slices, representing the real time location of the tumour. To compare the 3D CT target volume with a 2D target area from the MRI, the contoured 3D volume was projected onto the 2D sagittal plane, resulting in a 2D area that could be fairly compared with the sagittal 2D MR area.

Results: The projected 2D CT bin areas for the 5 patients had a mean (standard deviation) area of 4.12(0.35), 5.17(0.40), 2.99(0.34), 9.28(0.52) and 3.96 (0.35) cm². This is compared to the MR contoured areas of 5.02 (0.45), 7.13(0.67), 2.63(0.41), 7.52(0.57) and 4.07(0.41) cm² (Figure 1). While there are differences that may be attributed to binning errors from 4D CT reconstruction and intra-observer variations, contours from real time MRI do not appear to be systematically biased on target area compared to the CT contours.

Figure 1. Mean area for five lung tumors on CT, MRI and MIP. Error bars represent standard deviation.

Conclusion: Lung tumor target areas on dynamic MR are similar to those on 4DCT and confirm the accuracy of real time tumor imaging. With the platform’s ability for real time tumor tracking, reductions in irradiated lung volume can be achieved compared to motion encompassing treatment strategies, as indicated by the much larger MIP volumes.

EP-1777
Dosimetric benefits and reproducibility of DIBH technique guided by an optical system
F. Rossi¹, S. Russo², R. Barca¹, S. Fondelli¹, L. Paolotti¹, P. Alpi¹, B. Grilli Leonelli¹, M. Esposito¹, A. Ghirelli¹, S. Pini¹, P. Bastiani³¹
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Purpose or Objective: Surface imaging (Si) systems have been recently introduced in radiotherapy to check patient setup and to manage gated treatment procedure. The absence of additional radiation exposure, the execution rapidity and comfortable for the patients, make this approach particularly interesting. Aim of this work is the evaluation of a deep inspiration breath-hold (DIBH) technique guided by an optical system in terms of normal-tissue sparing, and positional reproducibility.

Material and Methods: The CatalystTM (C-RAD Sweden) is a novel phantom for dosimetric verification of gated SIB radiotherapy treatment plans. To benchmark the use of the phantom for 4D PET/CT scanning and dosimetric verification of gated SIB radiotherapy, from 4D PET/CT scanning to treatment planning and dose delivery. The first phantom holds a 3D-printed insert that mimics the variable PET tracer uptake in different slices, representing the real time location of the tumour. To compare the 3D CT target volume with a 2D target area from the MRI, the contoured 3D volume was projected onto the 2D sagittal plane, resulting in a 2D area that could be fairly compared with the sagittal 2D MR area.

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Material and Methods: The CatalystTM (C-RAD Sweden) is a valid solution for respiratory gated treatments offering visualization of the respiratory pattern and direct beam control. In combination with the C-RAD Sentinel™ system used for CT acquisition phase, Catalyst™ offers coverage for the whole chain from gated imaging to gated beam delivery (see figure 1). 20 patients that underwent BCS and left side adjuvant radiotherapy during 2015 were included in this study. Tumors were treated in DIBH with 3D conformal tangential beams. Median dose to the whole breast was 50 Gy in 25 fractions. For each patient a free breathing (FB) and a DIBH treatment plans were calculated and dose volume histograms were compared. The reproducibility of the DIBH during treatment was monitored by capturing 3D surfaces with CatalystTM system before and after set-up correction and at the end of the treatment fraction. Interfraction and intra-fraction variability were quantified in mean and SD displacements in translation (Lat, Long, Vert) and rotations (Rot, Roll, Pitch) over all the treatment fractions of the enrolled patients.

Figure 1: DIBH procedure guided by C-RAD optical systems with visual coaching.

Results: DIBH technique provided a significant dose reduction in Heart Mean Dose (13Gy FB vs 0.4 Gy BH), and LAD mean dose (10.7 Gy FB vs 2.0 Gy BH). Better PTV coverage (V 95% 88.9% FB vs 92.6% BH) in DIBH plans and no difference in Lung parameters (V10, V20 and Dmedia) were achieved. Inter-fraction variability before setup correction was relevant, but inter-fraction variability after setup correction was extremely reduced. Intra-fraction variability was <2.1 mm in translations and <1° in rotations, as showed in table 1.

Table 1: Quantification of set-up variability in DIBH treatments.

<table>
<thead>
<tr>
<th>Setup</th>
<th>Lat [mm]</th>
<th>Long [mm]</th>
<th>Vert [mm]</th>
<th>Rot [°]</th>
<th>Roll [°]</th>
<th>Pitch [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter-fraction</td>
<td>1.9</td>
<td>10.1</td>
<td>-6.9</td>
<td>0.8</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>before correction</td>
<td>2.1</td>
<td>9.0</td>
<td>4.3</td>
<td>1.0</td>
<td>1.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Inter-fraction</td>
<td>-0.4</td>
<td>-0.7</td>
<td>-0.1</td>
<td>0.5</td>
<td>0.4</td>
<td>-0.3</td>
</tr>
<tr>
<td>after correction</td>
<td>0.4</td>
<td>0.5</td>
<td>0.3</td>
<td>0.6</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Intra-fraction</td>
<td>1.4</td>
<td>2.1</td>
<td>1.7</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>(0.5)</td>
<td>(0.4)</td>
<td>(0.5)</td>
<td>(0.2)</td>
<td>(0.1)</td>
<td>(0.3)</td>
</tr>
</tbody>
</table>

Conclusion: In our experience DIBH is a reproducible and stable technique for left breast irradiation showing significant reduction of mean dose to the hearth and LAD and a limited inter-fraction and intra-fraction DIBH variability. This is a good promise in reducing the late cardiac toxicities associated with radiation therapy.

