coverage of at least 95% of the prescribed dose was achieved, the treatment plan would be considered as clinically acceptable.

Results: For 69% of the patients using a margin of 1/4 mm in/out of plane, the propagated CTV, which is about the voxel size of the MRI, D99% coverage for the gold standard CTV was achieved in for 69% of the patients using a margin of 8/8 mm in/out of plane for the propagated CTV. OAR doses remained far less than clinical criteria in all treatment plans. All treatment plans were made using a class solution objectives set.

Figure 1: Overview of MRI-guided daily ART workflow

Conclusions: Online MRI-guided ART seems feasible using only a small margin added to the automatically generated contours. Failures were seen only in patients with large daily variations in rectum filling. Currently, the used DIR method cannot account for these large deformations. Further improvements on the DIR have to be made to make feasible treatment plans for these patients in an automated workflow. For delivering the GTV boost, a somewhat larger margin was needed and needs to be further optimized.

Purpose/Objective: Hyperthermia is a clinical application of heat in which tumour temperatures are raised to 40-45°C. Hyperthermia is a proven radiosensitizer, which significantly improves clinical outcome for several tumour sites. Contrary to most anti-cancer treatments hyperthermia has no serious side effects when administered properly. Therefore, hyperthermia might be a good alternative for dose escalation, for instance for treatment of prostate tumours. This is expected to improve tumour control, while avoiding an increase in organs at risk (e.g. the rectum) can be a limiting factor, yielding under-dosage in a part of the PTV. Hyperthermia reduces the impact of these limitations.

Conclusions: A model to quantify the effect of combined hyperthermia and radiotherapy in terms of equivalent dose distributions was presented. Adding hyperthermia can be considered similar to a dose escalation. This model is useful to predict interaction of different cancer treatments and may be very helpful in discussions on dose escalation.

Purpose/Objective: Historically a number of techniques have been described that use combined photon and electron fields to conform the dose with depth. In recent years however this sort of treatment has largely been replaced with photon IMRT. It is proposed that to further improve dose distributions electron fields could be reintroduced to IMRT. The electron beam limited range and large penumbra could be balanced by modulating with photon MLC and combining with existing photon IMRT techniques. By finding the optimum mix of electron energies and photons it may be possible to reduce exposure to critical organs and reduce integral doses. The perceived disadvantages of high surface dose characterising electron beams becomes an advantage for cases where the CTV extends to the surface.

The purpose of this study is to develop a novel optimisation algorithm for combined electron and photon IMRT that allows spatial and energy modulation with standard unmodified linacs.

Materials and Methods: Isocentric electron beamlets delivered through the photon MLC of an Elekta linac were calculated using BEAMnrc Monte Carlo dose simulations. The CERR environment (A Computational Environment for Radiotherapy Research, Washington University Medical Centre) was used to manipulate the electron beamlets and to calculate photon beamlets using the quadrant infinite beam (QIB) dose calculation engine within CERR. An algorithm was then developed to optimise the combined electron and photon dose distribution. Beams are manually positioned to cover the target, with a single electron field positioned as a boost over the superficial section of tumour. The optimisation is then split into three stages.
A quadratic programming optimisation is used to modulate an electron beam for spatial fluence and energy by optimising the weights of overlapping beamlets. (2) The 6MV X-ray beamlet weights are optimised to cover voxels not reached by the electron beam. (3) An iterative optimisation minimises a cost function designed to incorporate the advantages and limitations of the technique. A number of optimisation methods, including evolutionary algorithms, have been evaluated for the minimisation this cost function. Results: The algorithm has been tested for simple geometries and can produce conformal dose distributions with low dose to proximal structures and a high dose to the skin surface. In the central part of the electron field the algorithm successfully optimises the weights of electron beamlets to remove the large electron penumbra for the unmodulated beam treated through the MLC. Electron energies are selected by the algorithm to optimise the dose with depth. Target volumes not covered by the electron field are covered by the compensating photon fields. Conclusions: An IMRT mixed energy mixed modality optimisation algorithm has been developed to optimise dose with the electron field as an energy modulated boost delivered through photon MLC.

PD-0587

Beam angle optimization using derivative-free algorithms incorporating beams-eye-view dose metrics

H. Rocha1, J. Dias1, B. Ferreira1, M.C. Lopes3
1INESC-Coimbra, Coimbra, Portugal
2FEUC, Coimbra, Portugal
3IN, Aveiro, Portugal

Purpose/Objective: The selection of appropriate radiation incidence directions may influence the quality of the treatment plans. However, many times in clinical practice, beam directions continue to be manually selected with consumption of large amounts of time and no guarantee of optimality. Some commercial treatment planning systems are designed to use local search and/or gradient-based algorithms in the beam angle space to address the beam angle optimization (BAO) problem. Due to the many local minima aspect of the BAO problem, such approaches are not efficient. We propose a novel approach that uses beam’s-eye-view ray tracing dose metrics within pattern search methods (PSM) in the optimization of the highly non-convex BAO problem.

