An in silico Trial of X-rays vs Carbon Ions in Lung Cancer Radiosurgery

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Introduction

Stereotactic body radiotherapy (SBRT) with photons to treat extra-cranial tumors in a single fraction has been shown to yield local control rates > 80 % with acceptable toxicity [1]. Scanned particle therapy (PT) has proven its efficacy for head and neck tumors, while treatment of mobile tumors of the lung is still challenging due to interplay and range changes. We performed an in silico case study comparing SBRT and PT (carbon ions) in lung cancer patients to investigate potential benefits of PT in radiosurgery.

Materials and methods

We used data of nine patients that were actually treated with SBRT at Fundação Champalimaud, Lisbon. The prescribed target dose is at least 24 Gy for 99 % of the target volume, with strict adherence to dose constraints for organs at risk (OAR). The actual SBRT treatment plans are compared to simulated treatment with PT using TRiP98 [2] on a 4D-CT. For SBRT, isotropic ITV-PTV margins of 3 mm were used. Due to range changes in PT we added margins 3 mm laterally and 1 mm in beam's eye view on CTV and then computed a range-considering ITV with 2 mm + 2 % range margins. Five times slice-by-slice rescanning was used to counter interplay.

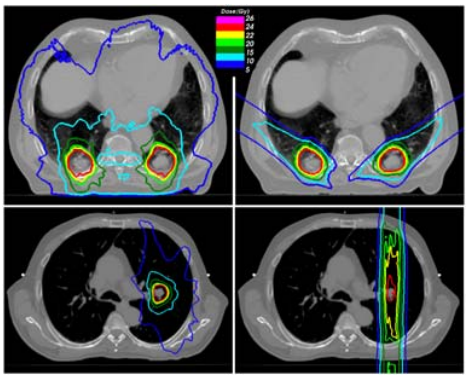

Figure 1: Dose cuts for SBRT (left) and PT (right) in two patients. The first patient (top) shows a favorable dose distribution of PT, while the second case (bottom) appears better suited for SBRT.

Results

Average peak to peak tumor motion was 5.6 mm (from 0.2 mm to 9.5 mm). Comparison of dose cuts between SBRT and PT is shown in Figure 1. Both therapies provided excellent target coverage and OAR doses within tolerances, except for three patients, where maximal allowed point dose in smaller airways was exceeded due to tumor proximity. Differences between SBRT and PT in dose deposition for 7 specific OAR are shown in Figure 2. On average all OAR receive less dose in PT, except for ipsilateral lung $D_{10\%}$. The most profound difference was in spinal cord and ipsilateral lung $D_{10\%}$, where the average dose difference was 4.2 Gy and -4.5 Gy, respectively.

Discussion

The results clearly indicate potential of PT in treating lung cancer. With smaller entry channel than SBRT, PT can deposit less dose in OAR, while maintaining same target coverage. This advantage varies with patient anatomy and lesion location, motion and size. The clinical relevance of possible further dose escalation or improved OAR sparing with scanned carbon ion therapy needs to be validated. This study will include a total of 20 patients, and also further investigate the robustness of PT.

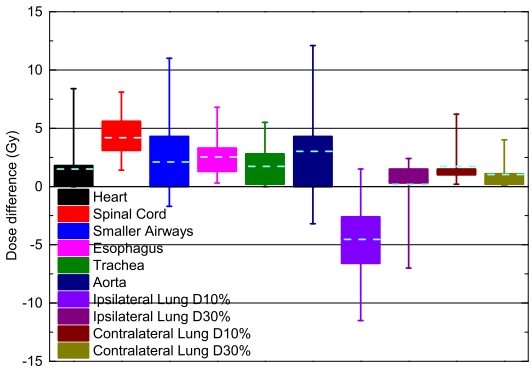

Figure 2: Box-and-whisker plot for dose difference between SBRT and PT for different OAR. Boxes contain data between 25 % and 75 %, dashed lines represent mean value and whiskers minimum and maximum values.

References

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