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Assessment of Image Quality in HyperSight CBCT and Conventional CBCT Images Using Planning CT as the Reference through Radiomic Features

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ABSTRACT

This study aims to compare HyperSight CBCT with conventional CBCT and planning CT for radiomic features, using statistical methods such as the Kruskal-Wallis H Test and the Intraclass Correlation Coefficient (ICC).
We conducted a retrospective analysis of ten cancer patients (six thoracic, two pelvic, two abdominal) undergoing radiation therapy, using three imaging techniques: planning CT, HyperSight CBCT, and conventional CBCT. Images were aligned with planning CT, standardized to 1-mm isotropic voxels, and radiomic features were extracted using PyRadiomics. Statistical analyses were performed in SPSS to evaluate agreement with the planning CT using ICC and to assess differences among imaging techniques.
Statistically significant differences in radiomic features were found between conventional CBCT and HyperSight CBCT (P=0.03), and between conventional CBCT and planning CT (P<0.05). No significant differences were observed between HyperSight and planning CT (P=0.63). ICC results showed poor to moderate agreement between conventional CBCT and planning CT (0.03 < ICC < 0.54), and moderate to excellent agreement between HyperSight and planning CT (0.5 < ICC < 0.95). HyperSight CBCT demonstrates comparable image quality to planning CT for radiomic feature extraction, highlighting its potential for quantitative CBCT imaging and clinical applications in outcome/toxicity assessment and mid-treatment adaptation.

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INTRODUCTION

Radiomics features serve as quantitative and objective metrics for assessing image quality, such as noise, contrast, etc. These high-throughput mathematical descriptors—including first-order (intensity) and texture features—quantify the relationships between pixels and voxels that can vary depending on imaging parameters such as the scanner used and the reconstruction methods applied. In clinical imaging, it is essential to evaluate the effectiveness of new techniques against established methodologies to determine if the newer options can adequately replace the traditional ones. Therefore, in this study, we try to answer the question of whether HyperSight can be a good replacement for conventional Cone Beam Computed Tomography (CBCT). For this purpose, we compare HyperSight CBCT to conventional CBCT and planning CT in terms of radiomic features. To achieve this, we employ statistical methods such as the Kruskal-Wallis H Test and the Intra-Class Correlation Coefficient (ICC).

METHODS AND MATERIALS

A retrospective analysis was conducted on ten cancer patients, including six with thoracic malignancies, two with pelvic tumors, and two with abdominal cancer, all of whom underwent radiotherapy. Each patient was imaged using three techniques: planning CT, HyperSight CBCT, and conventional CBCT, with the initial scan serving as a reference for alignment. Imaging took place on a TrueBeam linear accelerator (Varian, a Siemens Healthineers Company), and images from HyperSight and conventional CBCT were registered to the planning CT using a multi-resolution framework based on mutual information. All images were standardized to isotropic voxel dimensions of 1 mm. Radiomic features were extracted from the Clinical Target Volume using PyRadiomics software (version 3.0.1). Statistical analyses were performed using SPSS (version 31), focusing on Intraclass Correlation Coefficient (ICC) calculations to assess concordance with planning CT, and the Kruskal-Wallis Test to evaluate differences among the imaging techniques for insights into radiotherapy planning and assessment.

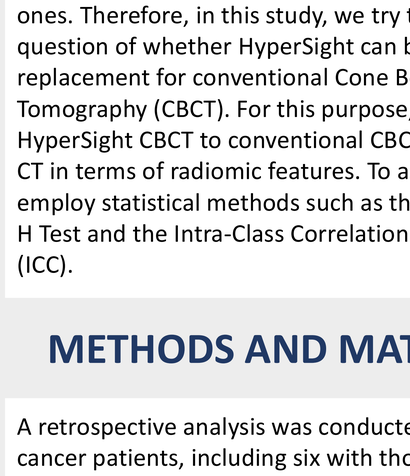

Figure 1. Illustration of a) Planning CT, b) conventional CBCT, c) HyperSight CBCT for a thoracic case

RESULTS

Figure 2 shows the comparison of three image modalities. The findings reveal a statistically significant difference in radiomic features when comparing conventional CBCT with HyperSight CBCT, as well as between conventional CBCT and planning CT (p-value < 0.05). However, no significant differences were observed between HyperSight and planning CT (p-value > 0.05). The ICC values were categorized as excellent reliability (> 0.9), good reliability (0.75–0.9), moderate reliability (0.5–0.75), or poor reliability (< 0.5) [1]. The outcome of this study indicates poor to moderate agreement between conventional CBCT and planning CT (0.03 < ICC < 0.54) and a moderate to excellent level of agreement between HyperSight and planning CT (0.5 < ICC < 0.95).

