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Evaluation of Dosimetric Effects on the Therapeutic Carbon Ion Beam Due to Gold Fiducial Markers

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Purpose/Objective
Accurate dose delivery and target localization are crucial in carbon ion beam therapy. However, gold (Au) fiducial markers cause significant dosimetric perturbations and induce metal artifacts in CT images, compromising efficacy. This study aimed to evaluate the degree of carbon ion beam dose perturbation within the SOBP using markers with different gold contents.

Materials and Methods
We used two different rod-shaped markers: Au 100% and Au 5%. CT images compared their imaging properties. The setup used a PMMA phantom with markers' axes perpendicular to the 380 MeV/u carbon ion beam, generating a 6 cm SOBP. Markers were placed at Position A (5.0 cm depth, mid-SOBP) and Position B (6.5 cm depth, distal SOBP). Dose perturbation was evaluated using EBT XD film, inserted at 0.5 cm intervals downstream from Position A. Film measurements were converted to physical dose after correction for quenching effects specific to the carbon ion beam's dose-response characteristics.

Results
Both markers showed differences in dosimetric and imaging properties. The Au 100% marker generated metal artifacts in CT scans, significantly hindering marker boundary identification and surrounding tissue visibility. In contrast, the Au 5% marker showed little to no severe imaging artifacts. Dosimetrically, the Au 100% marker induced a high dose reduction, ranging from -5.3% to a critical -44.3%, a marked difference compared to the Au 5% marker (reduction range: -1.8% to -7.2%). The degree of dose reduction and perturbation was confirmed to increase sharply with gold content.

Conclusions
The comparative analysis confirmed that the conventional marker (Au 100%) caused more severe distortion in both carbon ion beam dose and CT images than the Au 5% marker. The Au 100% marker caused a large dose reduction (up to -44.3%). The severe imaging artifacts generated by the Au 100% marker are a major factor contributing to treatment planning uncertainty.

Paper submission Plan

Yes

Best Presentation

Yes

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