Conclusions: A stoichiometric calibration is feasible using all three parameterizations. The resulting mean-calibration curves are similar for all three methods. However, when introducing a random variation in the measured CT-numbers, as is manifest daily from scan to scan, the parameterization using 3 fitting parameters demonstrates significantly larger variation in the calculated CT-numbers of the theoretical tissues. The impact of this to the uncertainty in the proton ranges in human tissues will be studied further.

PD-0457
Visibility of gold markers on optical coherence tomography for registration with CT: an esophageal phantom study
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Purpose/Objective: Detailed knowledge of the esophageal tumor boundary is currently lacking. This uncertainty leads to large margins and risk of geographic miss during irradiation. Optical coherence tomography (OCT) is a minimally invasive and high resolution (1-10 µm) imaging technique that obtains cross-sectional images of tissue based on the backscattering of light. OCT has a great potential for esophageal cancer, as cylindrical probes exist that can scan the surface using a single rotating optical fiber. Fiducial markers have been successfully applied in a variety of treatment sites to provide guidance during tumor delineation and setup verification. Recently, we successfully placed markers at the proximal and distal tumor borders in esophageal cancer patients. Integration of the OCT with the CT used for treatment planning is an unsolved problem. Visibility of markers on OCT is crucial for an accurate registration of the OCT with the planning CT. This study aimed to investigate the visibility on OCT of two commercially available gold markers at 3 different depths; enabling registration with CT.

Materials and Methods: OCT is similar to ultrasound, however, it uses near infrared light instead of sound. While OCT has a 10 times higher resolution than ultrasound, it suffers from a limited penetration depth in the range of 2-3 mm. We designed and manufactured a dedicated esophageal phantom, in which 3 different scattering materials represent esophageal wall layers (figure 1.A). Visicoil and Gold Anchor markers were implanted at different depths (0.2 mm, 0.6 mm, and 1.2 mm) and imaged using an endoscopic OCT imaging system (Nvision VLE Imaging System, NinePoint Medical, Inc.). Further, to evaluate whether in current clinical practice the fiducial markers are placed within the OCT visualization range; we retrospectively measured the distance between the implanted gold markers and the inner wall of the esophagus on the planning CT of 7 patients who underwent endoscopy-guided marker implantation. Additionally, we manually coregistered the phantom OCT and CT images with use of the markers.

Results: Figure 1.B shows that both types of gold markers are visible on OCT at all tested depths. Different scattering materials are visible on OCT. CT measurements from 7 patients (9 fiducial markers) yield that on average the markers were implanted at a depth of 1.7 mm (range: 0.7-6.3 mm) in the esophageal wall (table 1). For the 9 fiducial markers included in our retrospective analysis, 89% of the markers were placed at depths ≤2.0 mm and 44% were placed at depths ≤1.2 mm. Manual coregistration based on 2 markers was feasible (figure 1.C.).

Conclusions: We have designed and manufactured a dedicated esophageal phantom, enabling the study of the visibility of two types of gold markers at different depths on OCT. The results indicate that both Visicoil and Gold Anchor markers are visible on OCT at depths ≤1.2 mm. Based on CT measurements, the majority of the markers in current clinical practice are already placed within the OCT visualization range.

PD-0458
Estimation of the robustness of hypoxia PET quantification for multicenter data comparison
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Purpose/Objective: Hypoxia PET imaging may help to identify patients with radioresistant tumors. Previous studies identified the maximum tumor to background ratio (TBRm) in FMISO PET images as a potential prognostic parameter for local control. This study investigates the robustness of using a predefined TBRm threshold value to identify hypoxic tumors in multicenter clinical studies. Specifically, the effects of systematic deviations in the evaluation of TBRm between centers are analyzed. These are crucial due to the low contrast of hypoxia PET images.

