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 EQD_2. 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 $CTV_{control}$ 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 SUV_{max}. 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 EQD_2 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 SUVmax, hence the correlation of location of recurrence with increasing SUV was strong. Figure 1 displays how these finding translates into a voxel specific TCP at the given dose 70 Gy EQD_2.

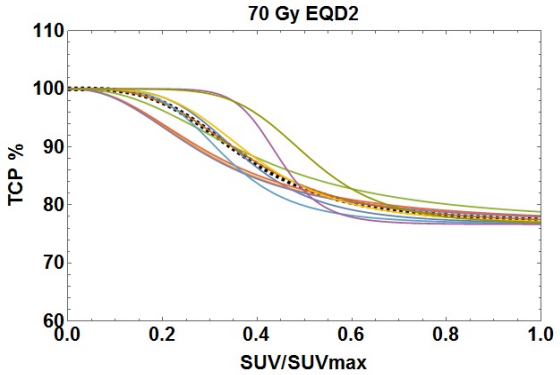

Figure 1: Voxel specific TCP at 70 Gy EQD2 for each patient, represented as lines in different colors. The dashed line represents the voxel specific TCP at 70 Gy EQD_2 merged for all patients.
Conclusions: This study presents a feasible method for determining relationships between tumor control and image 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: arctherapy vs intensity-modulated proton therapy

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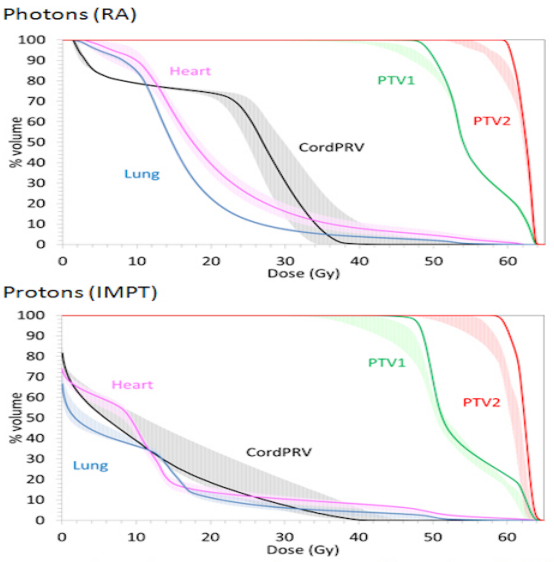
Purpose/Objective: Dose escalation to the gross tumour volume (GTV) has been proposed to improve local control in oesophageal cancer. However, a recent planning study for mid-oesophageal tumours [Warren IJROBP 2014] found that a simultaneous integrated boost (SIB) with acceptable heart and lung sparing 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 cm^3). These patients had mean PTV 327 cm^3, range 140-591 cm^3. 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 heart mean dose limit of 25 Gy was exceeded for one patient (25.3 Gy), where there is 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 $PTV1_{V95\%}$ coverage were not statistically significant for 19/21 patients. Boost volume coverage (PTV2 V_{95}) was less robust for IMPT, and plan uncertainty produced median GTV D_{98} 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.



Dose-volume histograms for optimal SIB plans (solid lines) for a typical mid-oesophageal cancer patient. The shaded areas represent the range of DVH values for the uncertainty plans.

PD-0527

Evaluation tool for plan robustness regarding patient setup using Monte Carlo methods

