A radiotherapy planning module for treatment individualisation based on tumour hypoxia PET imaging

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A treatment planning module has been implemented for the incorporation of hypoxia PET imaging into radiotherapy treatment planning systems aiming at determining the prescribed dose levels required for the achievement of high local control probability.

This module constitutes a valuable tool for the early identification of the clinical cases that might benefit from dose escalation in selected volumes.

Background
The clinical significance of tumor hypoxia is linked to poor outcome of both chemo- and radiotherapy. PET functional imaging based on dedicated tracers for hypoxia could provide 3D spatial distribution of hypoxic regions that have the potential to help individualising the treatment in the context of precision cancer medicine.

Materials and Methods

- PET data co-registered to the planning CT through hybrid deformable image registration available in the research version of the treatment planning system (TPS) RayStation is imported into the module (Fig. 2 (a), and the standardised uptake value (SUV) in each PET voxel is converted to oxygen partial pressure \( \text{pO}_2 \) (Fig. 2 (b), Fig. 3).
- Based on \( \text{pO}_2 \) thresholding and utilizing ROI target volumes for dose prescription are segmented (Fig. 2 (c)).
- Considering a user-defined level of local control, the required uniform prescription doses to the segmented volumes are calculated based on radiobiological prediction models and taking into account the dynamic character of the radioreistance at local level related to fluctuations in acute hypoxia (Fig. 2 (d)).
- The calculated doses are presented together with the corresponding TCP in each volume (Fig. 2 (e)).

Results
Quantifying hypoxia levels allow the semi-automatic segmentation of target volumes with respect to radiosensitivity to be used in dose-painting approaches [2]. (Fig. 3 and 4). Further degrees of freedom are provided, allowing for the consideration of volume-based cell density distribution affecting the calculation of prescription doses and TCP values.


![Fig. 1 Left Panel: PET-CT showing a hypoxia target volume of 10 mmHg \( \text{pO}_2 \) (light blue) in the primary (central) lesion; GTV and CTV are shown in green and pink, respectively. Right Panel: Dose distribution after the planning optimisation for the prescribed dose.]

![Fig. 2. Graphic user interface integrated in the research version of the treatment planning system RayStation (RaySearch Laboratories AB, Sweden)]]

![Fig. 3. \( \text{pO}_2 \) histogram for the \( \text{pO}_2 \leq 10 \) mmHg inside the GTV and TCP curve assuming 30 fractions.]

![Fig. 4. \( \text{pO}_2 \)-CT showing sub-volumes in the central uptake region considering \( \text{pO}_2 \) thresholds of 10, 20, and 30 mmHg (solid lines cyan, blue and green, respectively).]