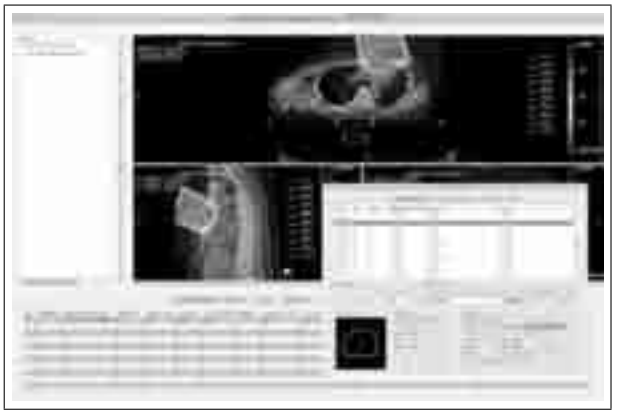
clinical electron beams in order to accurately calculate electron beam dose distributions in homogeneous and heterogeneous media. In addition to this, electron output factors can be quickly calculated, eliminating the need of an output measurement.
Materials: Twenty breast cancer patients who received adjuvant whole breast RT followed by an electron boost to the tumor bed were selected for this study. Patient treatment plans from Eclipse TPS were imported into MMCTP for a MC calculation of electron output factors, PDDs and 3D-dose distributions. MMCTP facilitates complex electron beam treatment planning using BEAMnrc and DOSXZYnrc MC codes for the calculation of output factors from various electron beam energies and applicator sizes. Measured PDDs and dose profiles at various depths of clinical interest and for multiple cutout sizes were used to commission the MC electron beam model. Electron beam commissioning also included 2D-measurements performed with EBT-2 GAFCHROMIC™ film in homogeneous and heterogeneous cases.
Results: Electron output factors for those fields were compared against measurements and were accurate to within 3.0%. A dose difference of 3% and distance-to-agreement of 3 mm were used to compared two dimensional dose maps using the gamma method, and results are very promising. The average electron MC calculation time was 2 hours.
Conclusions: Our accurate electron beam model incorporated into our MC-TPS is a valuable treatment planning tool for electron beams. Clinical electron treatment plans can be quickly recalculated within MMCTP for patient specific quality assurance (QA) verification. A clinical implantation will also provide the clinic with an automated alternative to the electron cutout output measurements.

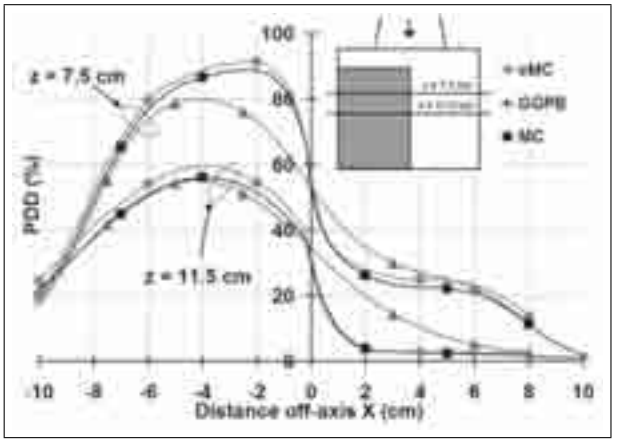


439 poster

MC-BASED VERIFICATION OF ABSORBED DOSE DISTRIBUTIONS IN THE LUNG CALCULATED BY TWO ELECTRON BEAM ALGORITHMS

J. Ojala[1 2], S. Hyödynmaa[1 2]
[1] TAMPERE UNIVERSITY HOSPITAL, Department of Oncology (Radiation Therapy), Tampere, Finland
[2] TAMPERE UNIVERSITY OF TECHNOLOGY (TUT), Department of Biomedical Engineering, Tampere, Finland

