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HyperSight-ARCHER Head and Neck Clinical Trial: Image Quality and Dose Calculation Accuracy in the Presence of Metal Artifacts

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ABSTRACT

Varian's HyperSight cone-beam CT (CBCT) system on the Ethos platform was evaluated in 30 head and neck cancer patients (24 with metal implants) to characterize image quality and dose-calculation accuracy across a range of metal artifact severities for CBCT-based adaptive radiotherapy.

HyperSight images reconstructed with iCBCT MAR and iCBCT Acuros were compared with planning fan-beam CT (FBCT) and conventional TrueBeam CBCT using image quality metrics, DVH metrics and gamma in artifact-free and artifact-affected regions.

HyperSight iCBCT MAR significantly reduced metal artifacts, improving HU accuracy and dose calculation near implants, while iCBCT Acuros achieved superior image quality and dose accuracy in implant-free regions. Both HyperSight reconstruction methods outperformed conventional TrueBeam CBCT in image quality and dosimetric accuracy.

HyperSight provides accurate CBCT-based dose calculation, with reconstruction selection depending on metal artifact severity.

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INTRODUCTION

Previous work[1,2] demonstrated that HyperSight[3] CBCT reconstructed with metal artifact reduction (iCBCT MAR) substantially improved image quality and dose calculation accuracy in the presence of dental implants, making it well suited for head and neck (H&N) adaptive radiotherapy. However, it remains unclear whether MAR reconstruction is the optimal choice when metal artifacts are minimal or absent, as the smoothing and interpolation used during artifact reduction may compromise image detail. This study compares HyperSight iCBCT MAR and the standard iCBCT Acuros reconstructions to determine the preferred imaging method across varying levels of metal artifact severity.

METHODS AND MATERIALS

Images from 30 H&N cancer patients (24 with dental implants) were acquired using a planning FBCT[4], HyperSight CBCT on Ethos[3], and conventional CBCT on TrueBeam[3]. HyperSight images were reconstructed using iCBCT Acuros and iCBCT Metal Artifact Reduction (MAR).

OAR-averaged Hounsfield unit (HU) deviations from FBCT, defined by Equation 1, were computed for selected organs at risk (OARs): the oral cavity, brainstem, submandibular glands, and parotid glands.

$$\Delta HU_{OAR} = \overline{HU_T} - \overline{HU_B} \qquad (1)$$

$\overline{HU_T}$ and $\overline{HU_B}$ are the mean HUs measured in the structure's central slice in test image T and baseline image B (FBCT), respectively.

For planning and dose calculations, the metal artifacts in the FBCT images were manually overridden to approximate realistic tissue density. CBCT images were rigidly registered to FBCT, and clinically approved plans were forward calculated. Dose-volume histogram (DVH) metrics were evaluated for the same OARs.

Gamma analyses were performed relative to FBCT at three slice locations shown in Figure 1: (a) below the mandible (mainly soft tissue), (b) above the oral cavity (bone and air), and (c) within the oral cavity (affected by metal artifacts).

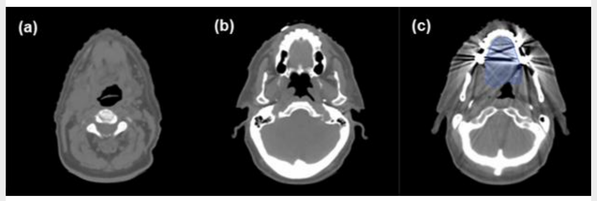

Figure 1. Slice locations free of metal artifacts (a & b) axial affected by metal artifacts (c), from the FBCT of a representative patient.

RESULTS

Figure 2 shows axial images from a representative patient on a slice containing the most severe metal artifact, demonstrating visible reduction with HyperSight iCBCT MAR.

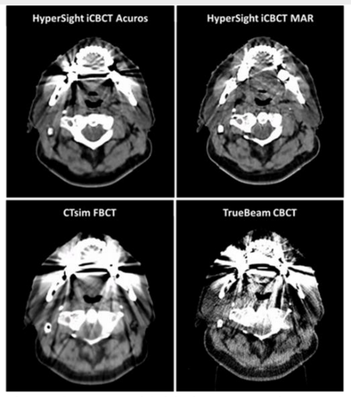

Figure 2. Images highlighting metal artifacts in the oral cavity for one patient.

