somewhat lower and much lower for systematic motion applied alone. In addition, anisotropic random motion provided stronger associations than the static DVH at high doses (70 Gy).
Conclusion: A simple model for rectal motion has been presented and the corresponding motion-inclusive DVHs have been investigated in relation to rectal morbidity. The motion-inclusive DVHs provided a stronger association with rectal morbidity as compared to the static DVH alone.

2039 POSTER

Clinical Validation in Phantoms and Patients of a 4D-CT Based Method for Lung Ventilation Measurement

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Background: Lung cancer patients referred to radiotherapy (RT) often present with regional lung function deficits, and it is therefore of interest to image their lung function prior to treatment. In this study a method was developed that uses a deformable image registration (DIR) between the peak-inhale and peak-exhale phases of a thoracic four-dimensional CT (4D-CT) scan to extract ventilation information. The method calculates the displacement vector fields (DVFs) resulting from the DIR using the so-called Jacobian map approach and applies this to extract information regarding regional lung volume change.
Materials and Methods: The DVFs resulting from DIRs were analysed to compute the Jacobian determinant of vectors in the field, thus obtaining a map of the vector gradients of the entire registered CT image, i.e. voxel-wise local volume change. Geometric and quantitative validation was achieved using images of both phantoms and patients. In the phantom studies, translations and deformations of known size and direction were introduced to validate both the DIR algorithm and the method as a whole. Furthermore, five patients referred to receive stereotactic body RT (SBRT) underwent two 4D-CT scans while immobilised in a stereotactic body frame (SBF): One scan was acquired with respiration restricted by an abdominal compression plate and the other scan under free breathing.
Results: In the phantom studies deformation errors were found to be of the order of the expected precision of 3 mm, corresponding to the image slice distance, in lateral and vertical directions. For the longitudinal direction a more pronounced discrepancy was observed, with the algorithm predicting displacement lengths of less than half of the physically introduced deformation. Qualitatively the method performed as expected. In the patient study an inverse consistency test showed deviations of up to 6 mm, i.e. almost twice the image slice separation. Jacobian maps of the patient images indicated well-ventilated areas as anatomically expected.
Conclusion: The established method provides a means of using a (commercially available) DIR algorithm to obtain a quantitative measure of local lung volume change. With further phantom and patient validation studies, quantitative maps of specific ventilation should be possible to produce and use in a clinical setting.

2040 POSTER

Adequacy Evaluation of GyE Using the Incidence of Late Skin Damage After Proton or Carbon Ion Radiotherapy for Patients Received With Total Prescribed Doses of 52.8 GyE/4fr or 64 GyE/8fr