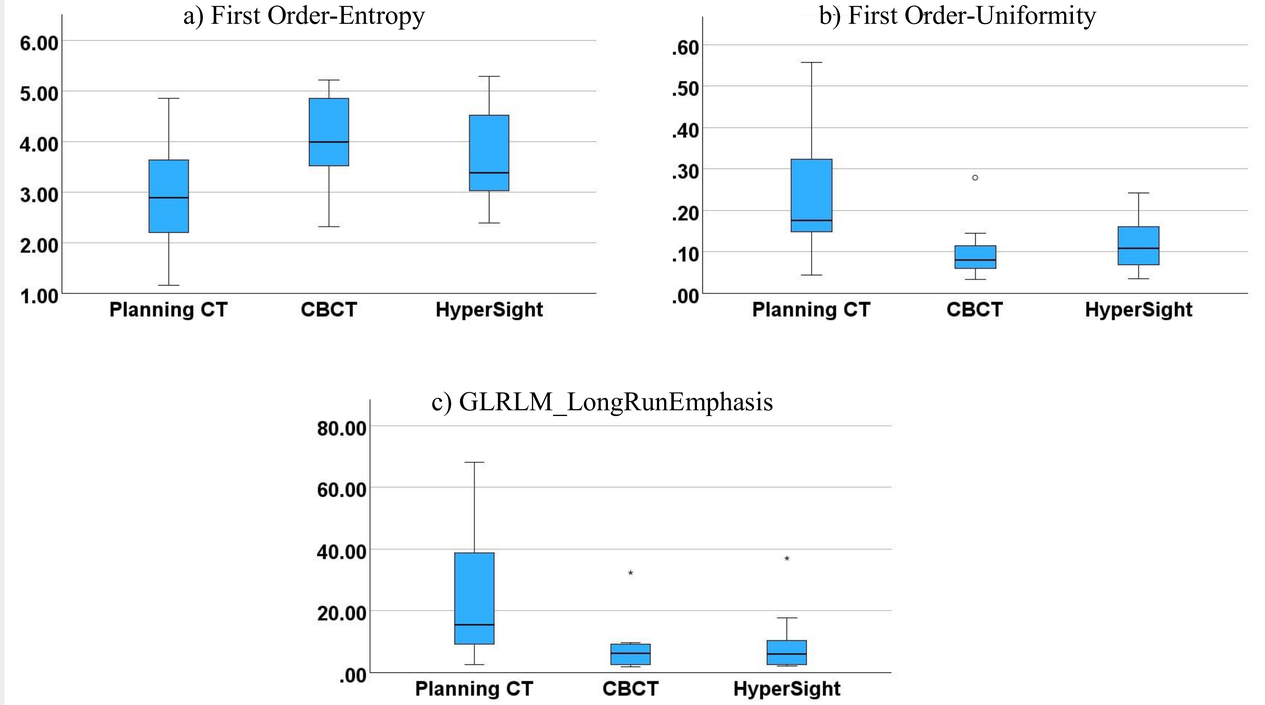

Figure 2. A significant difference in medians was found between CBCT and HyperSight CBCT, as well as CBCT and planning CT (P-value < 0.05). No significant differences were noted between HyperSight CBCT and planning CT for a) first-order Entropy, b) first-order Uniformity, and c) GLRLM_Long run emphasis.

DISCUSSION

Our findings reveal that the key Radiomics Features for image quality comparison include the Gray-Level Run-Length Matrix (GLRLM), Gray-Level Size Zone Matrix (GLSZM), Intensity Features, and Uniformity. GLRLM features such as Short/Long Run Emphasis describe graininess and texture and serve as indicators of noise levels.
GLSZM features such as Run-length variance (RLV) are highly sensitive to noise. Intensity Features such as the standard deviation or entropy of intensity values within a region of interest can reflect noise. Uniformity measures the consistency of intensity across an area.

CONCLUSIONS

The outcomes of this study suggest that HyperSight CBCT exhibits image quality that is comparable to that of planning CT, thus indicating its promising applicability in treatment planning processes. The findings highlight the potential benefits of adopting this advanced imaging technology in clinical practice.

REFERENCES

1. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med. 2016;15(2):155-63.