Materials and Methods: FMISO PET images were acquired four hours post injection for 20 patients with advanced head and neck carcinomas in a phase II FMISO dose escalation study. Median follow-up after definitive chemo-radiotherapy was 21 months (9-52 months). In a previous study based on this dataset the optimum threshold value for prognosis of local control was TBRm=1.9. Local control was significantly different between the two groups (p=0.005). The effect of systematic deviations in FMISO PET quantification between study centers are estimated by applying offsets of +/-10% and +/-20% to the evaluated TBRm values. Offsets of this magnitude may for example occur from different image reconstruction methods or due to variations in the definition of the background activity. The resulting Kaplan-Meier curves for these scenarios are compared by means of log-rank p-values. The TBRm threshold value for hypoxia is fixed at the previously defined value of 1.9.

Results: An increase of TBRm by 10% and 20% in all patient datasets results in decreased significance levels of p=0.046 and p=0.271, respectively. The initial value for undisturbed TBRm values was p=0.005. This situation may occur in study centers that systematically measure larger TBRm values compared to the conditions under which the reference threshold value was obtained. A decrease of TBRm by -10% and -20% results in a decrease to p=0.037 and p=0.310, respectively. This corresponds to a TBRm that is systematically smaller than under reference imaging conditions.

Conclusions: The results indicate that for low contrast hypoxia PET imaging the stratification of patients into hypoxic/normoxic subgroups is very sensitive with respect to imaging parameters and image evaluation methods, such as the reconstruction method and the definition of background activity. This is particularly important in multicenter studies using, e.g., different PET scanners, imaging procedures and analysis tools. A careful standardization and harmonization between centers seems necessary to avoid severe losses in stratification accuracy.

Poster Discussion: Young Scientists 8: Intrafraction motion management

PD-0459
Time-resolved differential motion of tumor and lymph nodes measured during lung cancer radiotherapy
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Purpose/Objective: The relative motion of tumor and lymph node (LN) targets during treatment is unknown, but challenges the accuracy of lung cancer radiotherapy. The purpose of this study was to investigate the differential time-resolved three-dimensional (3D) internal motion of lung tumors and LNs throughout the treatment course for lung cancer patients. This was done by analyzing the motion of implanted Visicoil markers in the projection images of daily setup CBCT scans and in intra-treatment kV images. Materials and Methods: Four patients with Visicoil markers implanted by EBUS bronchoscope in tumor and LN targets received radiotherapy for lung cancer delivered by IMRT in 30-33 fractions. Before each fraction, a setup CBCT scan with ~675 projections was acquired during a full gantry rotation. The Visicoil positions were segmented offline in each projection image using a semi-automatic template-based algorithm. From the segmented Visicoil positions the 3D Visicoil trajectories were estimated by a probability-based method. The 3D Visicoil motion during the entire treatment delivery was determined similarly at every third fraction from 5 Hz fluoroscopic kV images acquired perpendicular to the treatment beam. The CBCT scans were used for daily online soft tissue match on the primary tumor.

One of the four patients was selected for presentation in this abstract. This patient had four Visicoil markers implanted; one in the primary tumor (right hilum) and three in the mediastinal LN targets (LN stations 4R, 7 and 11R). Results: The motion of all four Visicoils during the setup CBCT scan is shown in Figure 1 for the first 24 fractions (only cranial-caudal (CC) motion presented). The LN motion is shown relative to the mean position of the tumor in each fraction, i.e. the shifts from fraction to fraction represent interfraction shifts relative to the tumor. The table presents the span of these interfraction shifts of the LNs relative to the tumor position (part a), and the interfraction motion amplitudes in the left-right (LR), CC, and anterior-posterior (AP) directions for all four targets (part b). The tumor had substantially larger CC motion than the LNs. Frequency analysis showed that the tumor only had respiratory induced motion, with no cardiac component, whereas the LNs had a considerable cardiac induced motion. In particular, the LN 4R mainly moved in the AP and LR directions due to dominant cardiac motion (Table 1b). Shifts exceeding 5mm were observed for some fractions for the mean LN position relative to the mean tumor position along both LR, CC, and AP direction (see Figure 1).