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Topic: Physics-Treatment planning – algorithms and methods

Title

Cellularity-guided dose painting in carbon ion radiotherapy for large sacral chordomas to maximize tumor control probability

Background and Aims

A high cellularity within the GTV has been previously investigated as potential negative prognostic factor in carbon ion radiotherapy (CIRT) for large sacral chordomas (SC). This work aims at assessing the feasibility and the potential clinical benefits of a cellularity-based dose painting (DP) approach.

Methods

The first 39 SC patients with baseline diffusion-weighted MRI (DWI), radically treated with CIRT at a single institution, were retrospectively selected for the analysis. The median follow-up was of 33.6 months, with 14 local relapses (LR) and 25 local controls (LC). Voxel-wise cell counts were estimated from DWI using a previously published microstructural model (Morelli et al.). A Poisson-based tumor control probability (TCP) model, trained on 33 patients, guided the optimization for the 6 remaining cases. A custom optimization function was implemented in a research-version of a commercially available treatment planning system (TPS) and used to maximize the TCP in the GTV by delivering higher RBE doses to regions with higher cell count. For each patient, a DP plan and a reference uniform-dose plan were optimized following the institution current clinical guidelines, with a LEM-I prescription dose of 73.6 Gy(RBE) in 16 fractions, with a sequential boost approach with target shrinkage after 9 fractions (Figure 1). For this first feasibility study, DP plans allowed the dose in the GTV to vary between 95% and 110% of the prescription, according to patient-specific cell count maps. All plans were required to adhere to clinical goals for the main gastrointestinal OARs (i.e. rectum, sigma, bowel, nerves, skin). DP and reference plans were evaluated using DVH, LVH, and TCP metrics, with statistical comparison via the Mann-Whitney U-test (alpha = 0.05).

Results

DP plans achieved significantly higher TCP (74.5% ± 2.7%) compared to reference plans (65.7%± 3.4%, $p<0.01$) while satisfying the OARs' clinical goals (Figure 2a). No significant differences were observed in LET_d metrics or dose metrics within the CTV margins (Figure 2b).

Conclusion

Integrating patient-specific cell count data into dose painting approaches can potentially improve the benefits of CIRT treatments enhancing TCP, without compromising the risk of potential side effects to OARs.

