HERO trial protocol was created in which approximately equal points were allocated to target dosimetry including conformity index (CI), and to OAR dosimetry. Where applicable, progressive scoring was used; for example, participants received a minimum score for meeting trial protocol and increasing points when OAR dose was reduced further below protocol. In addition to dosimetry metrics, delivery parameters including treatment plan geometry, delivery time and monitor units were analysed for the top 50 plans.

Results

A total of 160 plans were submitted from 28 countries. Treatment devices included linacs, CyberKnife (CK), GammaKnife (GK), TomoTherapy and particle therapy. The majority of plans were VMAT (101), followed by GK (20), CK (16) and IMRT (7) (Figure 1). The median score was 124.8 (out of 150) and maximum was 146.2, achieved with CK. The top 50 plans scored 134.5-146.2. Of these, VMAT/IMRT plans had superior CI100% compared with CK and GK, however VMAT was inferior to IMRT, CK and GK for CI50%. IMRT achieved lower normal brain receiving 12 Gy compared with VMAT, CK and GK (Figure 2). It should be noted that GK PTV margin in practice may be lower than for linac plans. For all techniques, all top 50 plans had at least 125% target maximum dose. Top 50 linac plan score was independent of monitor units, but all had at least three couch angles. Median VMAT delivery time was 14 minutes, compared with 25, 120 and 169 minutes for IMRT, CK and GK respectively (Figure 2).

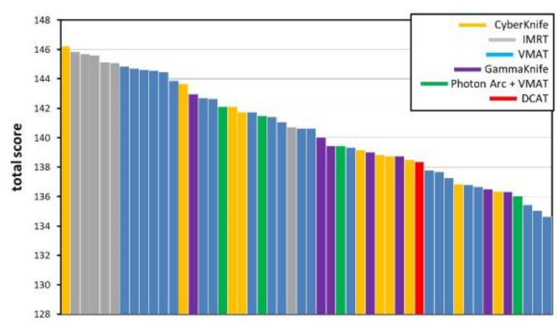

Figure 1: Waterfall plot of plan scores for the top 50 plans with delivery or planning technique denoted by colour

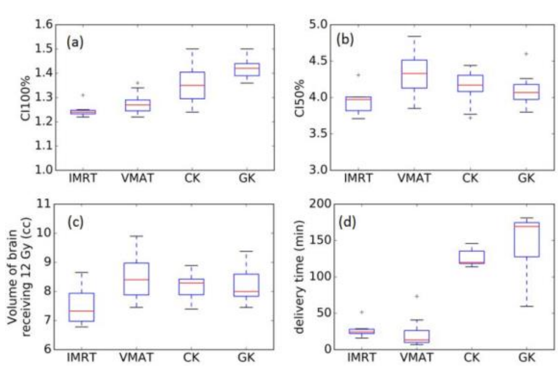

Figure 2: (a) 100% CI (b) 50% CI (c) volume of normal brain receiving 12 Gy and (d) delivery time for IMRT, VMAT, GammaKnife and Cyberknife in the top 50 scoring plans

Conclusion

In this international multi-metastases SRS planning competition, similar plan quality was achieved with across various SRS delivery systems. There was a vast range in delivery time required between different SRS delivery systems. This study did not however collect planning and QA time, or QA results, for which large variations between systems may be present.

OC-0522 Characterising dose changes due to unplanned gas cavities in Magnetic Resonance guided Radiotherapy

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Purpose or Objective

Due to Lorentz Forces, electron dose deposition within patients is altered during Magnetic Resonance guided RadioTherapy (MRgRT). Effects of the magnetic field are of particular interest at air-tissue boundaries, named the Electron Return Effect (ERE). Little work has been done on characterising the dosimetric effects of unplanned gas cavities in MRgRT on Organs At Risk (OAR), which could affect their dose constraints, depending on beam directions and the frequency of gas cavity presence. Here we characterise superficial dose changes around unplanned spherical air cavities during MRgRT in a single beam, as part of development a simulation platform for the dosimetric accuracy of MRgRT.