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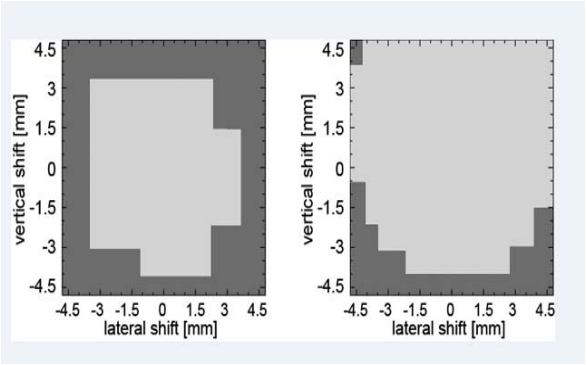
Purpose/Objective: Currently treatment plan evaluation is based on the inspection of the calculated dose distributions and dose volume histogram (DVH) parameters. The robustness with respect to setup uncertainties of the treatment plan is not taken into account in the evaluation process. Therefore the risk of missing the target or pushing dose to critical organs due to setup uncertainties is completely unknown. The purpose of this project is to develop a tool to assess the robustness of treatment plans taking into account random and systematic setup uncertainties.

Materials and Methods: In order to investigate the effect of random and systematic setup errors using Monte Carlo (MC) methods, the Swiss Monte Carlo Plan (SMCP) [1] was extended accordingly. The impact on the dose distributions is evaluated by calculating DVHs and dosimetric parameters as a function of the setup error phase-space. The evaluation tool allows specifying acceptance criteria by means of dose deviations from the original dose distribution. Based on these robustness-criteria, a robustness-map is generated dividing the setup error phase-space into two regions: one for which the robustness-criteria are met (acceptance-space) and another treatment-plan where the criteria are not fulfilled. A treatment-plan is more robust (in terms of the given robustness-criteria), compared to another if the acceptance-space is larger. In addition, deviations for DVHs or dose distributions compared to the original plan can be explored across the acceptance-space.

Results: The robustness evaluation tool is demonstrated on various cases and different tumor sites. As an example, Figure 1 shows the robustness map comparison of a 2 arcs and a 4 arcs plan for a head and neck patient using the VMAT delivery technique. In this case, the setup uncertainty phase-space was defined by translations between [-5mm, 5mm] along the x- y- and z-axis. The acceptance-space for the 4 arcs plan is significantly larger, i.e. more robust with respect to setup uncertainties. This is due to the fact that with the 4 arcs plan, a much better sparing of the spinal cord could be achieved.

Figure1: Robustness-map comparison for a head and neck treatment plan applying 2 arcs (left) and 4 arcs (right) using the VMAT delivery technique. The acceptance-space corresponds to the light grey colored area. The 4 arcs plan is superior compared to the 2 arcs plan under the given acceptance-criteria.



Conclusions: The construction and visualization of robustness-maps is useful to assess the robustness of RT treatment plans. This work is supported by Varian Medical Systems.

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[1] Michael K Fix, Peter Manser, Daniel Frei, Werner Volken, Roberto Mini and Ernst J Born: An efficient framework for photon Monte Carlo treatment planning. Phys. Med. Biol. 52:N425-437, 2007

PD-0528

Beam set-up selection using Pareto fronts for robust proton therapy planning in cervical cancer

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Purpose/Objective: Cervical cancer patients may benefit from intensity-modulated proton therapy (IMPT), preferably using a patient-specific beam set-up. However, beam set-up optimisation is currently not part of the plan optimisation process and the influence of the number of beams on dose distributions after robustness evaluation is unknown. The aim of this study was to develop a method to determine the Pareto front (PF) of robust IMPT plans to enable beam set-up selection for robust proton therapy planning in cervical cancer.

Materials and Methods: Planning CTs of 3 cervical cancer patients treated in prone position with photons were used. Per patient, 3 robustly optimised IMPT base plans using different beam set-ups were created with a prescribed dose of 46 Gy (23 fractions) to the target (CTV). Beam set-ups, planning objectives and minimal requirements for evaluation, including the evaluation objectives of interest (CTV D99%, rectum V30Gy) which span the objective space, are listed (Table). For IMPT plans with a fixed beam set-up, only an approximation of the real patient-specific PF can be derived and an iterative method to approach this PF was written using the scripting facilities in RayStation (RaySearch Labs., Sweden). Starting with a base plan, multiple plans with new