EP-1774
A novel phantom for dosimetric verification of gated SIB radiotherapy treatment plans
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Purpose or Objective: To validate a novel phantom intended for 4D PET/CT scanning and dosimetric verification of gated radiotherapy plans. To benchmark the use of the phantom for PET-driven, simultaneous integrated boost (SIB) radiotherapy planning and ion chamber validation.

Material and Methods: A multipurpose phantom and a set of inserts were designed and manufactured to simulate gated SIB radiotherapy, from 4D PET/CT scanning to treatment planning and dose delivery. The first phantom holds a 3D-printed insert that mimics the variable PET tracer uptake in
heterogeneous tumors. The insert has an outer low-uptake volume encompassing a high-uptake inner volume. SUV ratio of 1:2 was intended. The second phantom accommodates applicators that can hold Farmer ion chamber in a location matching the center of the inner volume and in four locations matching the outer volume. 4D PET/CT scans of the phantom were acquired with three breathing wave forms of ideal sinusoid and two patient-specific breathing patterns fed to the moving platform. Patient-specific wavefronts were selected to represent a regular and an irregular breathing. Two scenarios were investigated for image reconstruction, planning and delivery: a gate 30-70 window, and no gating. ITV were delineated on the obtained 4D PET/CT scans and 21 VMAT-SIB treatment plans were generated with two fractionation regimens:

- Conventional fractionation: 2 Gy/fx to outer ITV, 2.4 Gy/fx to high SUV inner ITV, 30 fx.
- Hypo-fractionation delivered in both flattening filter and flattening filter free (FFF) modes: 8 Gy/fx to outer ITV, 9 Gy/fx to inner ITV, 5 fx. Treatment plans were delivered in two gating scenarios: no gating and gate 30-70. Two ion chamber readings for the inner ITV, and two readings for one arbitrarily selected outer ITV were acquired. Measured doses in the inner ITV and the outer ITV were compared to planned doses.

Results: For both fractionation regimens and both delivery modes, measured doses in outer and inner ITV were between 93 and 99% of planned doses. Measured dose as compared to planned dose demonstrated independence from breathing pattern or gating window. In particular, measured doses in FFF mode were consistent with measured doses in filtered beam mode, 94-96% of planned dose.

Conclusion: The phantom has been validated for end-to-end use from 4D PET/CT scanning and radiotherapy planning, to dosimetric verification. Measured doses for SIB plans were in reasonable agreement for all three breathing patterns and for both gating windows and delivery modes.

Electronic Poster: Physics track: Inter-fraction motion management (excl. adaptive radiotherapy)

EP-1775
CBCT based prostate IGRT accuracy and PTV margins
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Purpose or Objective: Purpose: Image guided radiotherapy (IGRT) is the standard treatment of prostate cancer, widely based on Cone Beam CT (CBCT). The accuracy of CBCT based prostate registration is however not well established, conditioning the choice of the Planning Target Volume (PTV) margins. The goal of the study was to quantify the uncertainty of this registration and propose therefore appropriate margins.

Material and Methods: Materials and methods: A total of 306 prostate CT to CBCT alignments were analyzed in 28 prostate cancer patients treated by IGRT. The prostate was manually delineated on all the CBCT. Three prostate alignment modalities were afterwards simulated and compared, based on skin marks, on CBCT registration performed by the technologist at the fraction (IGRTt) and on the prostate contours. The IGRT uncertainty (IU) was defined as the difference between the contour based and the CBCT alignments, in each space direction. Dice index (DI) were calculated, based on the IU and the Van Herk formula.

Results: The Σ and σ for all treatment sites are summarized in table 1 as well PTV margins.

Results: The Σ and σ for all treatment sites are summarized in table 1 as well PTV margins. Conclusions: CBCT based prostate registration presents uncertainties requiring at least 3 to 5 mm PTV margins.

EP-1776
Assessment of setup uncertainties in modulated treatments for various tumour sites
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Purpose or Objective: The aim of this study was to analyse the patients setup errors for various tumor sites based on clinical data from modulated treatments using cone beam computed tomography (CBCT) imagine guidance and portal imaging for breast site. It was also calculated the planning target volume (PTV) margins of all disease sites and stipulated action level for online correction.

Material and Methods: The patients analyzed in this study were treated in our institution between January 2012 and December 2014 with VMAT and IMRT via flash technique for breast cancer. The various tumor sites were divides into six categories; 175 breast (1173 fractions); 53 thorax (475 fractions); 60 prostate (585 fractions); 100 H&N (858 fractions); 100 SNC (789 fractions) and 77 pelvis (620 fractions).

For every treatment fraction, it were acquired KV-CBCT images using the on-board imager (OBI) (Varian Medical Systems), and for breast cancer it were acquired MV portal images using the Electronic Portal Imaging Device (EPID) (Siemens AG) in the first week and twice per week. The registration procedure was performed for all treatments sites according to the tumor localization. For prostate site, it was also analyzed the physiological state of bladder and rectum. It were calculated the systematic (Σ) and random (σ) errors of couch shift obtained, and PTV margin (2.5Σ + 0.7σ).

Results: The Σ and σ for all treatment sites are summarized in table 1 as well PTV margins.