All treatment plans were set the clinically acceptable goals. The 4D-IMRT showed a statistically significant improvement (p<0.05) compared to 3D-IMRT in all relevant parameters. The 4D-VMAT plans further reduced all OAR parameters significantly (p<0.05), while maintaining identical target coverage. Phantom measurements confirmed that both techniques (IMRT and VMAT) can be safely administered.

Conclusion: By using the 4D-CT acquisition and mid-ventilation target delineation approach, significant PTV volume reduction was obtained. This method is improving PTV coverage and OAR doses using the same technique (IMRT). VMAT technique might further gain additional dosimetric benefits for patients with NSCLC.

PO-0845 Evaluating dosimetric indices in lung SBRT for establishing treatment plan quality guidelines
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Purpose or Objective: We applied a variety of published conventional and stereotactic plan quality dosimetric indices to describe and discern clinically achieved target dose distributions in Lung SBRT.

Material and Methods: Treatment plans of 100 Lung SBRT patients treated were retrospectively reviewed. The targets (n=102) were evenly distributed - right lung (53) and left lung (49). Patients were prescribed to a total dose of 50-60 Gy in 3-5 fractions. Dose optimizations were accomplished with 6 MV using either 2-5 arcs VMAT (90); 8-14 IMRT fields (6) or 10-16 static fields (6). Dose calculations were performed using AAA algorithm with heterogeneity correction. A literature review on dosimetric indices recommended for qualitative analyses of conventional and stereotactic dose distributions in target coverage, homogeneity, conformity and gradient categories was performed. From each patient treatment plan, the necessary parameters for calculating various indices were quantified.

Results: For the study, the mean (±SD) values for indices were: coverage (96.4 (±2.4) %); homogeneity (1.27 (±0.07)); Conformity (1.04 (±0.08)) and Gradient (1.27(±0.30) cm). Geometric conformity (g) strongly correlated with the conformity index (defined by van’t Riet /Paddick) (p<0.0001). All Gradient measures strongly correlated with PTV (p<0.0001). Evaluating High Dose Spillage, the average cumulative volume of all tissue outside the PTV receiving a dose of ≥ 105% of prescription dose was 0.94 (± 1.64) %. Considering Low Dose Spillage, the maximum % of prescription dose to any point at 2 cm distance in any direction from PTV was 56.0 (± 11.4) %. The lung volume (total lung volume - GTV) receiving doses of 20 Gy and 5 Gy (V20 and V5) were mean 4.9 % (± 3.1) and 16.9 % (± 9.0). The RTOG lung SBRT protocol advocated conformity guidelines for prescribed dose in all dosimetric evaluation categories were met in ≥94% of cases.

Conclusion: The high-rate of adherence to RTOG protocol dose conformancy guidelines in our study validates that indices derived from our SBRT lung plan dose distributions are a tool for establishing plan metrics in clinical trials, for scoring competing plans and as well for comparing inter-institutional lung SBRT plan dosimetric data. However, these indices should only be used as an additional tool to grade plan quality once a satisfactory treatment plan has been achieved judged on the basis of clinical expertise, acceptable dose distributions and dose gradients, while respecting critical organ and normal structure doses.

PO-0846 The impact of anatomical changes on the accumulated carbon ion dose in pancreatic cancer patients
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Purpose or Objective: Improvements in overall survival of pancreatic cancer patients after carbon ion radiotherapy have been reported from Japanese clinical trials. Due to the sharp distal dose fall-off, a high dose can be delivered to the tumor, while sparing the nearby healthy organs. However, changes in gastrointestinal gas volumes can greatly influence the carbon ion range.

We evaluated the robustness of carbon ion therapy for pancreatic cancer patients by investigating the impact of interfractional anatomical changes on the accumulated dose when using bony anatomy- and fiducial marker-based position verification.

Material and Methods: Nine pancreatic cancer patients, treated with photon radiotherapy in free breathing, were included in this retrospective planning study. The internal gross tumor volume (iGTV), internal clinical target volume (iCTV), duodenum, stomach, liver, spinal cord and kidneys were delineated on the (average) 4D-CT scan. Intratumoral gold fiducial markers were implanted in all patients to enable position verification using cone beam CT (CBCT).

