**Purpose/Objective:** In vivo dosimetry (IVD) in brachytherapy (BT) is aimed to assess doses to organs at risk (OAR) by direct measurements. It is also an independent method to detect errors in dose delivery, and thus might be used as for patient QA of the whole BT process. Widely spread in external beam radiotherapy (EBRT), IVD in BT has faced some issues, mainly related to uncertainties due to high step gradients and detector positioning.

In this study, we present and analyze the results of detector positioning.

**Materials and Methods:** The electrometer (MultiDos, PTW) is integrated in the afterloader (MultiSource, Eckert & Ziegler BEBIG). The software to calibrate the dosimeter and to visualize the measured dose is integrated in the treatment console.

The urethral probe (T9113, PTW) has a silicon diode in the tip of a rubber cable. To do the calibration we use a cylindrical phantom (Krieger phantom T9193, PTW). By means of a preconfigured plan in the MultiSource software, the source is set in the Krieger phantom geometric center. Dose rate in the calibration point, set at 8 cm from the source position, is calculated through the source activity. The dose rate calculation takes into account the Krieger phantom’s material (PMMA) and geometry which results in a factor 0.87 for Ir-192, and 0.93 for Co-60 compared with water and full scatter conditions. Despite dose rate at 8 cm is very small, the calibration shows a good signal to noise ratio (~40). We observe a sensitivity loss of about 0.75% per month. Uncertainties involved in the calibration has been established in other studies, and are around 7% (k=1 type B).

To do in vivo measurements, after needles insertion the detector is set in the urethra into a Foley catheter, and it is carried to an intermediate position, halfway between prostate base and apex, where dose gradients are expected to be smooth. A control point is set in the TPS (HDRplus 3.0.6, E&Z BEBIG) representing the detector position using real time sagittal ultrasound images.

**Results:** Measured dose deviation from that calculated with the TPS is in average -6.9%±4.0% (k=1 type A) for Ir-192 and -4.6%±3.1% (k=1 type A) for Co-60. Due to fact that we are using real time images for assessing the position of both needles and detector, these results show a better agreement than other previously published (Waldhäuser, 2005; Sharma, 2013). The negative systematic deviation might be caused by the effect of inter-needle attenuation, which is not taken into account in the TG-43 algorithm.

**Conclusions:** Despite current 3D image-based dose calculation algorithms are more accurate than IVD for dose assessment of OARs, this integrated system provides a simple way to avoid mistakes in treatment administration. The uncertainties are considerably higher than those we are used to in EBRT, but still good enough to do a comprehensive patient QA.

**OC-0177 Clinical implementation of in vivo source position verification in high dose rate prostate brachytherapy**

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**Purpose/Objective:** High dose rate (HDR) brachytherapy treatment is widely practiced but lacks independent routine treatment delivery verification to identify potential errors and ensure patient safety. We report our initial clinical experience with a novel, non-invasive, position-sensitive source-tracking system based on a flat panel detector (FPD) for treatment verification in HDR prostate brachytherapy.

**Materials and Methods:** The FPD was mounted in a standard operating theatre couch (BetaStar, Marquet) under a customised carbon fibre couch top assembly. Four prostate patients (8 treatment fractions) were included in this initial study. At treatment each patient was aligned on the couch with the target region centred over the sensitive imaging area of the FPD. Prior to treatment, three x-ray dwell position markers were inserted into selected catheters and a radiograph captured with the FPD to localise the implant relative to the detector. As the HDR source treatment dwells were delivered, images were acquired with the FPD and post-processed to determine the position of the source inside the patient. The source positions determined by the tracking system were compared to the treatment plan to verify correct treatment delivery.

**Results:** Measured source dwell positions confirmed correct transfer tube connection, source step size and patient/plan selection. The mean linear distance between measured and planned positions (example fraction shown in Figure 1) was 1.8mm (range 0.7 to 3.9mm) after rigid registration with the plan. The average measured dwell step size for all measured catheters was 2.5mm (range 1.9 to 3.1mm; s.d. 0.2mm). The absolute position of the measured source dwells was evaluated by comparing the measured dwell positions with x-ray dwell position markers from the pre-treatment radiograph (mean 3.9mm, range 0.8 to 9.9mm). This, together with the implanted gold fiducial markers, visible on the radiograph, provided verification of programmed treatment indexer length and therefore delivery to the correct anatomical location. The total impact on procedure time was less than 15 minutes.

**Conclusions:** The novel, non-invasive HDR brachytherapy treatment verification system was implemented clinically, providing verification of many treatment parameters by tracking the position of the HDR source as treatment was delivered. The novel application of the FPD allows verification that treatment delivery was free of potential human related errors identified in ICRP 97. This concept and system will meaningfully improve safety standards by allowing routine treatment verification in HDR...
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


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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

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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