brachytherapy across a range of clinical applications.

Figure 1: Measurement vs plan for 2 dwells in each of 5 catheters from a patient treatment fraction. A subset of all measurements is shown.

Poster Discussion: Brachytherapy: Clinical and physics

PD-0178
Parameterised rectal dose and associations with late-toxicity in high-dose-rate prostate brachytherapy
L. Hamlett1, D.A. Wood1, A. Atkenhead1, C. Hodgson2, J. Wylie3, A. Choudhury3, J. Logue3
1The Christie NHS Foundation Trust, Radiotherapy Physics, Manchester, United Kingdom
2The Christie NHS Foundation Trust, Statistics, Manchester, United Kingdom
3The Christie NHS Foundation Trust, Clinical Oncology, Manchester, United Kingdom

Purpose/Objective: In high dose rate (HDR) brachytherapy of the prostate, radioactive dwell positions are delivered by a single source inserted via needle catheters into the target volume. The rectal mucosa also receives dose during the treatment, which may lead to toxicity effects. An in house Matlab programme was utilised to parameterise the rectal dose allowing for association with patient reported late toxicity.

Materials and Methods: During treatment of a series of 76 patients, using ultrasound imaging to localise the anatomy and catheter locations. The target volumes and OAR were contoured on the ultrasound scan. The anterior rectal mucosal wall was identified by contouring the transrectal ultrasound balloon. Source positions and dwell times, along with the dose delivered to the patient were computed using the Oncentra Prostate treatment planning system (TPS). Data for the series of patients were exported from the TPS in DICOM format, and a series of parameterisation methods were developed in a Matlab environment to assess the rectal dose, as shown in figure 1.

The change in mean LENT SOMA bowel score was calculated for each patient for several post-treatment time points over a 5 year period, using pre-treatment score as baseline. Association between change in mean score and radiation dose to the rectum was the examined using spider plots.

Results: Contours of the anterior rectal mucosa were voxelised within Matlab to allow the dose to the rectal mucosa to be analysed directly from the 3D dose grid. Dose parameterisations based on dose-surface (DSH) and dose line (DLH) histograms were obtained. Parameters for both lateral and longitudinal extents of the mucosal dose were produced using dose-line histograms in the relevant directions. The results of the spider plots indicated 3 patients with the largest increases in mean LENT SOMA score (1.7, 1.7, 1.4) compared to pre treatment, had received higher doses of radiation to the rectum (50th percentile dose volumes 438, 455, 519cGy respectively) than the majority of the patient sample. For these 3 the most severe side-effects were seen at 6 months.

Doses ranged from 250 to 588cGy for the remaining 69 patients. For these patients increases in mean LENT SOMA score were 1 or less even though a number of them had received similar radiation doses to the rectum as the 3 patients described above.

Conclusions: We have using Matlab found a number of parameters to aid in quantifying the dose to the rectal mucosa during HDR prostate brachytherapy. The geometry of the transrectal probe standardises the rectal anatomy, making this treatment technique particularly suited to studies of this nature. The results of the analysis showed some small associations between dose and late reported toxicities; this is to be further studied using prospective data and considering other OAR.

PD-0179
An automated optimization tool for HDR prostate brachytherapy with divergent needles
M. Borot de Battisti1, M. Maenhout1, B. Denis de Senneville2, G. Hautvast1, D. Binnekamp1, J.J.W. Lagendijk1, M. Van Vulpen1, M.A. Moerland1
1UMC Utrecht, Department of Radiotherapy, Utrecht, The Netherlands
2IBM UMR 5251 CNRS/University of Bordeaux, Mathematics, Bordeaux, France
3Philips Group Innovation, Biomedical Systems, Eindhoven, The Netherlands

Purpose/Objective: The objective is the development of a fully automatic inverse dose planning optimization tool for MRI guided focal HDR prostate brachytherapy with divergent needles. The optimizer is tested in a planning study by assessing the dose volume parameters.

Materials and Methods: To develop a fully automatic optimizer for a given number of divergent needles (Figure 1a), the following parameters need to be optimized: (1) the position of the center of rotation (2) the angles of the needle and (3) the dwell times of the sources. The idea of our optimization workflow is to get the most benefit of the linear properties of the dwell times regarding the dose. The center
of rotation is exhaustively searched on a grid of 9 different points separated by 1 cm from the center of the insertion area (Figure 1b). For the needle angulation, the method by Poulin (2013) for parallel needle positioning was adapted as follows: a heuristic is determined by projecting the planning target volume (PTV) from the center of rotation into a transverse plane and k-means clustering on the indices of the latter surface is applied (Figure 1c). The dwell time is determined by the resolution of linear equations following a similar method described by Goldman (2009) for external beam radiotherapy, called Fast Inverse Dose Optimization (FIDO). To test this optimizer, a planning study for focal prostate brachytherapy was performed. The optimal parameters were determined to obtain the desired coverage (PTV D95 of 19 Gy) without exceeding the constraints of the organs at risk (D10% urethra of 21 Gy, D1 cc bladder and rectum of 12 Gy). The dose distribution was calculated on 10 patients (PTV volumes ranged from 8.5 cc to 23.5 cc with a median of 16.1 cc) for 2, 4, 6, 8, 10, 12 and 14 needles by using the earlier mentioned constraints as input.

