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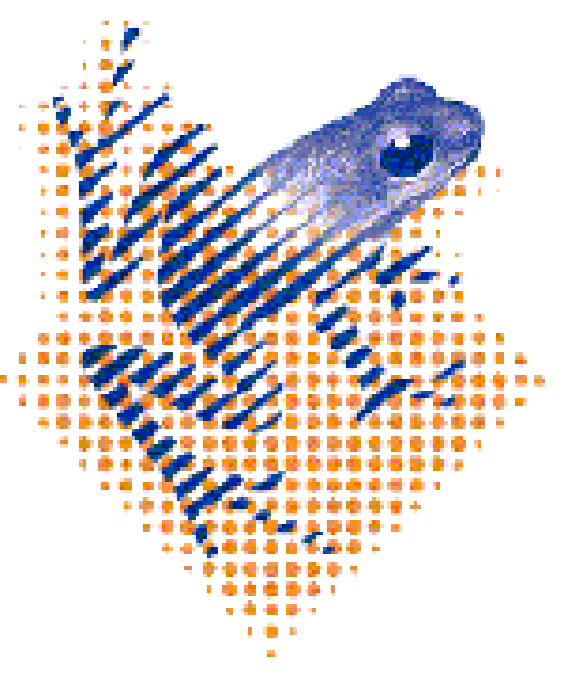
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Reproducibility of the lung anatomy under Active Breathing Coordinator control: Dosimetric consequences for scanned proton treatments



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ICR The Institute of Cancer Research

INTRODUCTION

Pencil beam scanning (PBS) is a highly conformal technology to treat cancer. The time structure of PBS makes the treatment of moving tumours challenging due to the interplay effect. For motion mitigation, an Active Breathing Coordinator (ABC) can be used to assist with breath-holding. As the treatment is delivered over several fractions with delivery times extending a feasible breath-hold duration, high reproducibility of ABC breath-holding is required. We evaluated the robustness of scanned proton therapy against anatomical reproducibility uncertainties when treating lung patients during ABC controlled breath-hold.

PURPOSE

To investigate dosimetric robustness of scanned proton treatment to the anatomical reproducibility uncertainties in the lung under ABC.

MATERIALS & METHODS

Four subsequent MRIs of three healthy volunteers were acquired under ABC controlled breath-hold during two simulated treatment fractions. Deformation vector fields between these MRIs representing the different breath-holds were used to deform CT scans of three non-small-cell lung cancer patients that matched visually (Figure 1). Per patient eight cases with different tumour sizes and locations were modeled (Figure 1). Intensity-modulated proton plans were created and split into sub-plans of 20 seconds duration (assumed breath-hold duration). The plans were recalculated on the deformed CTs that represent different breath-hold geometries to simulate the effect of the reproducibility of breath-holding during treatment on the dose distributions.