Purpose: In this work the purpose was to verify electron dose distributions calculated in both simple homogeneous water phantom and more complex phantoms with lung inhomogeneities by two electron beam dose calculation algorithms in Eclipse™8.6 TPS by Varian Medical Systems (Palo Alto, California, USA). The resulting dose distributions of the algorithms, Generalized Gaussian pencil beam (GGPB) algorithm and electron Monte Carlo (eMC) algorithm, were compared to MC calculations and measurements.
Materials: General purpose MC codes BEAMnrc/DOSXYZnrc were used to calculate dose distributions in similar phantoms as with GGPB and eMC, for which treatment plans were prepared using Eclipse™, simulating radiotherapy of volumes representing water phantom, water phantom with lung slab and a water phantom with half lung slab representing a simplified version of an anterior chest wall irradiation (See Fig.). The MC model was based on Varian Clinac 2100C/D linear accelerator and it was optimized for 16 MeV electron beam to produce dose distributions of high accuracy compared to measurements. MC dose distributions and measurement data were then used for verification of the algorithms.
Results: In homogeneous phantom eMC and GGPB show very good agreement with MC and PTW 34001 IC measurements, which were verified with a combination of Gafchromic EBT radiochromic film, Scanditronix DEB050 stereotactic diode and PTW 60003 diamond detector measurements. E.g., gamma values, using acceptance criteria of 1 % / 1 mm, for each PDD calculation at CAX compared to measurement were 0.26, 1.27 and 1.63 for MC, eMC and GGPB, respectively. In heterogeneous phantoms differences are more pronounced. Especially in phantom with half lung slab (See Fig. profiles at two depths) GGPB shows significant dose underestimation (max. ~20 %) in lung and overestimation in water adjacent to lung (max. ~20 %), whereas eMC results in much better agreement with MC dose distributions, showing an overestimation of 5 % at maximum.



Conclusions: We conclude that eMC introduces definite improvements into clinical electron beam dose calculation, especially in aforementioned geometries, when compared to GGPB. On the other hand, MC methods prove their usability as an accurate dose determination method for QA purposes. Anyhow, one has to bear in mind that since the dose differences in target volumes and/or OARs between the two algorithms may be relatively large, special attention has to be drawn, when using eMC after commissioning and assessing if a plan meets given dose prescription and/or DVH constraints. Criteria used with GGPB may have to be revised/modified to account for the increased dose calculation accuracy of eMC. E.g., with GGPB, in a chest wall irradiation with one anterior field the dose in lung would be underestimated, the dose in lung/mediastinum boundary and in coronaries would be correctly calculated and the dose in myocardium would be overestimated.

Young scientists ESTRO Poster Session: Functional imaging

440 poster

A GRADIENT-BASED SEGMENTATION METHOD FOR FDG-PET BASED GTV DELINEATION: CLINICAL VALIDATION IN NSCLC

M. Wanet[1], J. A. Lee[1], B. Weynand[2], M. De Bast[1], A. Poncelet[3], V. Lacroix[3], E. Coche[4], V. Grégoire[1], X. Geets[5]
[1] UCL CLINIQUES UNIV. ST.LUC, Center for Molecular Imaging and Experimental Radiotherapy , Brussels, Belgium
[2] UCL CLINIQUES UNIV. ST.LUC, Department of Pathology, Brussels, Belgium
[3] UCL CLINIQUES UNIV. ST.LUC, Department of Thoracic Surgery, Brussels, Belgium
[4] UCL CLINIQUES UNIV. ST.LUC, Department of Radiology, Brussels, Belgium
[5] UCL CLINIQUES UNIV. ST.LUC, Department of Radiation Oncology, Brussels, Belgium

Purpose: The integration of PET in the treatment planning is promising but remains technically complex especially for the accurate definition of the tumor boundaries in regard of many available tools. We developed an innovative PET segmentation method that exploits the image gradient information and was previously validated on phantoms and head and neck patients with pathological specimens. In this context, we aimed to validate this gradient-based segmentation method for GTV delineation on FDG-PET in NSCLC patients through surgical specimen, in comparison with threshold-based approaches and CT.
Materials: Briefly, the concept of the gradient-based method relies on the association of the boundaries of an object of interest with the gradient-intensity crests observed in the image. The acquired images are denoised and deblurred and these preprocessing steps sharpen the image gradient, making it easier to detect peaks of gradient magnitude with algorithms, such as the watershed transform. In this study, the validation of the method in NSCLC patients was performed using the surgical specimen as "ground truth" reconstructed in 3D. We compared the macroscopic primary tumor volume with GTVs obtained using contrast-enhanced CT and gated FDG-PET. For the delineation of the different GTVs, we used the gradient based method as well as the conventional threshold-based segmentation approaches (i.e. the source to background ratio method and fixed threshold values at 40% and 50%) on PET images reconstructed with voxel sizes of 2 and 4 mm and two window settings (i.e. lung and mediastinal windows) on CT images.