Results: The average coverage (D95 of PTV) and the dose on the organs at risk (D10% urethra, D1 cc of bladder and rectum) for all 10 patients are depicted in Figure 1d. The quality of the dose plan increases with the number of needle insertions. On average, a clinically acceptable plan is already reached by using four needle insertions. The complete optimization workflow took less than 20 minutes on a PC with a 3.10 GHz Intel® Core™ i5-2400 processor and 8 GB RAM using MATLAB R2013a.

Conclusions: The efficacy of the automated optimization tool was demonstrated for focal HDR prostate brachytherapy with divergent needles. On average, clinically acceptable plans were achieved using 4 needles or more.

PD-0180
Use of 3D-ultrasound for cervical cancer brachytherapy: an imaging technique to improve contouring
P. St-Amant1, W. Foster1, M.A. Froment1, P. Noel1, S. Aubin1, L. Beaulieu1
1CHU de Quebec, Radiation Oncology, Quebec, Canada

Purpose/Objective: To determine whether a real-time 3D-ultrasound (3DUS) imaging improves brachytherapy structure delineations for cervical cancer.

Materials and Methods: MRI, CT, 3DUS (Clarity AutoScan, Elekta, Montreal) and CT-3DUS fusion were all used for imaging the structures of interest (HR-CTV, cervix, uterus and rectum/sigmoid) for cervical cancer brachytherapy treatments of 8 consecutive patients. MRI images were acquired prior to brachytherapy following EBT. 3DUS was performed simultaneously to the CT planning in the treatment room. Fusion between 3DUS and CT was performed on the Clarity workstation and the contours were traced using the OncentraBrachy planning system (Elekta). Contouring was done by 3 physicians: 2 radiation oncologists (RO1 and RO2) and 1 diagnostic radiologist (DR) specialised in gynaecology. MRI contours traced by the DR were used as the reference set even though the applicators were not yet in place. The cervix and the HR-CTV were contoured three times by the DR to validate the stability of the reference. The absolute volumes and the transverse and longitudinal dimensions of the HR-CTV were compared with the reference for each imaging modality and physician.

Results: As expected the CT volumes are larger than MRI (Table 1). The RO contours of the DR and the ROs are significantly larger than the intra-observer variability. The difference comes from the fact that ROs include treatment considerations, which is not the case with the DR. The 3DUS volumes are closer to the MRI volumes for each physician, but standard deviations are the largest (32% to 42%). CT-3DUS fusions keep the benefit of 3DUS alone for volume definition while reducing significantly the variability for each physician. The variation in longitudinal dimension of the contours was found to have the largest impact on both inter-observers and inter-modalities differences in volumes.

Table 1: The mean and standard deviation of the difference of the contours compared to the MRI reference in percentage. The results are shown for the absolute volumes on each imaging modalities for the 3 physicians.

<table>
<thead>
<tr>
<th></th>
<th>DR</th>
<th>RO1</th>
<th>RO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI</td>
<td>0 (12)</td>
<td>-16 (16)</td>
<td>-11 (16)</td>
</tr>
<tr>
<td>CT</td>
<td>17 (19)</td>
<td>-10 (19)</td>
<td>-11 (15)</td>
</tr>
<tr>
<td>3DUS</td>
<td>8 (95)</td>
<td>-26 (22)</td>
<td>-22 (22)</td>
</tr>
<tr>
<td>CT-3DUS</td>
<td>8 (99)</td>
<td>-25 (21)</td>
<td>-29 (25)</td>
</tr>
</tbody>
</table>

Conclusions: Generally, 3DUS allows for contours closer to MRI, but offers little information on the OARs. The CT-3DUS helps to get that extra information and offers, in axial slices, contours closer to MRI in all cases for the ROs compared to the CT alone. The learning curve of 3DUS could also explain the large standard deviation seen. This technology is promising and requires further investigation to determine its usefulness in treatment planning.

PD-0181
Image-guided adaptive brachytherapy for cervix cancer: higher target dose by increasing planning aim
A. Li1, L.H. Djupvik1, K. Bruheim1, E. Nakken1, K. Skipar2, T.P. Hellebust1
1DNR - Norwegian Radium Hospital, Department of Medical Physics, Oslo, Norway
2DNR - Norwegian Radium Hospital, Department of Oncology, Oslo, Norway