planning objectives, drawn from a Gaussian distribution with the base plan objective as mean and a pre-defined standard deviation, were automatically generated using worst-case scenario optimisation. Plans were evaluated on robustness by selecting the single-worst of 12 simulated perturbation scenarios based on density (3%) and position (8 mm in all directions) errors. For the plans fulfilling all minimal requirements after robustness evaluation, the PF was estimated based on the dominating plans for which one objective of interest cannot be improved without deteriorating other evaluation objectives of interest. To iteratively improve the PF estimate, a new base plan was automatically created using average planning objectives of dominating plans for a next iteration. After 5 iterations with 20 plans each, dominating plans were determined to form the 2D PF. Per patient, PFs based on different beam set-ups were compared by investigating trade-off differences between objectives of interest.

Table: Beam set-ups, planning objectives and evaluation objectives used.

| Beam set-up | Gantry angles(*) | 2 beams | 90, 270 | 3 beams | 10, 50, 270 | 4 beams | 30, 90, 270, 330 |

Planning objectives

- CTV Minimal dose 46.8 Gy (w=120)
- Maximal dose 60 Gy (w=80, $\sigma$=50)
- Body Dose fall-off 0.6-3 Gy over 1.0 cm ($\sigma$=60)
- Rectum Maximal 30 Gy to 50% ($\sigma$=10% of the volume ($w$=30, $\sigma$=10)

Minimal evaluation requirements

- CTV At least 40 Gy received by 95% of the volume
- Maximal dose 50.4 Gy received by 2% of the volume
- Body At most 1800 cm² receiving 43.7 Gy
- Rectum At most 90% of the volume receiving 30 Gy
- Brain At most 25% of the volume receiving 45 Gy

Abbreviations: CTV—clinical target volume, Gy—gray, w—weight, $\sigma$—standard deviation, cm²—cubic centimetre.

Results: In total, 825 robustly optimised IMPT plans were automatically created and evaluated within 550 hours. Per derived PF, on average 25 plans (range, 11–45) did not fulfil all requirements and 15 dominating plans (range, 13–18) were found. The figure shows an example of dominating plans that form the PF (A) and PFs based on different beam set-ups used for comparison (B). For 2 out of 3 patients, PF comparison indicated a better trade-off between CTV D99% and rectum V30Gy for robust IMPT plans using 4 beams.

Conclusions: A novel method to iteratively determine PFs based on robustly optimised IMPT plans including robustness evaluation was successfully scripted in RayStation. We demonstrated the feasibility of beam set-up comparison using PFs for proton therapy planning in cervical cancer.

PO-0529

CT image features associated with patient-rated xerostomia after radiotherapy for head and neck cancer

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Purpose/Objective: Xerostomia is the most frequently reported side effect of radiotherapy in head and neck cancer and has a major impact on quality of life. Current measurements of xerostomia are either subjective or unpleasant for the patient. We hypothesize that volume and density of the parotid and submandibular glands, which can be objectively determined from CT-scans, are related to their function and can therefore be used as image biomarkers for xerostomia. To test this hypothesis, we investigated the association of these image features with patient-rated xerostomia.

Materials and Methods: This prospective study included 110 patients with head and neck cancer who were treated with radiotherapy. Patient-rated xerostomia was scored on a 4-point Likert scale using the EORTC QLQ-H&N35 questionnaire 12 weeks after treatment start ($X_9_{12\text{wk}}$) and 6 months after treatment ($X_9_{6\text{m}}$). In addition, CT-scans were made at baseline and 12 weeks after treatment. The CT density (in HU), volume (in cm³) and their change between both CT-scans were calculated for the parotid and submandibular glands. Associations with $X_9_{12\text{wk}}$ and $X_9_{6\text{m}}$ were calculated using univariable and multivariable linear regression and Pearson correlation (r).