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Purpose: Particle radiotherapy using proton and carbon-ion beams can theoretically produce a superior dose distribution to the target using the sharp distal falloff of the Bragg peaks. In addition, proton and carbon-ion beams have moderate (RBE = 1.1 in proton) or high relative biological effectiveness (RBE = 2−3.7 in carbon-ion beams depending on the depth in the spread-out Bragg peak), so a therapeutic advantage can be expected. But, in clinical situation, prescribed dose is identified as gray equivalent (GyE), which is the physical dose multiplied by the RBE of carbon ions or protons. And the RBE was determined by in vivo study using regenerating jejunal crypts of mice and in vitro study using colony formation assay of human salivary gland cancer cells. We irradiate patients by prescribed doses expressed in GyE that are directly related to photon doses under the assumption that all tissues are judged to have approximately the same RBE for carbon ions or protons.
Hyogo Ion Beam Medical Center (HIBMC) is the only medical institution where both proton (PRT) and carbon-ion radiotherapy (CiRT) are available. Skin is one of organ at risk in the treatment of particle radiotherapy. The purpose of this study is to investigate the incidence of late skin damages after PRT and CiRT limiting the same protocols of 52.8 GyE/4fr or 64 GyE/8fr and to evaluate the adequacy of GyE to the skin.
Methods: From June 2005 to July 2008, 179 skin regions of 158 patients received PRT in 50 or CiRT in 129. These patients, 118 males and 61 female, aged 36−91 (median 71) with various tumours including liver cancer in 84 (47%), lung cancer in 70 (39%), bone & soft tissue sarcoma in 17 (10%), others in 8 (4%), were followed after the therapy at least for more than a year.
One hundred thirty-four regions received a total prescribed dose of 52.8 GyE/4fr (PRT in 27 or CiRT in 107), and 45 received 64 GyE/8fr (PRT in 23 or CiRT in 22). Maximum skin doses were ranging from 5.3 to 64.0 GyE (31.7 GyE), and percent maximum skin doses to prescribed doses (%MAX_SKD) were 10–105% (60%). In spite of the retrospective study, there was no difference between PRT and CiRT regarding age, sex, PS, PTV, %MAX_SKD, fraction doses to the skin, biologically effective dose at an α/β ratio of 3 GyE at skin (BED3(skin)), and skin region except for the number of ports. Late skin damage was assessed by RTOG late morbidity scoring system. The median duration of follow-up was 25 months (range, 12−51 months).
Results: The incidence of late skin damage of grade 3 was in 8 regions (4.5%) and of grade 4 in 7 (3.9%) in all cases. In 52.8 GyE/4fr group, there was no difference ($p = 0.3073$) of the incidence of severe grade 3−4 late skin damage between PRT in 3 regions (11.1%) and CiRT in 6 (5.6%). In patients with 64 GyE/8fr, there was also no difference ($p = 0.9534$) between PRT in 3 regions (13.0%) and CiRT in 3 (13.6%).
Conclusion: These analyses showed no significant difference in the late skin reactions between PRT and CiRT in the same treatment protocols of 52.8 GyE/4fr or 64 GyE/8fr and concluded that it is adequate to use the GyE to the human skin for either PRT or CiRT.

2041 POSTER

The Impact of Metabolic Tumour Volume Parameters in Predicting the Treatment Outcomes of the Patients With Locally Advanced Pharyngo-laryngeal Cancer

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Background: To evaluate the impact of metabolic tumour volume parameters in tumour control of locally advanced pharyngo-laryngeal cancer (PLC) received radiotherapy and chemotherapy.
Material and Methods: Between June 2006 and December 2007, 60 newly-diagnosed non-metastatic PLC patients, who completed definitive intensity modulation radiotherapy, chemotherapy, and pre-treatment PET-CT scans. Metabolically active tumour regions were delineated based on pre-treatment PET-CT scans and CT simulation images. The optimal cutoff values of SUV_{max} and total lesion glycolysis (TLG) were determined by receiver operating characteristic (ROC) analysis.
Results: There were 97% males with median age of 39 years old and 65% of the patients were in Stage IV (Stage IVa:45% and IVb: 20%). The 2-year overall survival (OS) rate was 62.7% in stage III, 27.6% in stage IVa, and 25% in stage IVb ($p = 0.033$). The 2-year disease free survival (DFS): stage III 87.7%, stage IVa 33.9%, and IVb 33.3% ($p = 0.004$). The optimal cutoff values were 126 for the TLG of primary tumour (TLG-T), 19 for TLG of largest lymph node (TLG-N), 13.6 for SUV_{max} of primary tumour (SUV_{max}-T), and 7.1 for SUV_{max} of the largest lymph node (SUV_{max}-N). Patients with lower TLG-T and TLG-N were with significantly better 2-year DFS rate (69.5% vs. 31.5%, $p = 0.000$; 62.1% vs. 33.3%, $p = 0.004$, respectively), but there were no significant difference in OS ($p = 0.067$; $p = 0.463$). SUV_{max}-T did not influence the OS ($p = 0.463$) or DFS ($p = 0.062$). Primary tumour size was also analyzed for the DFS ($p = 0.001$) and OS ($p = 0.08$). On multivariate analysis, the independent predictive factors for DFS were the TLG-T ($p = 0.004$), SUV_{max}-N ($p = 0.016$), and stage ($p = 0.058$).
Conclusions: TLG-T and SUV_{max}-N were the significant predictors of disease free survival. Before entering definitive CCRT, the stage IVa and IVb group with lower TLG-T could be identified as a good candidate for the larynx preservation. Comparing to stage and SUV_{max}, TLG serves as a better reference in predicting the treatment response.