A comparison of high-LET-dose distribution between small and large tumors in carbon ion radiotherapy

Schafasand M. (1,2), Stock M. (1), Resch A. (1,2), Carlino A. (1), Georg D. (2), Fossati P. (1)

(1) MedAustron Ion Therapy Center, Wiener Neustadt, Austria
(2) Medical University of Vienna, Department of Radiation Oncology, Austria

Introduction

One of the main motivations for treating radioresistant tumors with carbon ion radiotherapy (CIRT) is the high linear energy transfer (LET) and the enhanced relative biological effectiveness (RBE) of carbon ions compared to protons. The dense ionization pattern of high LET radiation and the clustered DNA damage play an important role in the treatment outcome and thus, having higher LET in the target can be beneficial.

Depending on treatment site, target volume and shape, the volume covered by high-LET can vary substantially, which in turn, may influence the clinical outcome. Several studies have reported differences in the local control of small and large volume tumors for the same uniform RBE-weighted dose distribution.

The current study is a quantitative evaluation of the high-LET-dose distribution inside the target and aims to assess the differences between various tumor sizes.

Materials and Methods

From the chordoma, sarcoma and carcinoma cases treated with CIRT at MedAustron, each five patients with a large (volume ≥ 500 ml) and a small (volume < 500 ml) tumor were selected.

The “LET-based dose filtration”-functionality (in which the dose can be filtered as high-LET- and low-LET-dose based on a user specified LET threshold) implemented in the non-clinical version of RayStation 9A-IonPG (RaySearch Laboratories AB, Stockholm, Sweden) treatment planning system was used for this study to extract the high-LET-dose distribution among these two groups.

The two selected thresholds for this study were30 keV/µm and 50 keV/µm. At both thresholds, the mean high-LET-dose volume histogram (high-LET-DVH) of the small tumors was compared against the mean high-LET-DVH of the large tumors. In addition, a t-test with 95% confidence interval was used to compare the mean near-minimum (D98%), mean median (D50%) and mean near-maximum (D2%) among the two groups (small vs. large tumors).

Results

The fraction of high-LET-dose to the physical dose was always lower for the large tumors compared to the small tumors. While at 50 keV/µm threshold, only the median dose (D50%) showed a statistically significant difference between small and large tumors, all three metrices (D98%, D50% and D2%) differed significantly (p<0.05) among the two groups for the 30 keV/µm threshold.

Discussion

The current study showed that in large tumors, a smaller fraction of the physical dose is delivered in form of high-LET-dose compared to small tumors. The acquired values and selected LET thresholds in this study can be considered as starting parameters for future LET-based optimization in CIRT.