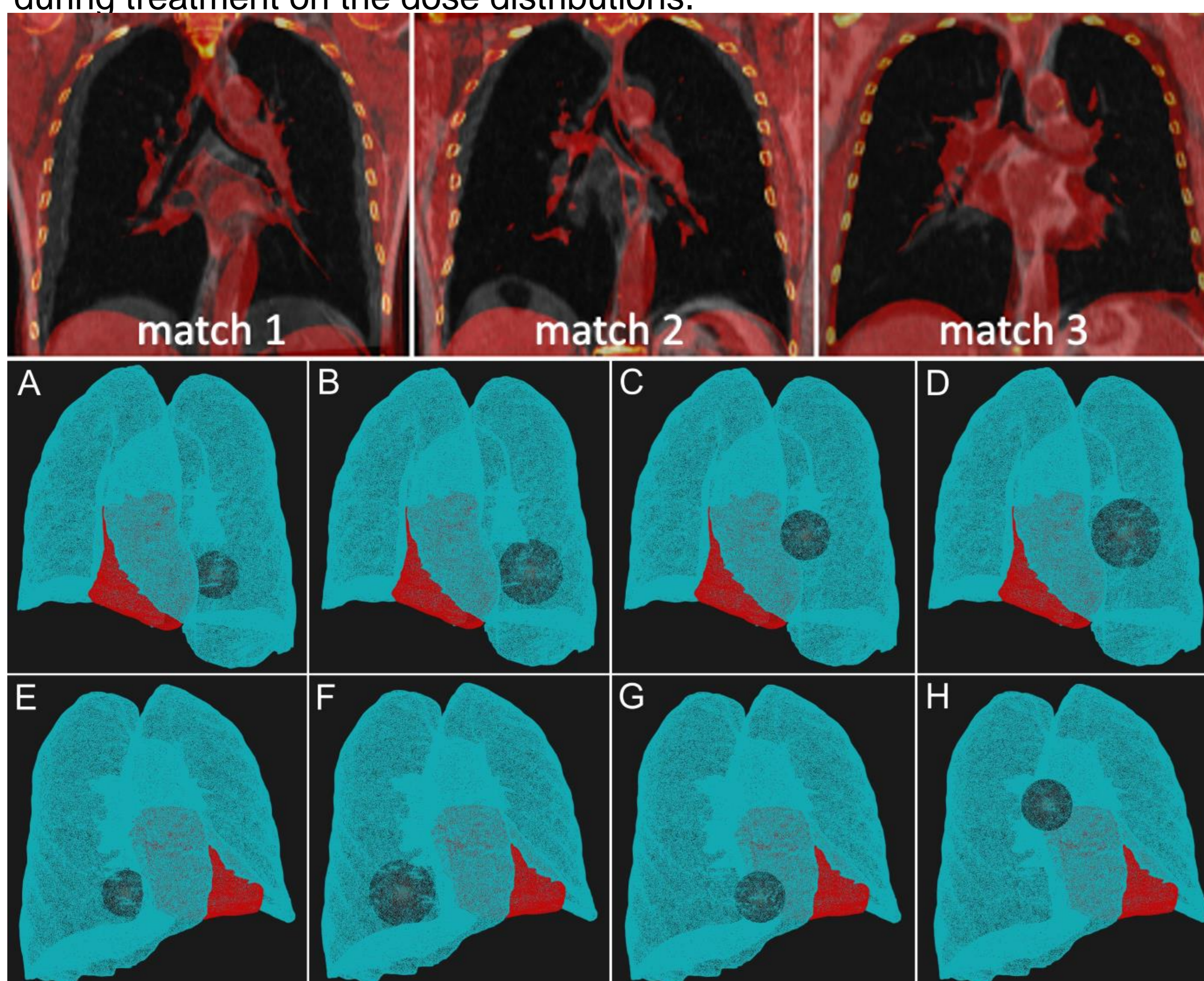


Figure 1. Fused views of the three patient/volunteer matches. 3D views of simulated tumour locations and sizes for patient number 2. A: left lower lobe, 4.5 cm diameter. B: left lower lobe, 6.5 cm diameter. C: left upper lobe, 4.5 cm diameter. D: left upper lobe, 6.5 cm diameter. E: right lower lobe, 4.5 cm diameter. F: right lower lobe, 6.5 cm diameter. G: right middle lobe, 4.5 cm diameter. H: right upper lobe, 4.5 cm diameter. Red coloured: heart. Blue coloured: lungs. Brown coloured: simulated tumour.

RESULTS

Dosimetric evaluation of the recalculated treatment plans showed <2% $V_{95\%}$ target coverage loss for 19/24 cases (Figure 2). Simulated tumours in the caudal regions showed a loss of $V_{95\%}$ up to 6.1%. Organs at risk doses differed little compared to the planned doses ($V_{5Gy} < 1\%$ for the heart and the lungs, $D_{0.1cc} < 1.4$ Gy to the spinal cord and esophagus). For one sample case (Figure 3), the planned and recalculated dose distribution is shown. The loss of CTV coverage is depicted by the dose heterogeneities shown in Figure 3(b).

