An interactive approach for local dose quantification from in-beam PET data

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The in-beam PET monitoring of carbon ion therapy supported the reliability of the treatment planning and patient positioning procedures at the GSI Darmstadt facility [1]. However, in some cases it detected deviations of the measured and the predicted β^+-activity distributions, due to minor inaccuracies in patient positioning or local changes of patient anatomy [1]. These discrepancies may correspond to small deviations of the applied and planned dose. Hence, a local dose quantification from PET images shortly after each therapeutic irradiation is highly desirable. Due to the lack of a feasible solution for the inverse problem relating the β^+-activity to the dose, an interactive approach has been considered. The implementation has been based on the dedicated tool used for the visualization of the PET measured and predicted distributions as contour plots superimposed onto X-ray CT images [2]. In case of deviations, an interactive modification of the patient CT consisting either in geometrical transformation (translation and rotation) or in local Hounsfield unit (HU) modifications in user-selected regions of interest (ROI) can be performed. The reliability of the modification is tested by a recalculation of the β^+-activity distribution with and without the CT changes. Actually, only the spatial distribution of β^+-decays is computed, in order to avoid blurring due to the imaging procedure. The calculation is local and analytical, in order to reach a "fast" (within few minutes) response. Only the pencil-like beams crossing the chosen ROI are taken into account. The depth-distribution of the main β^+-isotopes (^{11}C, ^{15}O and ^{10}C) is extrapolated from the PET database (DB) [3] containing the spatial distributions of positron emitters produced in PMMA ($C_5H_8O_2$) by ^{12}C beams of all the energy values used for therapy. The DB information is combined with the irradiation strategy (ion energy, fluence and position) and with the patient anatomy by means of the HU-ion range correlation [3], [4] and the stoichiometric calibration of the CT numbers suggested in [5]. The lateral-distribution is assumed to be Gaussian with a FWHM dependent on the beam focus and the average positron range in tissue. The lateral spread of the beam in depth is neglected. The distribution of β^+-decays is deduced from the isotope production and the time interval between the beam delivery and the end of the PET acquistion. If the recalculation supports the modification, a new dose distribution based on the elaborated CT is obtained by means of the treatment planning software [4]. Figure 1 and 2 show an example. For this patient an extreme but plausible tissue reduction was assumed on the basis of range and anatomical symmetry considerations. A new CT scan confirmed the conjecture. In such cases a new treatment plan may be defined, according to the physician's decision. Hence, the interactive approach can give an important feedback. The optional introduction of imaging effects on the recalculated distributions for a more direct comparison with the reconstructed PET images is under development. In particular, the effects of minor CT modifications on the PET attenuation corrections are currently studied. Moreover, the sensitivity and accuracy of the method as well as the potential of real quantitative PET data for local dose quantification are under investigation.

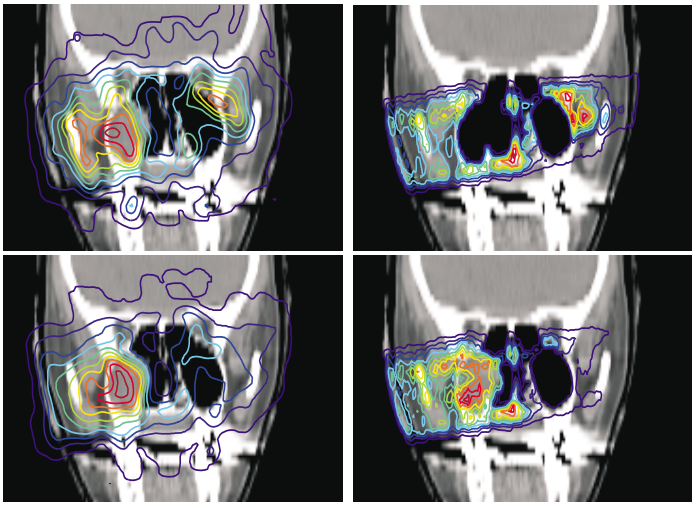

Figure 1: Left: Higher activation at the distal edge of the portal (entering the patient from the left of the picture) in the PET measurement (up) in comparison with the prediction (down). Right: The recalculation with (up) and without (down) CT modification well resembles the PET images (left), thus supporting the hypothesis.

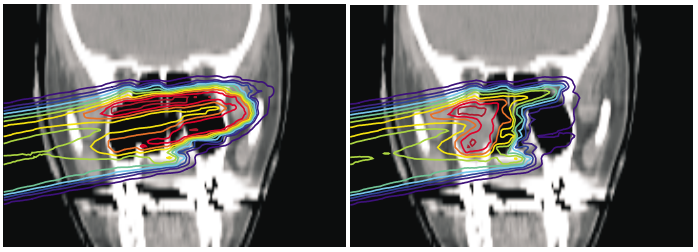

Figure 2: The effect on the recalculated dose distribution (left) in comparison with the planned one (right) is evident and in agreement with the PET observation (cf. Fig. 1).

References

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