviation as a function of reconstruction algorithm and insert material. As can be seen by differences in HU of up to 419 HU for the same high density insert (cortical bone), imaging parameters for adaptive radiotherapy must be carefully selected to ensure reliable dose calculation. It is recommended based on these findings that the RED to HU calibration curve used on the Ethos platform be selected to best represent the imaging acquisition parameters used on the scanner, and to possible forego using imaging parameters that may result in large deviations in HU values for the same RED value.

CONCLUSIONS

RED-HU calibration on the Ethos HyperSight CBCT is influenced by tube potential, and reconstruction algorithm, with differences of up to 419 HU. This is an important consideration for Ethos, as the CBCT is used in adaptive dose calculation and a single calibration curve is used across all imaging modes. Our further research is examining the effect of these HU changes on dose calculation and the impact of field-of-view, phantom location, and phantom diameter.