OC-0551
Deformable dose reconstruction of liver SBRT to investigate margin reduction with dose-probability PTV
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Purpose/Objective: SBRT at the mean respiratory position coupled with a dose-probability PTV spares more normal tissue than the internal target volume (ITV) method. For liver cancer, a potential challenge with PTV reduction is the poor tumor contrast on respiratory correlated (4D) cone-beam CT (CBCT). Deformable image registration resolved the mean position on 4D CBCT and accumulated dose in order to investigate PTV reduction on both the planned and delivered liver SBRT doses.

Materials and Methods: 21 tumors in 13 patients planned on exhale 4D CT and 27-49.8 Gy/6 fractions with an ITV-based PTV (CTexh), and treated in free-breathing with CBCT liver guidance, were retrospectively evaluated. Re-planning was done on the mid-ventilation CT (CTmid) using individualized dose-allocation (iso-NTCP ±5%) and dose-probability margins accounting for residual population inter-fraction tumor errors after liver guidance, intra-fraction motion, deformable registration accuracy, and patient-specific 4D CT tumor motion. The delivered dose was accumulated using biomechanical deformational registration of each 4D CBCT to model breathing changes, deformation and setup errors. This was done for the clinical CTexh plan, and for the CTmid plan after aligning the mean liver position between 4D CBCT and CTmid.

Results: Relative to CTexh plans with ITV, PTVs on CTmid were smaller by 1.3-29.5% (mean ± SD of 35.13%), enabling a dose escalation to the PTV 95% volume of 5.0±4.7 Gy (maximum 19.5 Gy). The delivered minimum tumor doses (0.5cc) for the CTmid plans were 4.2±3.7 Gy (maximum 14.8 Gy) higher than the doses delivered for the clinical CTexh plans. For the CTexh plans, only 1 patient (8%) had a decrease more than 0.5 Gy in the delivered minimum tumor dose, which was 4.8 Gy less than the dose planned to the PTV 95% volume on CTexh. This patient had 8 mm larger breathing amplitude on 4D CBCT versus 4D CT, and liver deformation causing a residual 4 mm systematic tumor error relative to the mean liver position on 4D CBCT. For the normal gastrointestinal tissues, the delivered maximum dose (0.5cc) for the CTexh plan exceeded the planning constraint by 1.7 Gy (5.4%) in one only patient’s esophagus due to the effect of breathing motion. However, for the CTmid plans no delivered normal tissue doses exceeded the planning constraints by more than 0.2 Gy despite the dose-escalation.

Conclusions: Liver SBRT planning and delivery at the mean respiratory liver with dose-probability margins enables a mean escalation of 5 Gy/6 fractions to the minimum tumor dose, potentially improving local control. Despite margin reduction, more than 90% of patients received the planned tumor dose without over irradiating the adjacent dose-limiting tissues.

OC-0552
Textural analysis for the characterization of structural variations in parotid glands during radiotherapy
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Purpose/Objective: During the Radiotherapy (RT) of head-and-neck cancer, parotid glands undergo to significant anatomic, functional and structural variations. These changes are likely to be pre-clinical signs of increased risk of acute (and late) xerostomia and could also be correlated to the severity of symptoms. Aim of this work was to propose texture analysis in order to characterize parotid gland structure and its changes induced by RT. Moreover, we investigated if early variations of textural features can be used to predict parotid shrinkage at the end of RT.

Materials and Methods: 20 parotid glands were analyzed using CT images of 10 patients treated with IMRT. To perform texture analysis, statistical indices (mean intensity (μ), variance (σ²), global and local entropy (S₁ and S₂), homogeneity (H)) were estimated from histogram and co-occurrence matrix; fractal dimension (FD) was calculated using variogram method. Textural features and volume (V) were extracted and free-breathing 4D CT images acquired during the treatment. In particular, significant changes are well visible in the first two weeks of the treatment and proven to be able to early predict final shrinkage. The significant decrease in μ, S₁ and FD could be related to the loss of acinar cells after irradiation and a consequent decrease in tissue complexity. Textural features, like FD and μ, could be used in addition to V as early descriptors of parotid shrinkage. The results obtained have demonstrated that multi-parametric performed better than mono-parametric analysis and that the best combination to predict parotid shrinkage is fractal dimension and volume variation during the first two weeks of treatment.

Conclusions: Texture analysis was able to characterize structural modifications on parotid glands during the course of RT, using CT images acquired during the treatment. In particular, significant changes are well visible in the first two weeks of the treatment and proven to be able to early predict final shrinkage. The significant decrease in μ, S₁ and FD could be related to the loss of acinar cells after irradiation and a consequent decrease in tissue complexity. Textural features, like FD and μ, could be used in addition to V as early descriptors of parotid shrinkage. The results obtained have demonstrated that multi-parametric performed better than mono-parametric analysis and that the best combination to predict parotid shrinkage is fractal dimension and volume variation during the first two weeks of treatment.