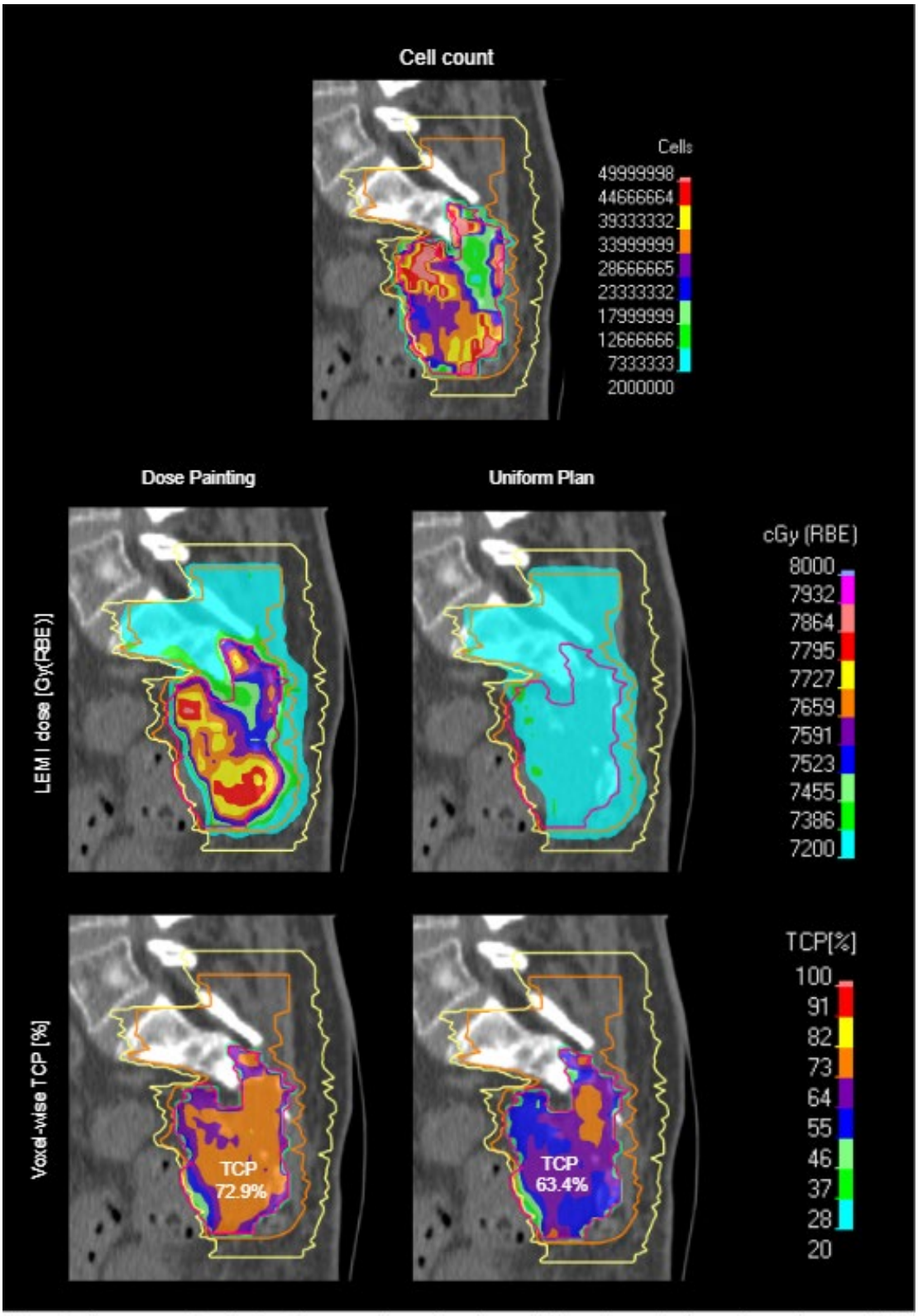

Figure 1. Case example showing the comparison of a dose painting plan against a uniform plan, and their corresponding voxel-wise TCP map. Overlayed, the overall TCP on the GTV. On top, the corresponding cell count map. In red the GTV, in orange the high-dose CTV and yellow the low-dose CTV.

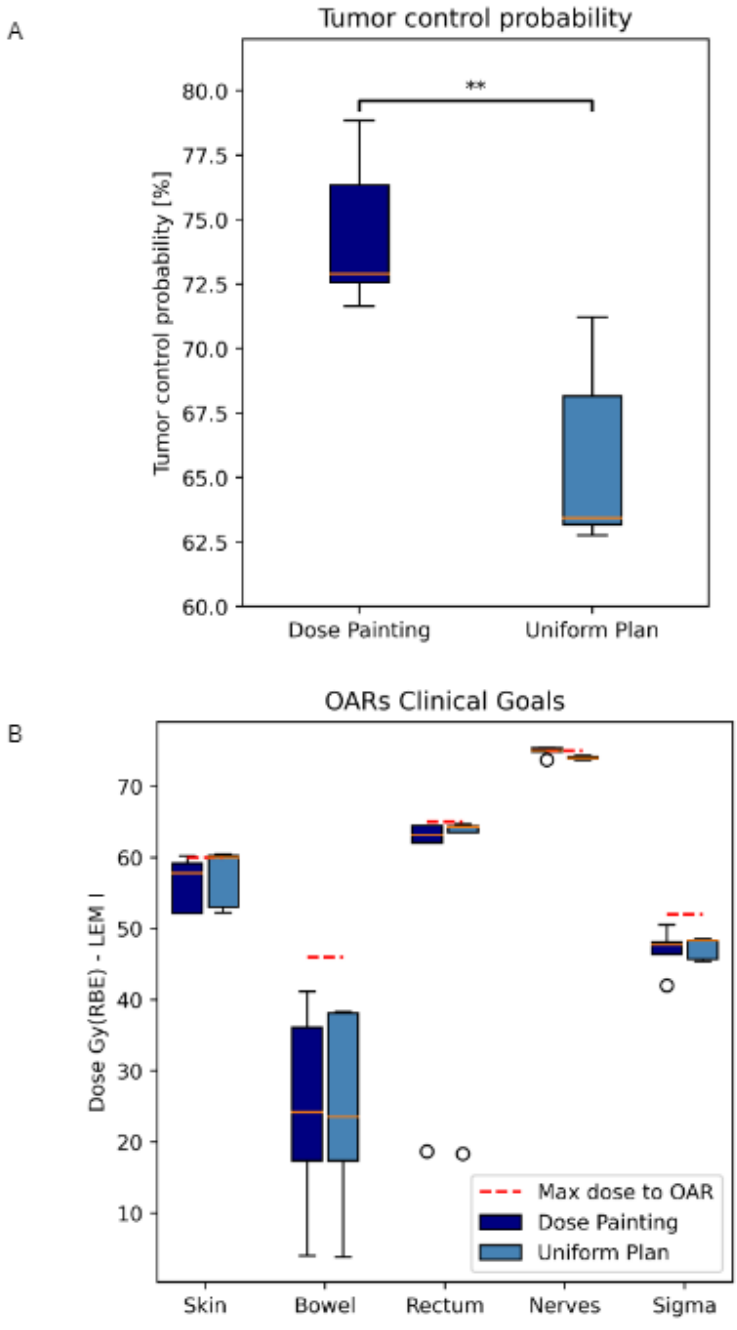

Figure 2. A) Boxplot showing the tumor control probability in the GTV for dose painting and uniform plans (n=6). ** p-value<0.01 B) Boxplot representing the adherence to clinical goals for OARs on the nominal plans (n=6).