Material and Methods

Three cuboid water phantoms containing varying spherical air cavities (0.5, 3.5, 7.5cm diameter) and a reference phantom without an air cavity were created. Monte Carlo dose calculations of a single 7MV photon beam under the influence of a 1.5T transverse magnetic field were produced using research Monaco 5.19.02 treatment planning system (Elekta AB, Stockholm, Sweden). Calculated dose distributions of phantoms with and without air cavities were compared using a spherical coordinate system originating in the centre of the cavity. Dose changes over the surface of the cavities, $\Delta D\%(\theta, \Phi)$, were fit to a modulated sinusoidal function of the form:
$\Delta D\%(\theta, \Phi) = A \sin(k1\ \theta + psi1) \sin(k2\ \Phi + psi2) + E$.
Absolute residual errors, defined as simulated-fitted delta dose, for the fit were quantified and reported.

Results

Figure 1 shows $\Delta D\%(\theta,\Phi)$ for all tested cavities. Hot and cold spots of up to +/- 70% are observed for larger cavities, with the largest effects observed about 12° off-axis.
The fitted $\Delta D\%(\theta,\Phi)$, fitting parameters and absolute residual error of the fit for the cavities are presented in Figure 2. All fits have a mean error <3% of the dose at the air cavity (<0.3% for the two larger cavities), and standard deviation of <6%, i.e., the sinusoidal function characterises the effect well. However, for all cavities the fit deteriorates at the sides of the cavities (indicated by the blue areas in figure 2(panels D-F)), mainly due to lack of attenuation by the cavity. Calculating the dosimetric effect for multiple beams is done by applying the equation per beam, while rotating the coordinate system according

to the beam direction.

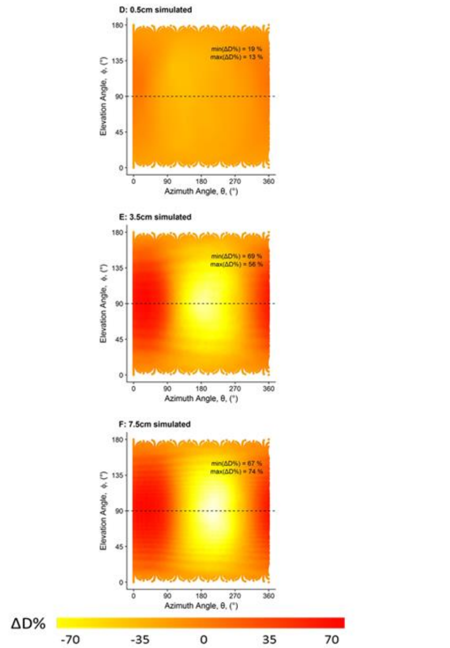

Figure 1: The dose changes, ΔD%(θ, Φ), occurring due to unplanned spherical air cavities (diameter 0.5, 3.5, 7.5cm respectively) forming in the path of a single beam during MRgRT using a 1.5 T transverse magnetic field. Clear areas of dose increase (red) and decrease (yellow) are observed around the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

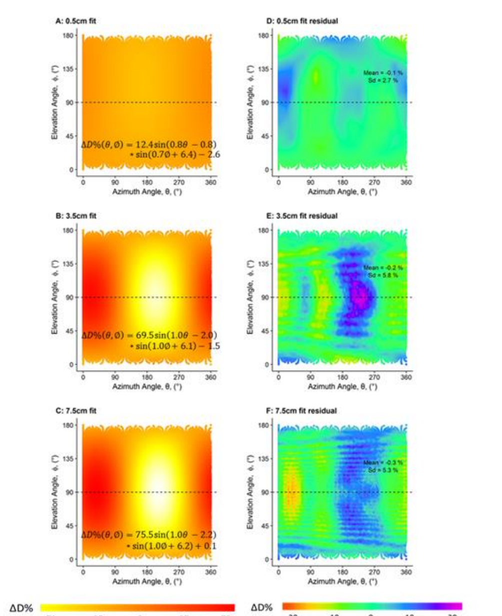

Figure 2: A-C: The fitted dose change maps for the surface of the cavities, produced using reduced-squared optimization to fit simulated data (figure 1) to a modulated sinusoidal function. The fitting parameters for each cavity are shown. D-F: The residual error of the fit for each cavity. The sinusoidal 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 (*f*MLD) 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 *f*MLD 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).