therapy. Biochemical failure (after receiving both EBRT and/or BQT) was based on Phoenix definition. Acute and late genitourinary and gastrointestinal toxicities were documented based on Common Terminology Criteria for Adverse Events (v4.0). Median follow-up after HDRB was 36 months (7-109 months).

Results: At the time of the study the 3-year biochemical relapse-free rate was 58% (74-42, 95% CI). Local relapse was 13% (23-3, 95% CI). 3-year systemic relapse rate was 7.4% (8.12-7.04, 95% CI) and the 3-year overall survival rate was 91% (101-81, 95% CI). Late genitourinary Grade 3 and 4 were 8.3% and 3.3%, respectively. Nine patients required urinary catheter, 5 patients required transurethral resection and 2 pts required suprapubic cystostomy. No Grade 3 or 4 rectal toxicity were observed in our study.

Conclusions: Salvage prostate HDRB is an effective modality for locally recurrent cancer after EBRT with an acceptable late genitourinary toxicity of 8.3%.

Proffered Papers: Brachytherapy 3: Physics - Treatment planning

OC-0091
Multidimensional dosimetric characterization of 106Ru applicators for brachytherapy of uveal melanoma
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Purpose/Objective: The dosimetry of 106Ru plaques typically relies on one-dimensional dose measurements on the central axis of the brachytherapy source. However, to better characterize the dosimetric properties and for comprehensive quality assurance of different applicator models multidimensional measurements are necessary, which in turn can be used for treatment planning. In this study radiochromic film measurements were performed in multiple planes and benchmarked with Monte Carlo (MC) simulations, micro-diamond and diode measurements in terms of absolute dose rates and relative dose distributions.

Materials and Methods: Using EBT3 films 2D dose distributions of three different applicator models (CCA, CCB and COB) were measured parallel to the central axis as well as on normal planes in a purpose-built and in-house developed polystyrene phantom. Source non-uniformity was evaluated in-air using films in a simple setup. All applicators were modeled using the MCNP6 MC code. Reference dose rates and dose distributions of MC and films were validated against BEBIG values and micro-diamond and diode measurements performed in a water-scanning phantom. The benchmarked dose distributions were superimposed on representative tumor geometries of a broad range of clinical target sizes. The respective dosimetric margins were determined for a given combination of target and applicator size in order to assess the applicator types in terms of their limits concerning tumor coverage and tumor volume.

Results: The agreement of absolute dose rates at a reference depth of 2 mm on the central axis of the applicator was better than 5 % comparing film measurements with respect to the manufacturer's data. The source non-uniformity evaluation yielded values < 10 %. The MC absolute dose rates showed larger deviations with up to 10 % deviations from film results. These high differences were close to the plaque's surface but quickly vanished for depths > 2.3 mm, depending on the applicator model. For the depth-dose profiles the measurements yielded a reproducibility (1 SD) < 4 % for all investigated applicator types and all detectors. A comparison of measured and calculated data using local γ-index criteria of 1 mm/5 % showed pass rates > 94 %. Tumor coverage was evaluated regarding the dose prescribed to the tumor apex. It was found that for a majority of cases the tumor-volume is either not sufficiently covered by the 100 % prescription isodose or does not provide a margin to allow for dosimetric uncertainties if the difference between applicator diameter and basal diameter ≤ 4 mm.

Conclusions: Multidimensional film dosimetry for 106Ru eye applications was successfully established and validated against MC calculations as well as other experimental methods. Both absolute and relative dose measurements were well within the tolerances given by the manufacturer. The multidimensional dosimetric information can be utilized in treatment planning.

OC-0092
DHW-based inverse planning of prostate HDR brachytherapy by simulated annealing rapidly gives good solutions
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Purpose/Objective: Inverse planning software for HDR brachytherapy currently used in hospitals employ dose-based penalty functions. The resulting treatment plans may require manual adjustments to meet clinical criteria. As treatment plans are changed intraoperatively after catheter insertion, computation speed is a relevant criterion. Therefore, new algorithms need to be developed that directly and rapidly optimize clinically relevant dose-volume histogram (DVH)-criteria. These algorithms rely on expensive general purpose solvers. In this work, we propose a local search algorithm, DVH-Optimization by Pure Simulated Annealing (DOPSA), which is independent of cost-intensive general purpose solvers, directly optimizes for clinically relevant criteria, and provides high-quality treatment plans within seconds.

Materials and Methods: We have devised a simulated annealing-based local search algorithm that maximizes the prostate volume receiving the prescribed dose, V100% , while strictly complying to imposed DVH-constraints, D10% and Dmax on rectum and urethra. The algorithm's architecture allows extensions to more constraints. The computationally most constraining step is addressed by efficient large-scale sparse matrix multiplication. Constraint satisfaction is parsimoniously evaluated and neighborhood searches dynamically adjust to local search space characteristics. The algorithm is compared to two existing DVH-based inverse planning algorithms, IPP by Slaw et al.(2011) and MILP by Gorissen et al. (2013), using data of three patients.

