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 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-equivalent (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, α/β = 3).

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of needles</td>
<td>9</td>
<td>2.3</td>
<td>6-14</td>
</tr>
<tr>
<td>GTV volume (cm³)</td>
<td>5.7</td>
<td>2.1</td>
<td>1.5-10.6</td>
</tr>
<tr>
<td>V100 (%)</td>
<td>94.2</td>
<td>3.2</td>
<td>86.7-99.4</td>
</tr>
<tr>
<td>V250 (%)</td>
<td>14.4</td>
<td>9.3</td>
<td>2.2-41.6</td>
</tr>
<tr>
<td>Total GTV D90 [EQD2, α/β = 3]</td>
<td>88.9</td>
<td>9.0</td>
<td>78.7-110.0</td>
</tr>
<tr>
<td>Total Rectum D2 cm³ [EQD2, α/β = 3]</td>
<td>13.5</td>
<td>5.6</td>
<td>3.7-23.9</td>
</tr>
<tr>
<td>Total Urethra D0.1 cm³ [EQD2, α/β = 3]</td>
<td>25.0</td>
<td>6.5</td>
<td>10.7-34.2</td>
</tr>
</tbody>
</table>

There were a significant correlation between the number of needles used and the volume of the GTV (R² = 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 D2cm³ and urethra D0.1cm³.

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:

\[
Dose_{\text{Error}_{\text{range,effects}}} = \frac{SD(D_{\text{blurred}} - D_{\text{planned}})}{mean\ D_{\text{planned}}}
\]

\[
Dose_{\text{Error}_{\text{interplay,effects}}} = \frac{SD(D_{\text{interplay}} - D_{\text{blurred}})}{mean\ D_{\text{blurred}}}
\]

**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.

**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 Antero-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.

**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.

**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.