

Theme: Physics

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Abstract Title: Optimizing RBE and OER Weighted Dose in Hypoxia-Targeted Carbon-Ion Therapy for Lung Cancer

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Background / Aims:

- Hypoxia poses a significant challenge to effective photon radiotherapy in oncology, as it markedly reduces treatment efficacy. Carbon-ion therapy demonstrates transformative potential to overcome hypoxia-induced treatment resistance.
- However, the dose-averaged linear energy transfer (LETd) within the target volume, as delivered by conventional intensity-modulated carbon ion radiotherapy (IMCT) plans, is often insufficient to induce clinically significant radiosensitization in hypoxic tumor subregions.
- This study aims to clinically validate the novel RBE and oxygen enhancement ratio (OER)-weighted dose (ROWD) optimization framework for carbon-ion radiotherapy, utilizing 18F-FMISO PET imaging for hypoxia mapping, and to systematically compare its performance against standard IMCT planning in enhancing therapeutic outcomes for hypoxic lung tumors.

Subjects and Methods:

- Hypoxia-guided ROWD optimization plans were developed through retrospective analysis of 18F-FMISO PET-CT imaging data from 13 lung cancer patients using the matRad platform.
- The workflow included: (1) voxel-wise OER modeling based on PET-derived hypoxia maps, (2) ROWD-based optimization integrating LETd and hypoxia effects, and (3) recalculation of radiotherapy plans under hypoxic conditions.
- Plan quality was evaluated by comparing dose-volume histogram (DVH) metrics, physical dose distributions, and LETd profiles between ROWD-optimized and IMCT plans.

Result:

- Both plans achieved adequate target coverage while adhering to the predefined dose constraints for all organs at risk (OARs).
- Compared to the IMCT plan, the ROWD-optimized plan delivered a significantly higher RBE-weighted dose to the hypoxic target volume (HTV).
- When accounting for hypoxia, the IMCT plan exhibited a marked reduction in HTV dose coverage, whereas the ROWD-optimized plan maintained full prescription dose coverage to the HTV.
- The ROWD approach facilitated substantial physical dose escalation in hypoxic regions, yielding a mean dose increase of 1.77 Gy compared to IMCT, while preserving similar LETd distributions.
- This study establishes ROWD optimization as a clinically viable paradigm for carbon-ion radiotherapy, effectively overcoming hypoxia-related limitations of conventional IMCT.