Results: The maximum doses (in EQD2) for different critical organs in the H&B case are presented in Table 1, along with doses calculated without deformable registration or compensation for biological dose effects. For medulla, deformable EQD2 values are approximately 10% less than for the rigid raw sum; for other organs the difference varies from 0 to 8%.

Conclusions: Considerations of dose to organs at risk may be a limiting factor for treatment planning of secondary malignancies at the same site. This work has shown a complete framework to examine re-treatment planning accounting for different patient positions, dose sizes and fractionation schemes of new and previous treatments. This accurate summed EQD2 distribution is helpful in seeing which dose tolerances are reached, and where the treatment plan could be modified further.

PD-0524
Visualization tool for Electromagnetic Dosimetry and Optimization (VEDO) during deep hyperthermia
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Purpose/Objective: Hyperthermia is still regarded as the most potent biological sensitizer for radiotherapy and chemotherapy. In addition to positive results multiple phase III trials, in many studies a statistical significant relationships between applied thermal dose and treatment effectiveness were found. The, prospective study of Jones et al. [1] and the large, retrospective study of Franckena et al. [2] are highly convincing and demonstrate a clear rationale for thermal dose escalation. These findings motivated us to develop a software to apply HT under objective control of an on-line hyperthermia treatment planning (HTP) system. International consensus exists that the application of HT will benefit strongly from on-line HT with 3D-visualisation and control of the heating pattern in the patient.

Materials and Methods: A software tool called VEDO (Visualization tool for Electromagnetic Dosimetry and Optimization) was created. The inputs required are: a 3D segmentation of the patient model comprising all tissues, target, OAR and pre-calculated electromagnetic fields. VEDO calculates Specific Absorption Rate (SAR) distributions and performs optimization using a particle swarm (PS) optimization algorithm. Spatial optimization weighting regions can be manually set. Clinically important quantifiers like predicted target SAR dose and maximum allowed power, based on SAR in critical tissues, are visualized.

Results:

VEDO provides an instant visualization of the SAR-distribution (as color wash) over the patients CT using the simulated electric fields and real-time measured phase and amplitude of the signals fed to each antenna element. Pre-treatment, VEDO is used by the MDs for decision making. During treatment, VEDO helps the operator to correlate the location of pain-complaints to predicted high SAR values near the indicated region; allowing re-optimization for reduction of the SAR at the indicated ‘hot-spot’ area. With this, complaint-adaptive SAR steering is used to convert hotspots in re-optimized settings, with reduced local SAR, that can directly be applied to the patient anatomy. In patients with head and neck tumors complaint adaptive SAR steering resulted in at least 20% increase of the SAR delivered to the target.

Conclusions: VEDO is completely objective and quantitative, and can be evaluated on its effectiveness. The latter is an important step towards abandoning treatment optimization based on experience of the hyperthermia staff members. The simulations using the patient anatomy also provides much more insight as compared to experimental SAR measurements in homogeneous phantoms. Clinical application of VEDO shows that the workflow is feasible and that re-optimization based on patient discomfort is effective in reducing complaints.


PD-0525
Analysis of recurrence probability versus pre-treatment FDG-PET SUV for RT patients with HNSCC for dose painting
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Purpose/Objective: To determine the relationship between recurrence locations and pre-RT 18F-FDG PET SUV data for patients diagnosed with HNSCC.

Materials and Methods: Based on a patient group of 90 patients treated with IMRT or VMAT, a retrospective investigation of local variation in TCP, depending on pretreatment 18F-FDG PET SUV through use of recurrence
locations was made. The inclusion criteria were patients diagnosed with HNSCC, completion of radiotherapy, $^{18}F$-FDG PET/CT based treatment planning and at least 6 months follow up time after completion of RT. The recurrence free frequency for this population was 77%. The patients went through RT with CTV volumes delineated for the lymph node regions and the primary tumor respectively and with the dosage of 70 Gy EQD2. The recurrence volumes were delineated on the treatment planning CT images by an experienced radiation oncologist guided by post treatment follow up data, post-PET-imaging and post-CT-imaging, but without use of the pretreatment PET images used in treatment planning. For the subpopulation with recurrences, the distribution of SUV in the recurrence volumes was analyzed patient by patient. CTV volumes without any recurrence were excluded. For each patient, a volume CTVcontrol was defined as the CTV volume excluding the recurrence volume, CTV recurrence. Voxels with SUV lower than 1 were excluded and the remaining SUV were normalized through dividing by SUVmax. Probability Of Failure (POF) was defined as the SUV frequency in CTV recurrence divided by the SUV frequency in the union of CTV recurrence and CTV control. The voxel specific TCP for 70 Gy EQD2 for each normalized SUV was defined as unity subtracted by the product of the recurrence frequency, 23%, with POF.