Figure 3a displays the OAR-averaged HU values relative to FBCT for all patients. Truebeam CBCT images exhibited the highest deviations across all OARs except for the parotid glands ($p<0.001$). Figure 3b shows DVH metrics differences relative to FBCT for the oral cavity and right parotid gland, as examples. Across all CBCT images, the median DVH-metric deviations were within 2% for all structures and metrics.

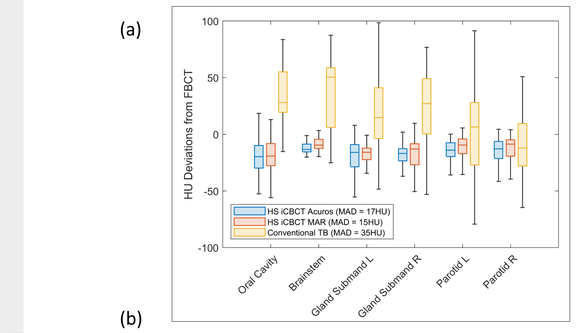

Figure 3. (a) OAR HU deviations from FBCT showing the median, quartiles, and the range. The mean of absolute deviations from FBCT, averaged across all patients and OARs are displayed in the legend. **(b)** Deviations in DVH-metrics relative to FBCT for the oral cavity and right parotid gland.

The gamma pass rates relative to FBCT evaluated for three slice locations are shown in Figure 4. HyperSight Acuros produced the highest gamma pass rates in artifact-free regions (slice a and b, $p<0.03$), while HyperSight MAR performed the best in artifact-affected regions (slice c, $p<0.001$).

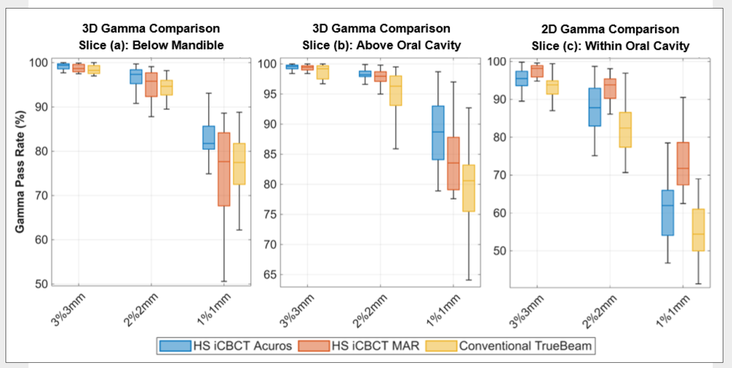

Figure 4. Gamma pass rates comparing VMAT dose distributions calculated on HyperSight iCBCT Acuros, HyperSight iCBCT MAR, and conventional TrueBeam CBCT, to the reference FBCT image for slice locations containing **(a)** mainly soft tissue, **(b)** bone and air, and **(c)** metal artifacts.

DISCUSSION

Despite substantial improvements in image quality on HyperSight, particularly relevant for contouring, the HU inaccuracies observed in Figure 3a generally had a limited impact on dose calculation accuracy. Across all DVH metrics shown in Figure 3b and the other evaluated OAR structures, no CBCT modality consistently performed better or worse. Even though conventional TrueBeam CBCT may provide acceptable dose estimates, its significant metal-induced streaking artifacts and field of view truncation effects can compromise anatomical interpretation required for adaptive planning. HyperSight addresses these practical limitations, supporting the clinical feasibility of CBCT-based adaptive radiotherapy.

In regions unaffected by metal artifacts (slices a and b), HyperSight iCBCT Acuros consistently achieved the highest gamma pass rates, suggesting more accurate representation of soft-tissue and bone HUs in artifact-free regions. However, in slices containing metal artifacts (slice c), iCBCT MAR outperformed both iCBCT Acuros and conventional TrueBeam CBCT. These findings are consistent with our previous image quality evaluation[1], in which iCBCT Acuros achieved image quality most comparable with FBCT in artifact-free regions, while iCBCT MAR performed best in the presence of metal artifacts. Together, these results suggest that while MAR improves the dosimetric accuracy in the presence of artifact-producing metal implants, it may not always be the optimal default imaging mode.

CONCLUSIONS

Image quality and HU accuracy from most onboard imagers are insufficient for reliable contouring and dose calculation. Our findings support the use of HyperSight for accurate CBCT-based dose calculations directly at the treatment unit with iCBCT MAR improving accuracy near metal artifacts, while iCBCT Acuros is preferred when artifact reduction is less critical.

REFERENCES

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