Results: In the univariable analysis a statistically significant relation was found between $X_9_{12\text{wk}}$ and change in volume of the parotid glands and change in density of the submandibular glands between the CT-scans at baseline and 12 weeks after treatment (Table 1). Furthermore, a statistically significant relation was found between $X_9_{6\text{m}}$ and change in density of the parotid glands and change in density of the submandibular glands.

Conclusions: A novel method to iteratively determine PFs based on robustly optimised IMPT plans including robustness evaluation was successfully scripted in RayStation. We demonstrated the feasibility of beam set-up comparison using PFs for proton therapy planning in cervical cancer.

Table 1: Univariable linear regression relating CT image feature changes to patient-rated xerostomia after 12 weeks and 6 months.

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>p-value</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Associations with Xerostomia, 12 weeks after treatment start</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parotid glands volume change (cm³)</td>
<td>$-0.039$</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Parotid glands density change (HU)</td>
<td>$+0.006$</td>
<td>$0.014$</td>
</tr>
</tbody>
</table>

| Associations with Xerostomia, 6 months after treatment |
| Parotid glands volume change (cm³) | $+0.039$ | $<0.001$ | $-0.362$ |
| Submandibular glands density change (HU) | $+0.014$ | $0.003$ | $-0.339$ |

Figure 1: Graphs show the change in volume and density of the parotid glands and the submandibular glands over 12 weeks for patients without (A) and with (B) xerostomia. A high density of the parotid ($\beta=0.004$, $p=0.03$, $r=0.22$) and submandibular glands ($\beta=0.004$, $p=0.05$, $r=0.20$) were predictive for $X_9_{6\text{m}}$. No baseline features were significantly associated with $X_9_{12\text{wk}}$. In the multivariable model the change in volume of the parotid glands and change in density of the submandibular
Results: The nadir of WBC and N (median values= 65% and ≤1780 x 10⁹/L) were found at half-therapy while it was at the end of RT for ALC (median= 30% of baseline). At univariate analysis, a lower baseline ALC (ALCbase) was correlated with G3 ALCend and G1 ALC12m (p=0.003). The resulting model for ALCend included ALCbase and WP-V40 (AUC =0.73); the model for ALC12m included ALCbase and IL-V40 (AUC= 0.82).

Conclusions: Two-variable models including ALCbase and DVH parameters of pelvic BM may predict acute G3 and late G1 lymphopenia after WP-IMRT in post-prostatectomy RT. The model could be used to reduce HT by constraining BM. Further validation on a larger population is ongoing.

PD-0531
Dosimetric investigation of rotational setup errors for spine stereotactic radiosurgery: a phantom study
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Purpose/Objective: A previous study showed that small rotational setup errors could have a considerable impact on the dose distribution for spine SRS. However, information on the relationship between rotational errors and dose distribution is limited. This study was therefore conducted to investigate experimentally the effect of rotational setup errors on dose distribution for spine SRS.

Materials and Methods: The contour definitions and treatment planning were as per RTOG 0631. A 16-Gy dose was prescribed in a single fraction by step-and-shoot intensity-modulated radiation therapy (IMRT) using seven coplanar beams with the Vero4DRT (Mitsubishi Heavy Industries, Ltd., Hiroshima, Japan, and Brainlab AG, Feldkirchen, Germany). An isocenter was placed inside the vertebral body. Setup error patterns were categorized into three groups. Only translational errors were generated for Group A, with the translational errors measuring the 1°, 2°, 3°, and 5° in the lateral (LAT), longitudinal (LNG), and vertical (VRT) directions, respectively. Only rotational errors were generated for Group B, and measured +1°, +2°, +3°, and +5° in terms of the tilt or roll angle. Combinations of translational and rotational errors occurred in Group C. Translational errors of 0 to 2 mm were generated in each direction and rotational errors of ±1° or ±2° in each direction. Data were acquired with a Delta4 phantom (ScandiDos, Uppsala, Sweden) and setup errors were generated with HexaMotion (ScandiDos, Uppsala, Sweden).