Results: POF was found to approach unity when SUV goes to unity and the function translates into a voxel specific TCP at the given dose 70 Gy EQD2.

Figure 1: Voxel specific TCP at 70 Gy EQD2 for each patient, represented as lines in different colors. The dashed line represents the voxel specific TCP at 70 Gy EQD2 merged for all patients.

Conclusions: This study presents a feasible method for determining relationships between tumor control and image information in voxels based on retrospective data for patient groups demonstrating localized recurrences. The obtained results could form the basis for prescribing dose at a voxel level, i.e. for dose painting by numbers.

PD-0526
Robustness of integrated boost plans for oesophageal cancer: archtherapy vs intensity-modulated proton therapy
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Purpose/Objective: Dose escalation to the gross tumour volume (GTV) has been proposed to improve local control in oesophageal cancer. However, a recent planning study for mid-oesophageal tumours [Warren IJROBP 2014] found that a simultaneous integrated boost (SIB) with acceptable heart and lung sparing was not possible for ~25% of patients when using arctherapy (RA). Intensity modulated proton therapy (IMPT) has been proposed to improve target coverage and normal tissue sparing compared to photon treatments [Welsh IJROBP 2011]. In this work optimal SIB RA and IMPT treatment plans and their robustness to set-up error and proton range error are compared.

Materials and Methods: 21 mid-oesophageal cancer patients representative of planning target volume (PTV) size were selected from the SCOPE1 (ISRCTN 47718479) database (mean PTV = 334 cm³). These patients had mean PTV 327 cm³, range 140-591 cm³. The protocol standard margins were re-applied to trial-derived GTV without modification to generate PTV1. A boost volume (PTV2) was created by adding an isotropic 0.5 cm margin to the GTV. The dose prescription (25 fractions) was 50 Gy to PTV1 and 62.5 Gy to PTV2. Two optimal treatment plans were then created for each patient using Eclipse v13 (Varian): a RA plan (2 arcs, 6MV) and an IMPT plan (70 - 250 MeV) using the beam arrangement described by Welsh. Dose-volume metrics for PTV1, PTV2, GTV, heart, and lung were compared for each patient for the optimal IMPT and RA plans (Wilcoxon test). Robustness was evaluated using the Plan Uncertainty tool provided in Eclipse. Set-up errors of ±0.5cm radially and ± 0.7cm axially were simulated to generate 6 RA uncertainty plans. An additional range error of ±3.5% was included for protons, to generate 12 proton uncertainty dose distributions. The median values of RA and IMPT uncertainty plans were compared using the Mann Whitney test.

Results: Optimal IMPT plans were able to achieve all dose constraints for 20/21 patients: the mean heart dose limited to 25 Gy was exceeded for one patient (25.3 Gy), where there was significant overlap with the PTV. IMPT reduced mean lung dose for each patient by 49.3% (median, IQR: 46.3 - 52.4%, Z=-4.02, p<.001). Mean heart dose was reduced by 40.3% (median, IQR: 37.8 - 45.3%, Z=-4.02, p<.001). Analysis of RA and IMPT uncertainty plans showed that differences in PTV1/vmax coverage were not statistically significant for 19/21 patients. Boost volume coverage (PTV2 V95) was less robust for IMPT, and plan uncertainty produced median GTV D95 across all patients RA= 62.9 Gy (IQR: 62.8 - 63.0 Gy) and IMPT= 62.1 Gy (IQR: 61.8 - 62.4 Gy) (p values <.001 to .03).

Conclusions: IMPT plans have potential for significantly sparing lung and heart for all mid-oesophageal patients compared to RA. However, the SIB proton plans appear less robust for coverage of the dose boost region than photon plans, which may compromise the predicted improvement in local tumour control for these patients.