Effects of anatomical changes on the dose using proton treatment planning system

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Purpose/Objective: Proton therapy has the potential to deliver a superior distribution of radiation dose to the patient compared with photon therapy. On the other hand, proton treatments are more sensitive to setup variations and anatomical changes. In particular, a site where proton therapy could be highly beneficial is lung cancer. However, the anatomical changes in lung cancer provide a big challenge to deliver the planned dose. As part of the development of probabilistic planning systems, where knowledge about geometric uncertainties is taken into account during plan optimization, we are studying the effect of observed anatomical changes in lung cancer patients on scanned beam proton treatments.

Materials and Methods: We selected three lung cancer patients with tumors close to the mediastinum that might be eligible for SBRT with protons, while they cannot be delivered with photons due to dose-limiting constraints. For each patient we had the planning CT and five CBCT scans available. We used the research Pinnacle3 Intensity Modulated Proton Therapy (IMPT)/Spot Scanning treatment planning system (TPS) version 9.100 to create a proton plan for each patient using the original planning CT scan. These proton plans were kept very simple, consisting of two beams and optimized using the same objectives as the photon treatment plan. For every fraction, a CBCT was made just before the treatment. These scans represent the anatomy of the patient at that particular treatment day. We did not consider respiration motion, but used motion compensated CBCT scans to describe the ‘baseline’ anatomical changes. The CBCT scans cannot be directly used in the TPS to recalculate the dose as Hounsfield unit are not calibrated. Instead, the planning CT scan was deformed to each CBCT scan and recalculated using the original plan in Pinnacle3. The dose differences between the planned and delivered proton dose was evaluated.

Results:

Patients 1, 2 and 3 were analyzed. These patients were scanned 3 times per week and 3 separate boost plans (VMAT, IMPT and IMIT) were created to boost the PTVmax using 50 GyE for HN and 50.4 GyE for PC patients. Furthermore, 3 separate boost plans (VMAT, IMPT and IMIT) were created to boost the PTVmax up to 70 GyE and 78 GyE for HN and PC cases, respectively. Doses to the primary OARs i.e. brainstem, myelon, larynx and parotid glands were assessed for HN cases. Additionally, various OARs whose sparing can be associated with improved quality of life after treatment were delineated. For PC cases doses to bladder, rectum as well as femoral heads were analyzed. In order to sum up the total doses, dose matrices of the initial VMAT plans and the respective boost plans were mapped together.

Results: HN cases: The targets goals were easily met, with higher median dose found for VMAT+VMAT compared to VMAT+IMPT and VMAT+IMIT. Considering additional OARs a big improvement was found for larynx comparing to VMAT+VMAT results. Similarly, D2GyE was on average 2 GyE lower for contralateral parotis and 1.5 GyE lower for brainstem. Moreover, no significant difference was detected between VMAT+IMPT and VMAT+IMIT. Considering additional OARs a big improvement was found for VMAT+IMPT and VMAT+IMIT. Considering additional OARs a big improvement was found for VMAT+IMPT and VMAT+IMIT. Considering additional OARs a big improvement was found for VMAT+IMPT and VMAT+IMIT. Considering additional OARs a big improvement was found for VMAT+IMPT and VMAT+IMIT. Considering additional OARs a big improvement was found for VMAT+IMPT and VMAT+IMIT. Considering additional OARs a big improvement was found for VMAT+IMPT and VMAT+IMIT. Considering additional OARs a big improvement was found for VMAT+IMPT and VMAT+IMIT.
Assessment of improved organ at risk sparing for meningioma for structures that are associated with better quality of life after therapy.

Conclusions: Looking at target coverage no significant differences was observed between the 3 evaluated treatment concepts. However, combining particles and photons spares OARs more beneficially compared to sole photon treatments. Moreover, a combination of carbon ions and photons may result in limiting doses to those structures that are associated with better quality of life after therapy.

Purpose/Objective: To investigate the combination of photons, protons and carbons for an optimal study design for the treatment of meningioma. Meningiomas lesions frequently show an aggressive local growth and a high incidence of tumor recurrences after neurosurgical resection. The rapid dose fall-off of particles and the increased RBE of carbons could be of potential benefit leading to increased local tumour control as well as an improved OAR sparing.

Materials and Methods: Based on the gross tumor volume (GTV) two different planning tumor volumes (PTV) were constructed for 4 meningioma patients: The initial PTV (PTV\textsubscript{init}) treated with 25x2 GyE and the boost PTV (PTV\textsubscript{boost}) with 3x6 GyE. For the initial clinical target volume (CTV\textsubscript{init}) a margin of 1 cm was added to the GTV adapted to the surrounding tissue. CTV\textsubscript{init} plus 3 mm formed PTV\textsubscript{init} and for PTV\textsubscript{boost} the GTV was enlarged by an isotropic margin of 3 mm. Different organs at risk (OARs), delineated using pre- and post operative MRI information adapted to the planning CT, were considered: eyes, optical nerves, chiasm and brainstem. Intensity modulated photon plans (IMXT) were created with Monaco (V3.0, Elekta) and intensity modulated proton and carbon ion plans (IMPT and 12C) using TRS (V4.41, Elekta-GMS) and TRIPMB, respectively. For IMXT 6 beams were used for PTV\textsubscript{init} plans and 4 beams for PTV\textsubscript{boost} plans. IMPT and 12C treatment plans were created assuming fixed beams. Two beams separated by a couch angle of 20-30° from ipsilateral side were used for PTV\textsubscript{init} and two beams from crano-caudal direction for PTV\textsubscript{boost}. Using the software CERR (Version 4.1, May 2012) dose matrices for the following combinations were generated: IMXT + IMPT or IMC; IMPT + IMXT or IMC; IMPT + 12C; IMXT + 12C. Plan quality was analyzed by evaluating conformity and homogeneity index (CI, HI) according to ICRU83, V95%, D2% and D50%; D2%, D50% and Vd values were investigated for OARs.

Results: V95\textsubscript{PTV} was higher than 95% for all plans but best for 12C. CI was worst for IMXT\textsubscript{init} with 0.57±0.03 and higher than 0.72 for IMPT and 12C. HI for 12C was 0.04±0.01 and thus 3 times better than for IMXT, for both PTVs. OAR sparing for particle therapy was highly coincident and tumor size dependent. No remarkable difference in dose was observed for the ipsilateral optical nerve and the chiasm. 12C as single technique could reduce D\textsubscript{max} to the contralateral optical nerve by 10 GyE. The mean dose to the contralateral eye was reduced from 5.0±3.7 GyE for IMXT+IMXT to 3.2±1.9 GyE for IMXT+IMPT/12C. Moreover, IMPT and 12C as sole treatment modality reduced the dose to 0 GyE. V20\textsubscript{norm} of the brainstem was higher than 90% using IMXT as initial technique and less than 50% when using IMPT and 12C (figure 1).

Conclusions: Highly conformal IMPT and 12C plans could be generated with a non-gantry scenario. Improved OAR sparing favors sole 12C and proton plans, which is should be included in future trial design for meningioma patients.