ESTRO - Physics track
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4D log file-based proton dose reconstruction: Fraction-wise interplay analysis in clinical practice

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Purpose/Objective

Pencil beam scanning (PBS) proton therapy (PT) in patients with intra-fraction, breathing-induced tumour motion might result in unrecognized deviations from the planned dose distribution. Our work pursued the clinical roll-out of a 4D log file-based proton dose reconstruction (4DlogReco). By that, we monitor the interplay effect and study its relevancy in an ongoing clinical study at the University Proton Therapy Dresden (UPTD).

Material/Methods

We had developed and experimentally validated a 4DlogReco (in RayStation v.8) based on amplitude-sorted 4DCTs, PBS machine log files and synchronized motion log files. The workflow and data handling was verified in the clinical treatment planning system by a retrospective analysis of four complete PBS-PT treatment series (incl. lung, oesophageal and pancreatic carcinoma; mean motion ≤5mm; 20-33 fractions) of patients who received weekly in-room 4DCTs for monitoring interfraction changes. For the final 4DlogReco translation into clinical practice, we initiated the MOBIL study (Monitoring Of Breathing for Interplay study with Logfiles).

Available patient data were analysed fraction-wise (Fig1). We considered individual critical organs at risk (OAR; lung, heart, spinal cord, kidneys, oesophagus), the clinical target volume (CTV) coverage, mean dose, near-maximum dose and homogeneity index [D_{98}, D_{mean}, D_1, HI=(D_1-D_{98})/$D_{prescribed}$] and the deviations from the plan in the fraction-wise worst case (Δ_{wc}) and in the accumulated dose (Δ_{acc}).

Results

The 4DlogReco was successfully translated into clinical application. So far, two patients (oesophageal and pancreatic carcinoma; mean motion ≤5mm; 19 and 30 fractions) had been treated within the MOBIL study. Daily 4DlogReco took about 15min incl. data processing and dose calculation, and should speed up by an automatic log file retrieval and GPU-based dose calculation after TPS upgrade.

For the six investigated patients (incl. the four workflow test patients), intra-fraction motion led to CTV parameter differences in the worst-case fractions of $\Delta_{wc}(D_{98})$=(-15.5 – -3.4)pp, $\Delta_{wc}(D_1)$=(-0.1 – 3.5)pp and $\Delta_{wc}(HI)$=0.04 – 0.17, while there were smaller changes in the accumulated dose of $\Delta_{acc}(D_{98})$=(-2.6 – -0.6)pp, $\Delta_{acc}(D_1)$=(-1.3 – 0.4)pp and $\Delta_{acc}(HI)$=0.00 – 0.03 (Fig2). The individually relevant OAR dose parameters remained uncritical in line with the so far investigated minor motion amplitudes.

Conclusion

The first 4DlogReco workflow capable to deal correctly with amplitude-sorted 4DCTs provides a fraction-wise verification of the interplay-affected delivered and accumulated dose to moving targets. The clinical implementation of this QA module at UPTD had a direct influence on our institutional treatment protocols, as PBS-PT of lung cancer patients is now admissible for motions up to 15mm. The monitoring of such patients will provide valuable insights on the necessity of further motion compensation and of considering the accumulated 4DlogReco doses during treatment adaptation.

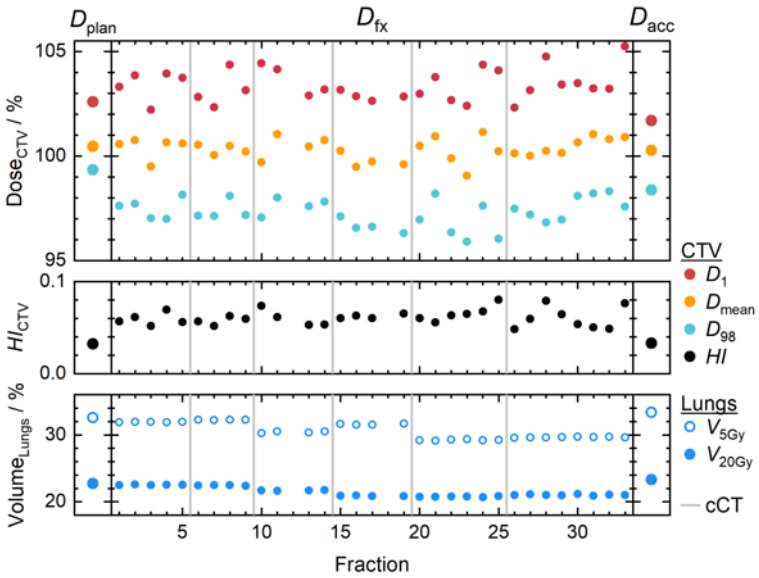

Fig1: Exemplary analysis of dosimetric parameters from the planned dose (D_{plan}, left), the fractionwise calculated 4DlogReco (D_{fx}, middle) and the accumulated dose distribution (D_{acc}, right) of a lung cancer patient during the testing phase. There are clear deviations from the planned target dose, especially for the clinical target volume (CTV) coverage, mean dose and near maximum dose (D_{98}, D_{mean}, D_1, top) as well as its homogeneity index (HI, middle). Dose parameters for the lungs (V_{5Gy} and V_{20Gy}, bottom) remain uncritical in this case. Vertical grey lines indicate new control CTs (cCT).

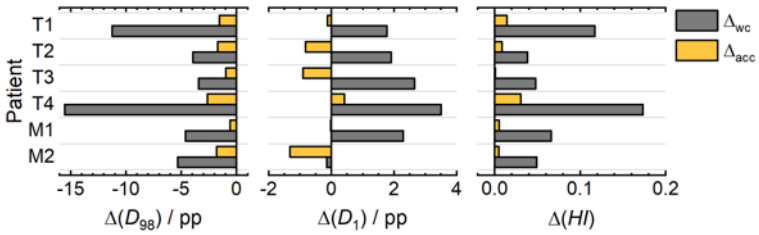

Fig2: Deviations from the planned CTV coverage, near maximum dose and homogeneity index (D_{98}, D_1, HI) in the fraction-wise worst case (Δ_{wc}, grey) and in the accumulated dose (Δ_{acc}, yellow) over the whole investigated treatment series for the four workflow test patients (T1-T4) and the two patients analyzed within the MOBIL study (M1, M2). Negative differences indicate lower values than planned. A reduction in CTV coverage is found in all patients, with an average loss of 1.5pp (percentage points) in the accumulated dose. The most severe deviations in all three CTV parameters for both Δ_{wc} and Δ_{acc} are found in a lung cancer patient (T4), indicating the sensitivity of the proton dose delivery in highly heterogeneous and intra-fractionally changing regions.