Treatment plans were created using a 4-beam passive scattering technique. A smearing technique was used to account for patient setup errors; a safety margin of 3 mm was applied to compensate for range uncertainties. Plans were generated to deliver at least 95% of the prescribed dose (36GyE in 12 fractions) to 99% of the iCTV.

To enable dose calculations on the daily CBCTs, the planning CT was deformably registered to each CBCT. The gastrointestinal gas volume visible on each CBCT was copied to the deformed CTs. Next, fraction doses were calculated by aligning the treatment plan according to a bony anatomy- and a fiducial marker-based registration. For both registration methods the resulting fraction doses were rigidly summed to acquire the accumulated dose.

We compared both accumulated doses to the planned dose using dose-volume histograms (DVHs) and calculated DVH parameters for the iGTV and iCTV (Dmean, D2%, D98%) and organs at risk (Dmean, D2cc).

Results: The D98% of the target volumes showed the largest differences (Figure). For the bony anatomy-based registration, D98% reduced significantly from 99.6 ± 0.2% (iGTV; mean ± standard deviation) and 98.6 ± 0.5% (iCTV) as planned to 92.3 ± 3.8% and 81.9 ± 7.7% for the accumulated dose, respectively. For the marker-based registration, this was slightly improved to 95.1 ± 4.0% (iGTV) and 88.6 ± 4.0% (iCTV), which was still significantly different from planned.

For the duodenum, severe deviations were observed in the DVHs between the planned and accumulated dose. Both the direction and magnitude of the deviations differed considerably between patients. The other organs showed minor changes.
Conclusion: Severe reductions in target dose coverage were observed as an effect of interfractional anatomical changes. The difference between the position verification methods was a lesser issue compared to the effect of the anatomical changes.

PO-0847
Implementing the new ESTRO guideline for elective breast radiotherapy with the humeral head as PRV
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Purpose or Objective: The new ESTRO consensus guideline for target delineation for elective breast radiotherapy (Offersen Radiother Oncol. 2015) establish the humeral head and connective tissues 10 mm around it as Planning Risk Volume (PRV). The objective was to implement these guidelines for sparing the humeral head in elective breast radiotherapy with level 1 and 2 (L1/L2) lymph nodes by comparing three different planning techniques.

Material and Methods: Ten patients with left-sided breast cancer were enrolled in a planning study performed in Pinnacle3 v9.8 (Philips). All patients were planned with 16 x 2.66Gy on the breast (PTVp) and the elective L1/L2 lymph nodes (PTVn). We compared three techniques: IMRT with high tangential field (HTF), 6-field IMRT and VMAT. The humeral head PRV (hh+10) was included with an objective of V40Gy < 1cc for all three techniques. Treatment plans were obtained with the inverse planning tool and optimization was achieved by decreasing the dose to the organs at risk (OARs: lungs, heart and right breast) as low as possible while maintaining a PTVp V95% of 97% and PTVn V90% of 95%.

For the high tangential fields, the cranial border of the fields was extended to include PTVn. The leaves of the 5 mm multi-leaf collimator were then closed to exclude hh+10 to reduce the dose to the humeral head and the surrounding tissue. This technique is currently used in our clinic. The 6-field IMRT technique consisted of tangential fields and four additional fields (at 330, 20, 80 and 170 degrees) to ensure proper coverage of the cranial part of the breast and the lymph nodes. The cranial border of the tangential fields and caudal border of the four additional fields was set 1 cm below the attachment of the clavicle at the sternum. The third technique was a VMAT dual arc from 305 to 180 degrees.

Results: HTF resulted in an average PTVp V95% of 97.2% and an average PTVn V90% of 90.4% (see Table 1). With the additional fields of the 6-field IMRT technique, the coverage of the lymph nodes increased significantly to on average 98.0% (p < 0.01) while PTVp did not vary significantly (p = 0.92). The doses to the OAR were comparable between the HTF and IMRT technique. The coverage of PTVn increased when using VMAT to an average of 99.5% (p < 0.01 compared to HTF and p = 0.19 compared to IMRT). The dose to the OAR increased as well. The mean dose to the contralateral breast increased significantly from 0.66Gy with HTF and IMRT to 2.36Gy with VMAT (p < 0.01 for both).

