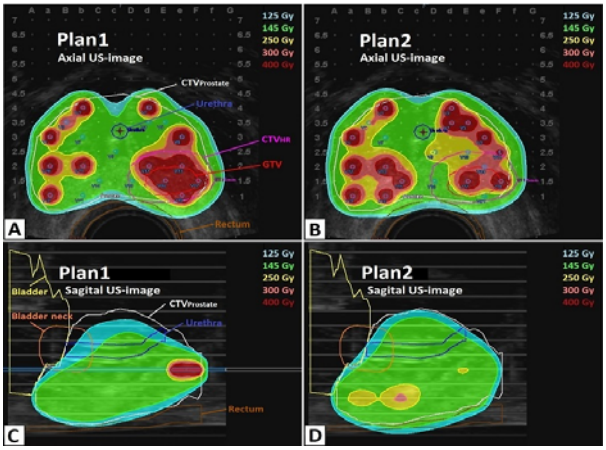
Figure 1. Panels A+C abd B+D illustrate respective dose distribution for Plan1 and Plan2 for one patient case.



Conclusions: A differential target and dose prescription strategy was technically feasible with LDR-BT seed planning and resulted in a significant dose reduction to both urethra and bladder neck, as compared to standard clinical dose planning.

OC-0229

Focal salvage HDR brachytherapy for prostate cancer recurrence after primary external radiotherapy

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Purpose/Objective: Focal brachytherapy (BT) is investigated as an alternative to whole gland BT for salvage treatment of recurrent prostate cancer to potentially improve functional outcome while maintaining cancer control. The aim of this study was to evaluate feasibility and toxicity of such treatment using high-dose-rate (HDR) brachytherapy.
Materials and Methods: Seventeen patients were included in this prospective pilot study from May 2012 to July 2014. All the patients had received primary external beam radiotherapy with total dose of 70-78 Gy and experienced biochemical failure according to Phoenix criteria. Inclusion criteria were PSA <10 at inclusion, no detectable metastases on FACBC-PET-CT or pelvic MRI and a visible relapse tumour on FACBC-PET-CT or multiparametric MRI. All patients performed a bone marrow aspiration to assess the presence of micrometastatic disease in bone marrow. The salvage BT was delivered in 3 fractions with planning aim of 10 Gy to the tumour volume. For each fraction, separated by two weeks, the needles were applied using transrectal ultrasound (US) guidance. The gross tumour volume (GTV) was delineated in the US images based the on pre-treatment MR and FACBC-PET-CT imaging. The urethra and the rectum wall were also delineated. Intra-operative treatment planning optimisation was performed for each fraction. Dose-volume-histogram parameters were found and 2Gy-eqivalent (EQD2) total dose were calculated using the LQ-model. The toxicity was scored using the EORTC/RTOG scale.
Results: The median age of the patients was 69 years (range: 60-75). Table 1 summarises the key dosimetry parameters achieved for this study. The GTV was in average 24% the whole prostate gland (range: 6-56). For all the patients the GTV D90 was above the total planning aim of 78 Gy (EQD2, $\alpha/\beta = 3$).

Table 1. Average, standard deviation (SD) and range for the key dosimetry parameters.

Parameter	Average	SD	Range
Number of needles	9	2.3	6 - 14
GTV volume [cm^3]	5.7	2.1	1.5 – 10.6
V100 (%)	94.2	3.2	86.7 – 99.4
V200 (%)	14.4	9.3	2.2 – 41.6
Total GTV D90 [EQD2, $\alpha/\beta = 3$]	88.9	8.0	78.7 – 110.0
Total Rectum D2 cm^3 [EQD2, $\alpha/\beta = 3$]	13.6	5.6	3.7 – 23.9
Total Urethra D0.1 cm^3 [EQD2, $\alpha/\beta = 3$]	25.0	6.5	10.7 – 34.2

There were a significant correlation between the number of needles used and the volume of the GTV ($R^2 = 0.39$, $p<0.001$). However, no correlation was found between the number of needles and the GTV D90, or between the volume of the GTV and the GTV D90.
The median follow-up was 9 months (range: 3-21). Three patients (16%) experienced grade 2 genitourinary (GU) or gastrointestinal (GI) symptoms (GU urge, pollakisuria and urine leakage). Only one patient reported grade 3 pollakisuria. In Figure 1 the GU and GI toxicity grades are plotted against the total EQD2 dose for rectum D2cm^3 and urethra D0.1cm^3.