Results: Any solution by the algorithm provides a treatment plan which conforms to the imposed DVH-criteria. Based on the available data of three patients, the proposed algorithm displays advantages over both alternative optimizers: DOPSA consistently outperforms IPP in plan quality at negligible differences in speed. MILP takes considerably longer to provide plans of comparable quality but, given sufficient
Magnetic field strengths of 1.5T are typically used, as image distortions caused by inhomogeneities of the main magnetic field (B₀) are considered acceptable. Lately, there has been an increased interest in 3.0T MRI, as it leads to a higher signal to noise ratio. However, distortions become more pronounced with increasing field strengths. Because little is known about the magnitude of image distortions on the applicator and patient at 3.0T MRI, the aim of this study was to quantify deformations on the applicator and with increasing field strengths. Because little is known about the magnitude of image distortions on the applicator and patient at 3.0T MRI, the aim of this study was to quantify deformations on the applicator and with increasing field strengths.

Solution quality (percentage of the target volume receiving the prescribed dose, V₁₀₀%) versus computation time for the proposed algorithm (DOPSA) and existing algorithms (IPIP, MILP). Data for three patients, averaged over 250 replications each.

Conclusions: Our local search algorithm optimizes DVH-criteria and is extendable to additional DVH-constraints. Furthermore, our algorithm outperforms an existing general purpose solver-based algorithm and is generally advantageous in terms of computation speed.

**OC-0093**
Quantification of deformations on 3T MRI for the Utrecht Interstitial CT/MR brachytherapy applicator
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**Purpose/Objective:** MRI is often used in brachytherapy treatment planning of gynaecological cancers. Magnetic field strengths of 1.5T are typically used, as image distortions caused by inhomogeneities of the main magnetic field (B₀) are considered acceptable. Lately, there has been an increased interest in 3.0T MRI, as it leads to a higher signal to noise ratio. However, distortions become more pronounced with increasing field strengths. Because little is known about the magnitude of image distortions on the applicator and patient at 3.0T MRI, the aim of this study was to quantify deformations of the Utrecht Interstitial CT/MR applicator (Elekta Brachytherapy) at 3.0T using a homogeneous phantom.

**Materials and Methods:** We built a MRI-compatible phantom that suspended the applicator in water (Fig 1A) and scanned it on a Philips Ingenia 3.0T MRI. Multi-echo images were acquired and from these we calculated a frequency shift (Δf) map of the spins by unwrapping phase differences between two echoes. This map, as a sequence independent measure of image distortions, allowed us to calculate the theoretical shift (Δx) along the length of the intrauterine device for any MR-sequence. T₁-weighted images (voxel size 0.75x0.75x3.5mm³, BW-200Hz/voxel) were also acquired. Two scans were obtained using opposing read-out directions as deformations occur primarily in this direction. By rigid matching of these images we determined the applicator shift (Δxmeas) that was caused by deformations, for three different positions along the length of the intrauterine catheter. The theoretical Δx determined from the T₁-weighted scan protocol parameters and the Δf map were compared to Δxmeas to verify whether the Δf map can be used to calculate Δx. Finally, the Δf map of the cervix was acquired in a healthy volunteer without the applicator to determine the susceptibility artifacts in vivo and calculate the mean Δx using the same parameters as used in our T₁-weighted sequence.

**Results:** In the phantom, Δf decreased towards the ovoids (Fig 1B), resulting in average Δx=0.29±0.05mm in front of the tip, Δx=0.10±0.04mm at mid intra-uterine and Δx=0.05±0.04mm near the ovoids (Fig 1C). By matching the images with opposing read-out directions on the phantom, the measured shift was 0.1 mm at most, at the tip of the catheter. A mean Δx of 0.36±0.24 mm was found in vivo near the cervix. The Δf spread (1SD) determined in vivo was considerably larger than the spread found in the phantom (76 Hz vs. 41 Hz, Fig 1D).

**Conclusions:** Our phantom study showed that deformations using 3.0T MRI on the applicator are small compared to the imaging pixel size. The range of Δf in the female pelvis without applicator is large compared to the phantom with applicator, as the phantom provides a more homogeneous B₀ than the anatomy of the patient. However, the determined theoretical shift was found to be small near the cervix (mean 0.36 mm).

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**OC-0094**
Commissioning of a titanium Fletcher applicator for 1.5T and 3T MRI-only based cervical brachytherapy
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**Purpose/Objective:** Development of MRI scan protocols for 1.5T and 3T MRI-only based treatment planning using a titanium Fletcher applicator for combined intracavitary and interstitial cervical brachytherapy. Scan protocols were optimized to allow geometrically accurate anatomical delineation and applicator reconstruction, while respecting MR safety limits.

**Materials and Methods:** The MR-conditional/CT-compatible applicator (Fletcher-style, Varian) with titanium intrauterine and ovoid probes and plastic (PEEK) needles was positioned in gel phantoms with plastic markers as reference points. The composition of the phantoms was prepared such that T₁ and T₂ were different to enable segmentation of the applicator and the ovoids in MR images.