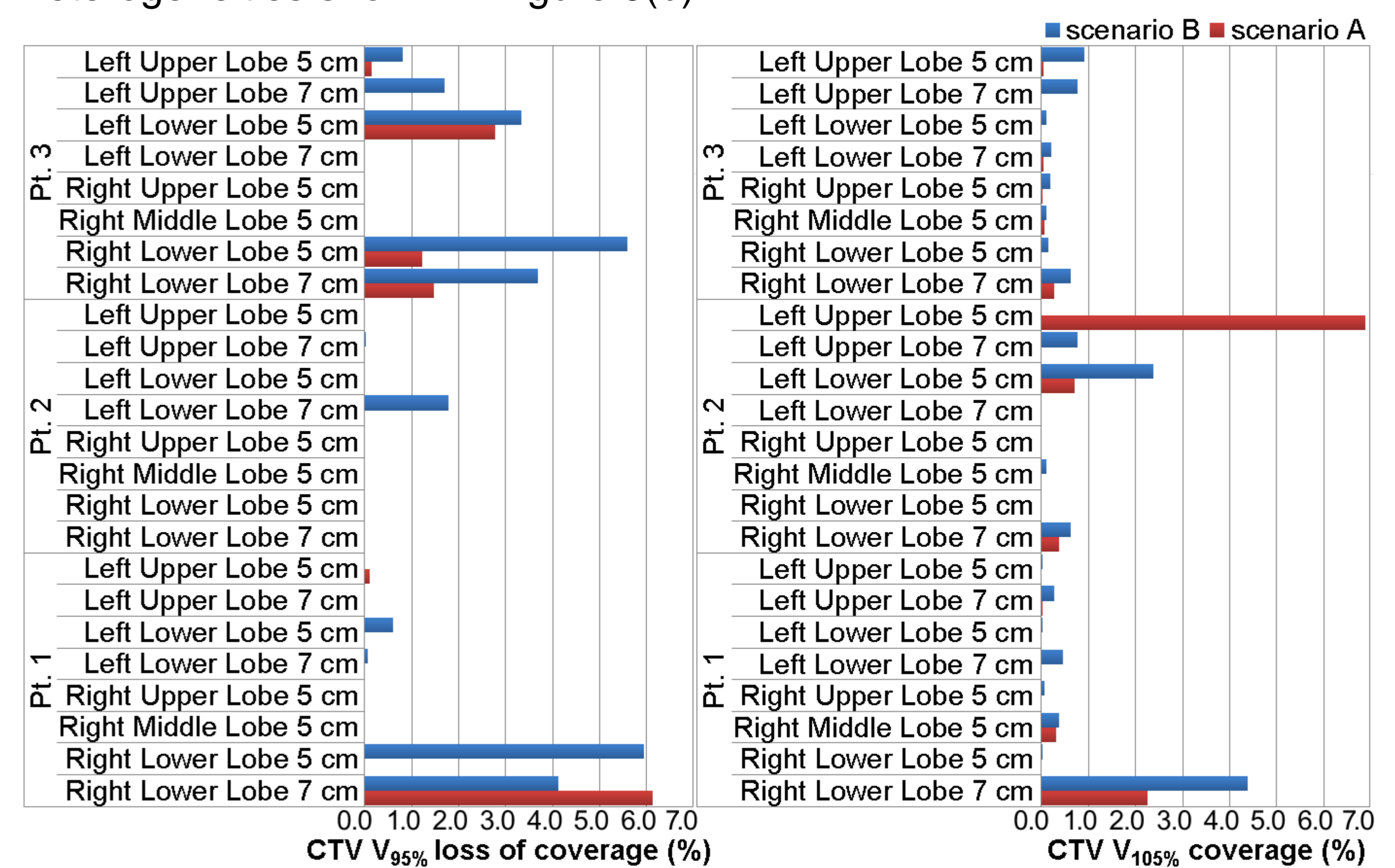


Figure 2. The $V_{95\%}$ loss of coverage and the $V_{105\%}$ of the CTV for each simulation and all patients. The tolerance thresholds (yellow lines) were set to 2% loss of target coverage and 1% $V_{105\%}$ coverage.

