
Proceedings Paper:
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to the beam direction.

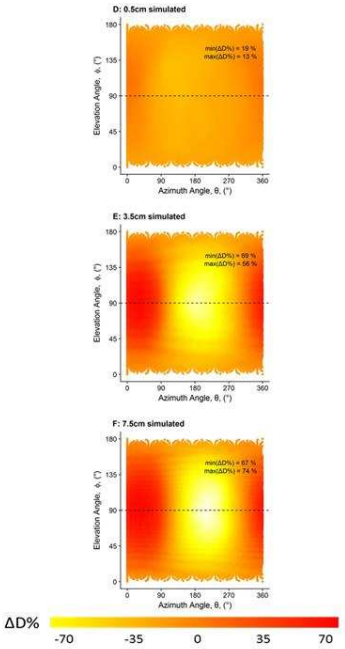

Figure 1: The dose changes, ΔD%(θ, Φ), occurring due to unplanned spherical air cavities (diameter 0.5, 3.5, 7.5cm respectively) forming in the path of a single beam during MRgRT using a 1.5 T transverse magnetic field. Clear areas of dose increase (red) and decrease (yellow) are observed around the cavities. Minimum and maximum dose changes become larger for larger air cavities, increasing from the region of 15 % in small cavities to 70 % in the largest cavity for cavities.

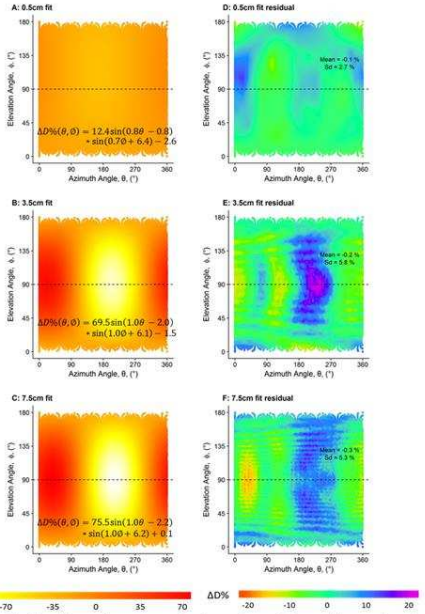

Figure 2: A-C: The fitted dose change maps for the surface of the cavities, produced using reduced-squared optimization to fit simulated data (figure 1) to a modulated sinusoidal function. The fitting parameters for each cavity are shown. D-F: The residual error of the fit for each cavity. The sinusoidal function fits the simulated data well overall, with all mean errors <3% and the standard deviation <6%. The fit deteriorates in the same location around the larger cavities however, indicated by the blue area. This could be due to the lack of attenuation through the cavity, which does not appear to follow a sinusoidal pattern as effects due to ERE do.

Conclusion

We quantified dosimetric changes due to unplanned gas cavities in MRgRT using Monte Carlo dose calculations. Dose changes around the surface of unplanned spherical air cavities can be well characterised as a modulated sinusoidal function. The fit does deteriorate slightly in a consistent place around each cavity. Work is currently being done to extend the model beyond the cavity surface, create a generalised form for the relevant cavity diameters, and to implement the fit function into a simulation platform that takes multiple beam directions into account.

OC-0523 3He MRI for functional lung avoidance VMAT treatment planning in lung cancer

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Purpose or Objective

Radiation-induced lung toxicity (RILT) is a dose limiting complication of thoracic radiotherapy that impacts on the clinical benefits of dose escalation strategies in lung cancer. Lung dose volume parameters have a limited ability to identify patients at risk of RILT and recent studies suggest functional dosimetric parameters provide stronger predictive values than conventional anatomical parameters. The incorporation of regional ventilation information obtained via hyperpolarised gas MRI has been shown to reduce functional lung dose in conformal (3D-CRT) and fixed-field intensity-modulated radiotherapy (ff-IMRT) planning. Here we report the effects of hyperpolarised ^{3}He MRI for volumetric modulated arc therapy (VMAT) in a cohort of lung cancer patients.