OC-0553
Automated assessment of lung tumour response from routine cone beam CT early during a course of fractionated RT
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Purpose/Objective: Cone Beam CT (CBCT) is widely used for patient position verification but also contains tumour volume information that may allow treatment plan revision based on an on-line assessment of individual tumour response. One challenge in such an approach is the time needed to delineate the tumour volume on all CBCT scans. In this study, we present an automated method for measuring the tumour volume and the accuracy by which the tumour regression at the end of the treatment course can be predicted after one-third and two-thirds of the treatment course.

Materials and Methods: The study comprises 1579 CBCT scans acquired at regular intervals during fractionated radiotherapy for non small cell lung cancer in 102 patients treated to 60 or 66 Gy in 2 Gy fractions. Deformable registrations of CBCTs to the planning CT scans were performed automatically by use of the open source software Elastix. The average Jacobian determinant of the deformation field within the GTV was used as a measure of the tumour volume in the CBCT relative to the planning CT. Precision of the method was evaluated as the deviation between the measured tumour volume and the volumes of the adjacent CBCTs. In order to reduce inter-fraction variations, exponential fits were made to the measured volumes. The fits were performed based on data of the initial one, two, and three thirds of the treatment course. The accuracy of the predicted volume at end of treatment from the first two fits was compared to the volume based on all the CBCT scans. Validation of the automated method against manual tumour volume delineation was performed on the last CBCT scan for nine patients representing various types of tumour regression.

Results: The predicted versus actual volume at end of treatment is shown in the scatter plot. It is seen that the relative volume has a smooth distribution over the range 0.4 up to 1.1. Inter-fraction reproducibility of the measured volume relative to the adjacent CBCTs had a standard deviation of 0.039. The standard deviation of the error differences between the final volume and predictions one- or two-thirds into the treatment course were 0.13 and 0.055, respectively. Automated and manual volume measurements showed strong
Conclusions: Routine CBCT images of lung cancer patients allow an automated estimation of tumour volume with a precision of 3.9%. The volumes estimated by our method correlate strongly with manually delineated volumes. One-third and two-thirds into a course of fractionated RT, tumour volume regression at the end of therapy can be estimated with a precision of 13% and 5.5%, respectively. If a correlation between regression at the end of therapy and long-term clinical outcome is established this method would be an efficient tool allowing for response adaptive radiation therapy.

Purpose/Objective: To validate two semi-automatic fluorodeoxyglucose (FDG) positron emission tomography (PET) segmentation methods for GTV delineation in laryngeal and hypopharyngeal cancer, in comparison with histopathology and manual FDG-PET delineations.

Materials and Methods: Before total laryngectomy, 22 patients (mean age, 62.3; range, 52-79 years) with T3 (n=3) or T4 (n=19) squamous cell carcinoma of the larynx (N=12) or hypopharynx (N=10) underwent preoperative imaging. Thirteen patients underwent an FDG-PET and a high-resolution computed tomography (CT) scan. The remaining 9 patients underwent an FDG-PET/CT scan. The GTV was manually delineated on the PET scans by a radiation oncologist. The larynx specimen was fixed with formaldehyde and sliced transversely in 3-mm thick slices. Whole-mount hematoxylin-eosin stained (H&E) sections were obtained and registered to the thick-slice photos. A pathologist delineated the tumor tissue in the H&E sections. The specimen was reconstructed in 3D, and rigidly registered to the preoperative CT and PET scans. The GTV was semi-automatically segmented on the PET scans using a gradient-based watershed method and a gaussian based method. To account for partial volume effects, the segmented masks were resampled to a 1x1x1 mm³ grid before being converted into a delineation. Different margins around the PET based GTVs delineations were automatically drawn, and the coverage of tumor tissue on pathology was determined.

Results: The average GTV volume determined with the watershed (16.0 ml) and gaussian (16.8 ml) segmentation methods resembled the average tumor volume on pathology (15.5 ml). The average manually segmented GTV volume was 40% larger (21.8 ml) (figure). The tumor coverage was best for the manual delineations (81%), followed by the gaussian (74%) and watershed (70%) delineations. To cover 95% of tumor in pathology in all patients, a margin of 7, 9 and 7 mm was required around the manual, watershed and gaussian delineations, respectively (table). These margins led to a total delineated volume of 70.7, 82.0 and 62.2 ml, respectively. The mismatches between the PET and the tumor localization as derived from histopathology might be partly explained by registration errors and deformations of the specimen. Dealing with partial volume effects is crucial to obtain the delineation out of a segmented mask.

Conclusions: Both semi-automatic segmentation methods estimated closely the average tumor volume on pathology, and the tumor coverage by both methods was similar. Manual delineations showed a better coverage, but overestimated the average tumor volume by 40%. The gaussian and watershed methods are two easy and robust methods to determine a first estimate of the GTV, on FDG-PET. However, these segmentations must be adapted on the planning CT scan by a radiation oncologist, to correct for partial volume effects and CT-PET registration errors.

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