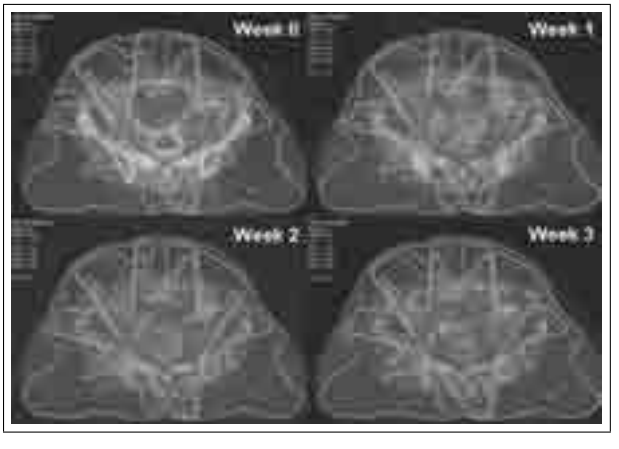
Results: FDG-PET provided volumes close to the surgical specimen while both lung and mediastinal windowed CT led to a large overestimation of the macroscopy especially for cases of poor defined tumor (atelectasia or lung fibrosis). In contrast, the mediastinal windowed CT accurately assessed the macroscopic specimen when tumors were well defined. Among various PET segmentation methods, estimation of the true tumor volume was the best through gradient-based technique. Furthermore, PET images with a low resolution (i.e. 4 mm voxels) resulted in larger GTVs on average, independently of the segmentation method used.
Conclusions: FDG-PET improved the GTV definition in NSCLC compared to CT particularly when the primary tumor was surrounded by modifications of the lung parenchyma. In this context, the gradient-based method outperformed the threshold-based ones in terms of accuracy and robustness as previously observed on phantoms and head and neck patients. Therefore, we believe that the gradient-based method should be used as the reference segmentation in the field of PET-driven delineation of head and neck and lung tumors.

441 poster

FLT PET IMAGING FOR WEEKLY EVALUATION OF BONE MARROW RESPONSE TO CHEMORADIATION THERAPY IN CERVICAL CANCER PATIENTS

S. McGuire[1], G. Jacobson[1], Y. Menda[2], L. Ponto[2], B. Gross[1], J. Bayouth[1]
[1] UNIVERSITY OF IOWA HOSPITALS AND CLINICS, Radiation Oncology, Iowa City, USA
[2] UNIVERSITY OF IOWA HOSPITALS AND CLINICS, Radiology, Iowa City, USA

Purpose: The purpose of this study was to evaluate the dose response of bone marrow (BM) using FLT PET imaging at multiple time points during chemoradiation therapy.
Materials: Two cervical cancer patients were enrolled in an IRB approved protocol to obtain FLT PET images prior to and during chemoradiation therapy. The pre-therapy image was used as a control for bone marrow FLT uptake change and to create a bone marrow sparing IMRT plan. Initially, an IMRT plan was created to meet target and normal tissue standards specified in RTOG 0418. Then, bone marrow volumes identified using FLT PET SUVs were added to the optimization to spare bone marrow without significantly changing normal tissue or target DVHs. Each subject was imaged 1 week (after 5 fractions), 2 weeks (after 10 fractions), and 3 weeks (after 15 fractions) post therapy of 1.8 Gy/fraction to the PTV and 1 cycle of 70 mg cisplatin chemotherapy/week. Weekly CBCs were monitored throughout chemoradiation therapy to correlate with change in FLT uptake in bone marrow. The bone marrow dose response was measured by FLT PET mean SUV within 1 Gy/week dose volumes within the boney pelvis, lower vertebrae, and femurs.
Results: Example axial images from the FLT PET week 0, 1, 2, and 3 scans of subject 1 with the total isodose distribution overlay are shown in Figure 1. FLT uptake is visibly diminished after week 1 within the 15 Gy isodose level (3 Gy/week). After week 2, the FLT uptake in the bone marrow is indistinguishable from background. Mean BM SUV decreased 50% in the 4-5 Gy volume and a ~70% maximum decrease occurred at 7 Gy or higher after 1 week of therapy for both subjects. Mean BM SUV also decreased ~50% or more in the 4-6 Gy volume after 2 weeks of chemoradiation therapy, and a ~80% maximum decrease occurred at ~14Gy for both patients. Both the mean SUV decrease of 50% and maximum decrease occurred at higher dose levels after 3 weeks for subject 1. A 50% decrease was not exceeded until the 6-9 Gy volume. However, a 50% decrease for subject 2 was exceeded in the 3-6 Gy volume after 3 weeks. A ~83% maximum decrease occurred at ~24 Gy for both subjects. The systemic effect of bone marrow activity change during therapy was observed in WBC changes for both subjects. Subject 1 WBCs were 5.3, 4.4, 4.0, and 2.4 K/mm3 for weeks 0, 1, 2, and 3 respectively. Subject 2 WBCs were 12.2, 8.8, 7.3, and 4.6 K/mm3 for weeks 0, 1, 2, and 3 respectively.