Materials and Methods: PSM are derivative-free optimization algorithms that require few function evaluations to progress and converge and have the ability to better avoid local entrapment making them a suitable approach for the resolution of the BAO problem. PSM are organized around two phases at every iteration: one that assures convergence to a local minimizer (poll), and the other (search) where flexibility is conferred to the method allowing searches away from the neighborhood of the current iterate. Beam’s-eye-view dose metrics assign a score to each beam direction and can be used within the PSM furnishing a priori knowledge of the problem so that directions with larger dosimetric scores are tested first improving results and computational time. Locally advanced head and neck clinical cases were selected to test this approach. The planning target volumes included the primary tumor, the high and low risk lymphnodes. Organs-at-risk (OARs) included the parotids, the brainstem, and the spinal cord. For each case, a setup with seven equi distant beams was chosen using CERR (computational environment for radiotherapy research). The resulting treatment plan was then compared with the plan using the optimal beam setup obtained by PSM incorporating beam’s-eye-view dose metrics (PSM-BEVD).

Results: For the clinical cases retrospectively tested, the use of prior knowledge of the patient in our tailored approach showed a positive influence on the quality of the local minimizer found. The objective function value of the fluence optimization problem was reduced in average more than 10% when using the optimal beam setup obtained by PSM-BEVD instead of the traditional equidistant beam arrangement. The improvement of the local solutions in terms of objective function value corresponded to high quality treatment plans with better target coverage and with improved organ sparing.

Conclusions: PSM-BEVD has shown ability to avoid local entrapment and efficiency on the number of function evaluations leading to a fast convergence which is of the utmost importance in a busy clinical practice. Our results have shown that a global derivative-free beam angle search yields superior quality plans.

PD-0588

Validation of apparent diffusion coefficient calculation in rectal tumors

H. Nissen1
1Veje Hospital, Medical Physics, Veje, Denmark

Purpose/Objective: Recently, there has been an increased focus on using diffusion-weighted magnetic resonance imaging (DWI) to evaluate tumor response to radiotherapy (RT). The parameter used to evaluate tissue diffusion is the apparent diffusion coefficient (ADC). In this work we examine some properties of the calculated ADC for rectal tumors: (i) the short term reproducibility of the ADC, (ii) how the ADC depends on the range of b-values and (iii) the dependence on scan time.

Materials and Methods: In our department, rectal cancer patients referred for concomitant chemoradiotherapy receive a pre-treatment MR scan including DWI. The DWI sequence has 11 b-values between 0 and 1100, in-plane resolution is 3x3mm and slice thickness 4.6mm. Patients have received either a single DWI scan with 4 signal averages (NSA) or two consecutive scans each with 2 NSA. Here we present data from 27 patients. Regions of interest (ROI) are drawn using a semi-automated algorithm, which, for each individual patient, selects areas exhibiting an atypically high signal. This is evaluated on the b = 1100 slices. This method provides a consistent way of defining ROIs. The ROIs defined this way corresponds well to the areas exhibiting low ADC. For each patient ADC is calculated on a voxel by voxel basis by fitting a mono-exponential function to the signal. The ADC of the ROI is then defined as the mean of the voxel ADCs over the ROI. To test (i) reproducibility, we compare the ADC between the two 2NSA scans as well as evaluating the images by eye. We also examine the effect of applying a goodness-of-fit estimation to each fitted voxel and including only voxels where a mono-exponential fit is a good description of the signal decay. Testing (ii) ADC dependency on the range of b-values and (iii) on the scan time is done by comparing the ADCs for calculations on different subsets of b-values and signal averages.

Results: We find that (i) the calculated ADCs are highly reproducible, with variations between the ADC from the first and second scan being on average 5-10% depending on the sequence of b-values used. However, individual scans can show much larger variation. Including the goodness-of-fit calculations improves the reproducibility to 2-4% and especially reduces cases of large differences. (ii) The ADC depends on the range of b-values used, showing a systematic increase as b-values shift towards lower values. This effect is mostly patient independent. (iii) We find no evidence of the number of signal averages affecting the ADC.

Conclusions: We have found that for rectal tumors the calculation of an ADC value is (i) reproducible, but to achieve the best results, and especially to avoid large deviations it is preferably to include a goodness-of-fit estimate. (ii) The calculated ADC depends on the range of b-values used. The mostly patient independent nature of this scaling suggests, that it may be possible to make a mapping between different b-value ranges. (iii) The calculated ADC does not depend on the number of signal averages.

PD-0589

Is geometrically accurate diffusion-weighted MRI of esophageal cancer possible and useful?

A.L.H.M.W. van Lier1, G.J. Meijer1, M.A. Moerland1, F.L. Lever2, O. Reerink3, M. van Vulpen3, I.M. Lips4, C.A.T. van den Berg1
1U.M.C. Utrecht, Radiotherapy, Utrecht, The Netherlands

Purpose/Objective: Esophageal tumours are difficult to delineate on CT images as there is no distinct contrast between healthy tissue and the tumour. Therefore, delineation is merely based on anatomical abnormalities such as wall thickening. For other tumour sites (e.g. prostate) it was shown that diffusion-weighted MRI (DWI) can improve tumour visualization. Unfortunately, DWI is prone to geometrical inaccuracies due to distortions in the main magnetic field. Those distortions are most prominent at locations with changing magnetic susceptibility (e.g. close to air/tissue boundaries). This might prove to be a problem for esophageal imaging. Aim of this work is to correct the geometrical distortions using a magnetic field distortion map and to investigate the residual errors.

Materials and Methods: Three patients eligible for neoadjuvant chemoradiation were included in this pilot study. A free-breathing DWI scan with echo-planar readout was optimized to reduce the effect of field distortions. Heavy diffusion weighting (b=800 s/mm²) was