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Analysis of dose deposition in lung lesions: a modified PTV for a more robust optimization.

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Introduction: In lung cancer, SBRT is often used to deliver high doses to a small dense lesion (GTV) moving into a low density tissue (the margin generating the PTV).

In order to reach an acceptable degree of accuracy, type B or MC-based algorithms should be adopted. If a modulated technique (IMRT or VMAT) is used to treat such inhomogeneous PTV, an apparently homogeneous dose distribution is delivered, but high photon fluence is generated inside a 3D shell (PTV-GTV) due to its low electron density (ED). This situation gives the paradox that the dose distribution is apparently uniform, but the GTV, which will move into the PTV, will receive a dose that depends on its position. This work was designed to evaluate this phenomenon and to suggest a more robust dose optimization.

Methodology:

A TPS Monaco 5.11 (Elekta, SWE) with a MC algorithm was used to simulate a SBRT treatment in a dummy patient (55 Gy in 5 fractions). In a first step, in order to evaluate the dose discrepancy on the target when the motion of the high ED GTV is considered, the photon fluence was optimized for the original PTV ED (ED_o) and then used to calculate the dose on a “forced” PTV ED (ED_f) in which the ED of the PTV was forced to the mean ED of the GTV.

In a second step, the photon fluence was optimized for PTV ED_f and then used for the dose calculation on PTV ED_o in order to evaluate the dose variation on the lower ED region of the PTV.

In both steps, the recalculation was done employing the same beam arrangement, and parameters as used in the original plans so that the segmentation and photon fluence were identical with the same number of MU. Dosimetric comparisons between the original and recalculated dose distribution were made in each step in terms of: dose profiles through PTV, and D_{mean}, D_{98%} and D_{2%} for PTV-GTV, the maximum difference between 3D dose distributions was also evaluated.

Results:

Using Monaco MC algorithm, In step 1 dose profiles, calculated on ED_o and ED_f, differ up to 6.6%, 3.4% and 3.8% on longitudinal, sagittal and transversal axes along the plan isocenter (center of GTV). Dose increments of 1.6% for D_{98%}, 2.5% for D_{mean} and 5% for D_{2%} were obtained for PTV-GTV (see figure). A maximum dose difference of 9% of the prescribed dose was obtained between the 3D dose distributions.

In step 2 the maximum difference between dose profiles was -3% for all three axes along the plan isocenter. A reductions of -1.5% for D_{98%}, D_{mean} and D_{2%} were achieved for PTV-GTV. The maximum difference between the 3D dose distributions was 6% of the prescribed dose.

Conclusions:

A static GTV should receive an homogeneous and unvaried dose, but step 1 shows that the dose delivered to GTV, when it moves, reaching a position inside the PTV where the photon fluence is optimized for low electron densities, is higher than what estimated on the original ED_o map. The GTV is thus irradiated in a more homogeneous way in step 2 in which the fluence is optimized for its mean ED everywhere in the PTV. We propose that, in lung small lesions, the PTV is modified in terms of electron density thus considering the GTV mobility. Optimizing the photon fluence for the “forced” mean electron density appears an effective way to evaluate the dose actually delivered to the GTV.

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