### Table 1: Dosimetric parameters for the planning target volumes (PTVp and PTVn), planning risk volume (humeral head + 10 mm) and the organs at risk for high tangential fields (HTF), 6-field IMRT and VMAT

<table>
<thead>
<tr>
<th></th>
<th>HTF</th>
<th>IMRT</th>
<th>VMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTVp V95% (%)</td>
<td>97.2 (91.8 - 99.5)</td>
<td>97.1 (96.8 - 97.3)</td>
<td>97.8 (96.6 - 97.4)</td>
</tr>
<tr>
<td>PTVn V90% (%)</td>
<td>90.4 (73.7 - 89.7)</td>
<td>89.5 (89.5 - 90.9)</td>
<td>90.5 (96.2 - 99.9)</td>
</tr>
<tr>
<td>hh+10 V40Gy (%)</td>
<td>0.45 (0.1 - 0.9)</td>
<td>0.67 (0.1 - 1.83)</td>
<td>0.70 (0.1 - 1.35)</td>
</tr>
<tr>
<td>Lungs Dmean (Gy)</td>
<td>4.7 (3.9 - 6.1)</td>
<td>4.8 (3.8 - 5.9)</td>
<td>5.2 (4.2 - 6.8)</td>
</tr>
<tr>
<td>Heart Dmean (Gy)</td>
<td>5.3 (4.6 - 6.1)</td>
<td>2.9 (1.6 - 5.7)</td>
<td>3.6 (2.8 - 5.7)</td>
</tr>
<tr>
<td>Right breast Dmean (Gy)</td>
<td>0.6 (0.3 - 0.9)</td>
<td>0.6 (0.3 - 0.7)</td>
<td>2.3 (0.6 - 4.2)</td>
</tr>
</tbody>
</table>

Conclusion: The humeral head and surrounding tissues as defined in the new ESTRO guideline can be spared with the 6-field IMRT or VMAT technique. It is not possible through high tangential fields without reducing PTVn coverage. A 6-field IMRT technique including tangential fields and four additional fields to cover the lymph nodes and the cranial part of the breast leads to adequate coverage of the primary target and the lymph nodes without increasing the dose to the other OARs.

PO-0848
Simultaneous integrated protection (SIP): a new concept for high precision radiation therapy
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Purpose or Objective: Stereotactic radiotherapy near critical serial organs at risk (OAR) requires specific caution to avoid severe toxicity. Current strategies are to (1) rule out SBRT as a treatment option, (2) to use full dose SBRT and expose patients to higher risks, (3) to homogenously underdose the entire planning target volume (PTV), or (4) to trim PTV margins individually and non-quantifiably. We here describe a novel IMRT prescription method termed simultaneous integrated protection (SIP) for quantifiable and comparable dose prescription to targets very close to dose limiting structures. This work will be focussed on the planning of SBRT.

Material and Methods: For patients with infringement of dose constraints to at least one serial OAR, e.g. central airways, bowel, we defined a planning risk volume (PRV). The intersection volume of the PTV with the total planning target volume (PTV_SIP) was defined as the protection PTV_SIP and the vast non-intersecting majority of PTV_SIP as the dominant PTV (PTV_dom). Radiotherapy treatment planning was performed using IMRT. Dose was prescribed to PTV_dom according to ICRU in 3, 5, 8 or 12 fractions. If in doubt, preference to a higher number of fractions was given as a function of the size of PTV_SIP. D_max was allowed to be up to 130% of the prescribed dose. No specific dose was prescribed to the PTV_SIP but dose was required to stay just within the constraints for the respective OAR. Dose-volume-histogram (DVH) analysis was based on absolute volumes of OARs, not on PRVs.

Results: This method led to a fall off region within PTV_SIP between the PTV_dom and the OAR. We here demonstrate this approach for six patients. Two had lesions in the chest, one in the liver, two in the pancreas and one in the left kidney (Figure 1). Size of the PTVs (PTV_SIP) ranged from 14.5 to 84.9 mL (median 49.2 mL, mean 49.7 mL; Figure 2). Sizes of PTV protection subvolumes (PTV_SIP) ranged from 1.8 - 3.9 mL (median and mean 2.8 mL). Relative PTV_SIP ranged from 2.9% - 13.4% of the size of PTV_SIP (median 7.4%). Noteworthy, the largest ratio, 13.4%, was an absolute volume of 2 mL, only. D_min of the PTV_SIP was significantly lower in patients