Material and Methods

Ten non-small cell lung cancer (NSCLC) patients being planned for radical radiotherapy underwent inspiratory breath-hold CT and same-breath anatomical ^{1}H MRI and hyperpolarized ^{3}He MRI ventilation at the same inflation state as CT. The ventilated lung was segmented using a fuzzy c-means clustering algorithm. Binary ventilation maps were registered to breath-hold CT via its same-breath anatomical ^{1}H MRI. VMAT plans with two partial arcs that minimised dose to the anatomical lung volume were compared with plans that minimised dose to the ^{3}He defined functional lung volume. For each pair of plans, the volume of functional lung receiving ≥ 10Gy (fV_{10}) and ≥ 20Gy (fV_{20}), mean functional lung dose (fMLD) and percentage of planning target volume (PTV) receiving 95% of the prescription dose (PTV_{95}) were compared.

Results

Incorporation of ^{3}He MRI ventilation information led to statistically significant median reductions in fV_{10} of 1.3% (range: -0.1–2.4%; p=0.016) and fV_{20} of 0.8% (range: -0.2–1.1%; p=0.007). A small but significant reduction in fMLD of 0.3Gy (range: 0.1–0.4 Gy; p=0.005) was also observed. There was no difference in target coverage: median difference in PTV_{95} of 0.0% (range: -0.2–0.1%; p=0.447). Patients with the largest individual reductions in fV_{10} and fV_{20} demonstrated large functional defects either in close proximity to the target volume or at the periphery of the ipsilateral lung. Significant negative correlation between the percentage of ventilated ipsilateral lung and both fV_{10} and fV_{20} was also observed (R_s = -0.707, p = 0.022 and R_s = -0.665, p = 0.036 respectively).

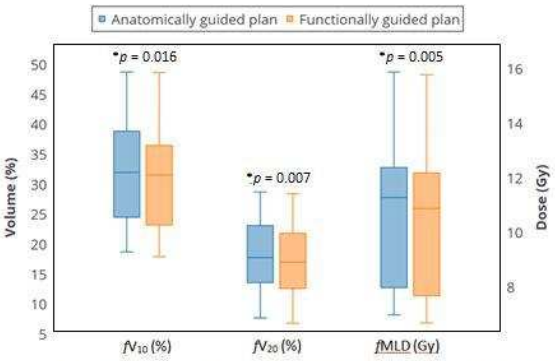

Fig1: Boxplot of functional dosimetric parameters for anatomically and functionally guided VMAT plans.

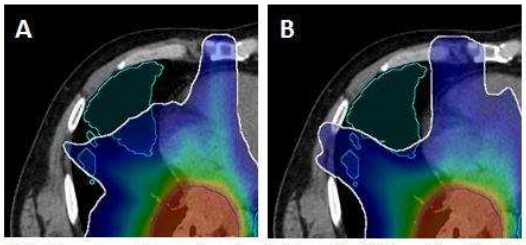

Fig2: Transverse views of anatomically guided (A) and functionally guided (B) VMAT plans for a representative patient. Cyan contour indicates the ventilated volume within the lung as defined via ^{3}He MRI. White contour shows the 20Gy isodose, which can be seen to preferentially avoid the ventilated volume in the functionally guided plan.

Conclusion

Functionally-guided VMAT plans incorporating regional ventilation information from hyperpolarised ^{3}He MRI can permit dosimetric reduction to the ventilated lung volume without compromising PTV coverage. The degree of reduction is however less than that previously reported for 3D-CRT and ff-IMRT planning, which may be attributable to increased dose conformity with VMAT. The location of ventilation defect in relation to target volume is an important factor in reducing function lung dose, with the greatest reduction possible in patients with significant ventilation defects located in the ipsilateral lung.

OC-0524 A two-beam non-coplanar class solution to supplement VMAT in prostate SBRT

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Purpose or Objective

An advantage of coplanar VMAT in SBRT is short delivery time. It also avoids long planning times related to optimization of non-coplanar beam arrangements, and most commercial TPSs lack advanced options for beam angle optimization (BAO). On the other hand, optimized non-coplanar setups can often significantly improve SBRT dose distributions. In this study we used automated planning with integrated BAO to explore advantages of VMAT supplemented with≤5 noncoplanar IMRT beams, aiming at plan quality improvement relative to VMAT while limiting the increase in treatment time. The analyses resulted in a proposal for a two-beam noncoplanar class solution to supplement VMAT.