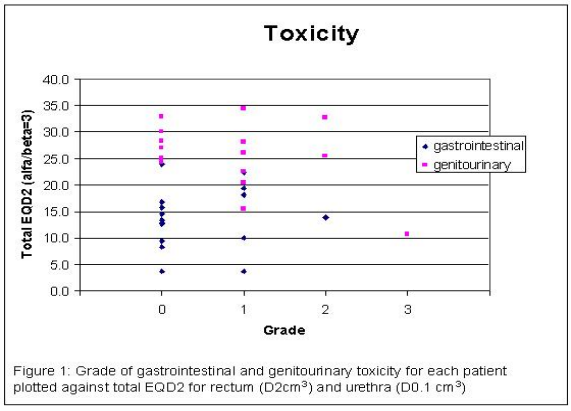

Figure 1: Grade of gastrointestinal and genitourinary toxicity for each patient plotted against total EQD2 for rectum (D2cm^3) and urethra (D0.1 cm^3)

Conclusions: Our results suggest that focal HDR salvage brachytherapy is feasible with a GTV D90 above the planning aim for all the patients. The toxicity was acceptable; however, longer follow up is needed.

Poster Discussion: Intrafraction and interfraction management

PD-0230

Quantifying the impact of respiratory parameters in the spot scanning proton dose delivery

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Purpose/Objective: Respiratory motion cause significant dose errors in IMPT for lung cancer patients due to induced variations in range and the interplay effect. The aim of this study was to investigate the relation between the respiratory amplitude and the dose errors due to the these effects.
Materials and Methods: Intensity-modulated proton therapy (IMPT) plans with co-planar beam directions perpendicular to

the the dominant Cranio-Caudal(CC) direction of motion were optimized for 4 NSCLC lung cancer patients in Pinnacle v9.1. The plans were made on mid-position CT with iGTV density override, spot size σ =6 mm and spot spacing 1σ. The total prescribed dose was 66Gy in 24 fractions to be delivered to >95% of planning target volume (PTV). The fractionated proton treatment delivery was simulated by an in-house developed time dependent simulation algorithm which integrates 4D deformation vector field (DVF) and realistic respiratory trace determined from CBCT images. The DVF describes the anatomical changes of each point over the respiratory cycle as a cyclic function. Each cycle is synchronously modified with the phase, scale and offset information from the real respiratory trace. The impact of the interplay effect in our simulation was reproduced through **Dose with Interplay to be compared with a simple shift invariant blurring of the dose the Blurred Dose.** We used the following formulas for quantifying the impact of interplay and range (blurring) effects on dose errors:

$$DoseError_{range\_effects} = \frac{SD(D_{blurred} - D_{planned})}{mean\ D_{planned}}$$

$$DoseError_{interplay\_effects} = \frac{SD(D_{interplay} - D_{blurred})}{mean\ D_{blurred}}$$

Results: Dose errors introduced by the interplay effect demonstrated different relationship with the respiration amplitude compared to the blurring effects. The errors due to interplay effects showed linear relationship with the amplitude in all patients. The blurring effect on the other side caused dose error with quadratic dependence on the amplitude (Figure 1). Our preliminary data also suggest that the dose errors due to interplay effects exhibit faster rise rate with the amplitude as the tumor size increases.

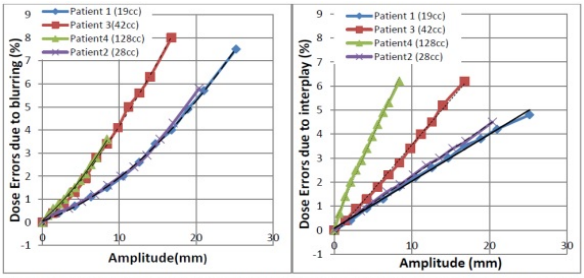

Figure1. Dose errors introduced by blurring effects (left) and interplay effects (right) as a function of the amplitude in four patients; blue –Pat1 (GTV 19cc); purple-Pat2(GTV 28cc);red-Pat3(GTV 42cc); green –Pat4(GTV 128cc)

Conclusions: The dosimetric consequences from the interplay and range effects in proton therapy are related to the amplitude. Large tumors with higher amplitude of motion seem to be more sensitive to dose errors.