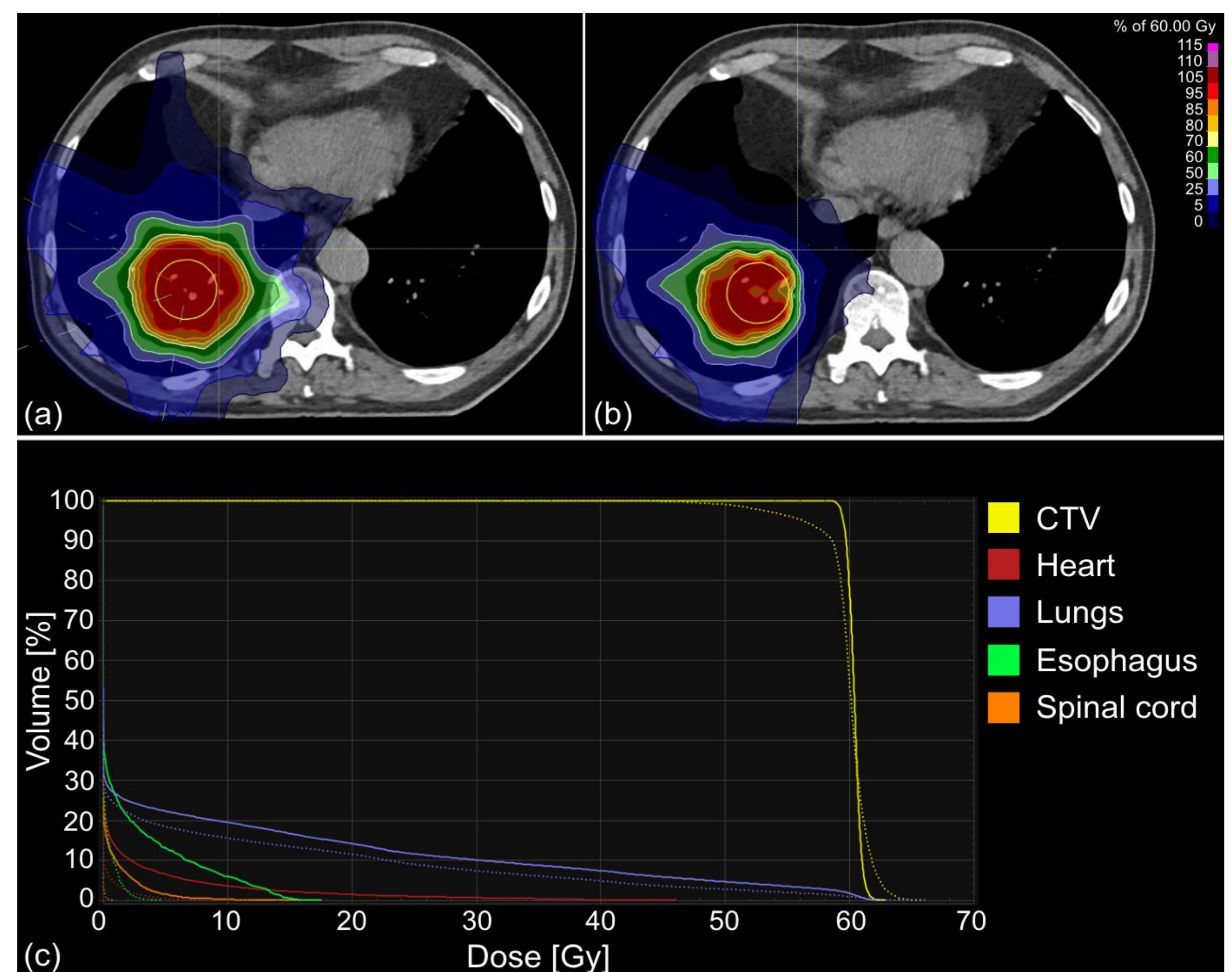


Figure 3. (a) Transversal view overlaid with the planned 3D dose distribution for a patient with a simulated tumour in the right lower lobe (7 cm CTV). (b) Transversal view of the dose distribution after re-calculation under realistic breath-hold conditions (scenario B). (c) Dose volume histogram of the planned dose (solid lines) compared to the re-calculated dose (dotted lines).

CONCLUSION

When treating under ABC controlled breath-hold, robustly optimized IMPT plans lack robustness to caudally located lung tumours. For most other cases anatomical variations between repeated ABC breath-holds have limited dosimetric consequences.