Material and Methods

For 20 prostate SBRT patients with a prescribed dose of 38 Gy in 4 fractions, our platform for fully automated multi-criterial treatment planning was first used to generate dual-arc VMAT plans supplemented with five non-coplanar IMRT beams with optimized patient-specific beam orientations (VMAT+5). Next, based on the selected non-coplanar beam directions in the patient group (20x5 beams in total), two preferred non-coplanar beam directions were selected as class solution (CS), and for each of the 20 patients a VMAT+CS plan was automatically generated. The VMAT+CS plans were benchmarked against a) dual-arc coplanar VMAT plans, b) the VMAT+5 plans, and c) IMRT plans with 30 computer-optimized non-coplanar beams (30NCP). For comparison, all plans were normalized to have identical PTV coverage. Deliverability of generated plans was verified with QA measurements by executing plans at the linac, where treatment delivery times were also measured.

Results

Fig. 1 shows treatment plan parameters for the four treatment approaches normalized to the values of VMAT. Overall the quality of VMAT+CS plans is similar to VMAT+5, while optimization times were reduced by a factor of 25 due to the omission of BAO. Compared to VMAT, VMAT+CS significantly reduced doses to rectum and bladder and dose bath, showing median percentage differences from 1-24% for rectum D_{1cc}, D_{mean}, V_{40GyEq}, and V_{60GyEq}, bladder D_{mean}, and patient V_{xGy} (all p<0.001, Fig. 1). All VMAT and VMAT+CS plans passed the dosimetric QA tests (3%/1 mm criteria) with average Gamma passing rates of 98.3±1.0% and 98.3±0.7%, respectively. Compared to VMAT, VMAT+CS plans required 3% less MU on average and only 1.9±0.7 min longer total delivery time. Compared to 30NCP, VMAT+CS plans were considered clinically equivalent with respect to high doses in the rectum and bladder (Fig. 1A) and much faster to deliver, while 30NCP had more favorable low dose bath (Fig. 1B).

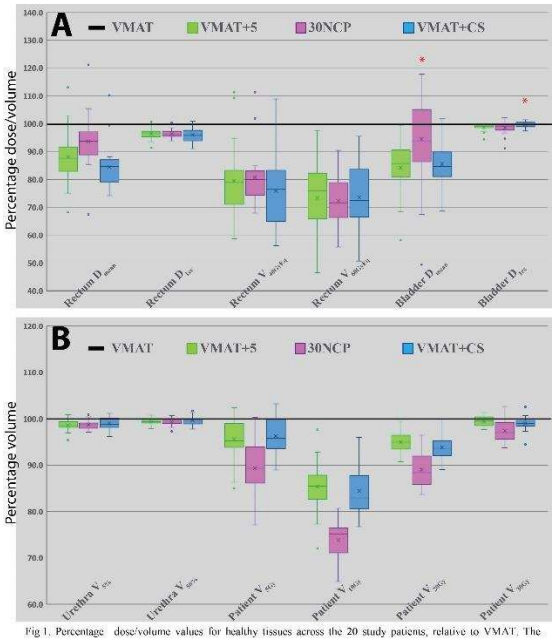

Fig 1. Percentage dose/volume values for healthy tissues across the 20 study patients, relative to VMAT. The central line of each box represents the median value, and its upper and lower edge the 25th and 75th percentiles, respectively. The x mark inside each box represents the mean value. The whiskers extend to the minimum and maximum values, or to 1.5 times the inter-quartile range from the top/bottom of the box. Values outside this range are plotted individually as outliers.

* indicates no statistically significant difference compared to VMAT.

Conclusion

Using an algorithm for fully automated multi-criterial beam profile and beam angle optimization (BAO), we derived a two-beam non-coplanar class solution (CS) to supplement VMAT for prostate SBRT. Adding the CS beams to a coplanar VMAT plan resulted in substantial improvements in treatment plan quality with a minimal increase in treatment time. The fixed CS avoids the need for patient-specific BAO.