PD-0231

Time-resolved internal target translation and rotation during liver SBRT treatments

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Purpose/Objective: A high accuracy is crucial in stereotactic body radiotherapy (SBRT) treatments, but may be compromised by both translations and rotations of the target during treatment. While target translations have been investigated in detail, only few studies have addressed rotations. This study presents the first measurements of time-resolved intra-fraction internal target translations and rotations during liver SBRT using CBCT projections.

Materials and Methods: Twenty-seven patients with three implanted gold markers received three to six-fraction SBRT on a conventional LINAC. One to three CBCT scans were acquired during each fraction (186 CBCTs in total). The three markers were retrospectively automatically segmented on the CBCT projections using in-house developed software. The 3D trajectory of each marker was estimated using a probability based method.

Intra-fraction translation and rotation of the marker constellation with respect to the mean position over the whole scan were calculated using Singular Value Decomposition (SVD) (Fig 1.). Motion range and Pearson's correlation coefficients (R) per scan between the six degrees of freedom were investigated for patients with motion amplitude exceeding 1mm.

Results: Figure 1 shows an example of the time-resolved translation and rotation of the marker constellation during a CBCT acquisition. Table 1 presents the 2-98 percentile range of translation along and rotation around the Right-Left (RL), Superior-Inferior (SI) and Anterio-Posterior (AP) axis. The motion was the largest in the SI direction (mean range of 8.93 mm) while the rotation was of similar magnitude around all three axes. Rotations higher than 10 degrees were occasionally observed.

The highest correlation was observed between AP and SI translations (Fig 1.) with mean R = -0.85 (SD = 0.22). The negative correlation means that cranial motion is associated with posterior motion. There was significant correlation (either positive or negative) between the SI translation and RL rotation in general, except for five patients with substantial cardiac induced motion for at least one marker (gray bars in figure c). Thus cranial motion is associated with rotation around the RL axis in either direction, but consistently the same direction for the same patient.

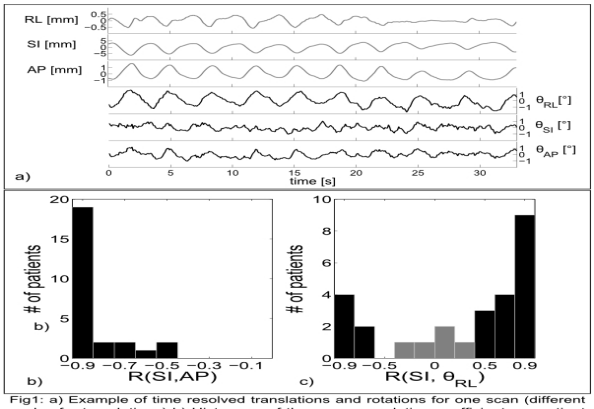

Fig1: a) Example of time resolved translations and rotations for one scan (different scales for translations) b) Histogram of the mean correlation coefficient per patient between SI and AP translation (1 patient with low AP motion excluded). c) Histogram of the mean correlation coefficient per patient between SI translation and RL rotation. The gray bars correspond to five patients with low rotation-translation correlation due to substantial cardiac induced motion.

Direction of motion	Intra-fraction motion range	
	mean	range
RL translation [mm]	1.61	0.22-8.49
SI translation [mm]	8.93	0.89-27.92
AP translation [mm]	3.93	0.53-11.61
3D translation [mm]	9.90	1.82-29.55
RL rotation [°]	3.79	0.79-13.02
SI rotation [°]	2.79	0.67-10.13
AP rotation [°]	3.78	0.77-21.72

Table 1: 2-98 percentile motion range for translation and rotation for 27 liver SBRT patients.

Conclusions: Highly time resolved translations and rotations of targets in liver SBRT were determined for the first time on a conventional LINAC using CBCT projections. Considerable intra-fraction translations and rotations were observed.