Conclusions: In two subjects, 5 Gy decreased FLT uptake 50% or more as measured by mean SUV in the bone marrow of the pelvic region. This decrease appeared to be independent of time within the first 2 weeks for one subject and within 3 weeks for the other. It may be that bone marrow radiation dose response is independent of time and fractionation schemes usually implemented for normal tissue sparing. FLT PET was useful in identifying active bone marrow in the pelvis and demonstrating spatial bone marrow toxicity early in chemoradiation therapy.

442 poster

DYNAMIC FDG-PET IMAGING FOR TREATMENT MONITORING IN RADIOTHERAPY OF CANINE HEAD AND NECK TUMORS

A. Soevik[1 2], J. Rødal[2 3], H. Kippenes Skogmo[1], E. Malinen[2]
[1] NORWEGIAN SCHOOL OF VETERINARY SCIENCE, Department of Companion Animal Clinical Sciences, Oslo, Norway
[2] NORWEGIAN RADIUM HOSPITAL, Department of Medical Physics, Montebello, Norway
[3] NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, Department of Physics, Trondheim, Norway

Purpose: To investigate the potential role of dynamic FDG-PET imaging in treatment monitoring and early response assessment in fractionated radiotherapy of canine head and neck tumors.
Materials: Three dogs with spontaneous head and neck tumors received intensity-modulated radiotherapy (IMRT) with 42 47 Gy given in 10 fractions. Dynamic FDG-PET imaging was performed 4 5 days prior to the start of radiotherapy, at mid-treatment (after 16.8 18.8 Gy), and at 3 12 weeks after the completion of treatment. Dynamic contrast-enhanced CT (DCECT) was also performed at the pretherapy session. From the dynamic PET images, the kinetic rate parameters K1 k3, the vascular fraction (VB), and the metabolic rate of glucose (MRglc), were obtained through the application of a three-compartment pharmacokinetic model. Furthermore, time-activity curves (TACs) were evaluated, and the standardized uptake value (SUV) 45 minutes post injection was calculated.
Results: For all three patients, MRglc and SUVdecreased and k2 increased from the pre- to the intertherapy PET session, while response patterns varied between patients for the remaining parameters. However, parametric maps of most of the pharmacokinetic parameters showed increased heterogeneity from the pre- to the intertherapy PET session. There was in general good agreement between the DCECT uptake curves and the initial phase of the PET TACs. Furthermore, the changes observed in the TACs from pre- to intertherapy PET sessions were most pronounced at the end of the uptake curves, indicating that the metabolic changes predominated over the vascular changes in response to treatment. In patients where tumor regrowth was detected on the post-treatment PET examination, both MRglc and SUV were increased on the post-treatment PET scan compared to the inter-treatment values.
Conclusions: Kinetic analysis of dynamic FDG-PET images may prove useful for monitoring the effect of radiotherapy. Furthermore, the changes in FDG uptake kinetics may provide information on changes in tumor biology during and after treatment and may help elucidate how these relate to treatment response.

443 poster

QUANTITATIVE DCE-CT IMAGING QUALITY ASSURANCE WITH A NOVEL DYNAMIC FLOW PHANTOM

B. Driscoll[1], H. Keller[1 2], C. Coolens[1 2]
[1] PRINCESS MARGARET HOSPITAL, Department of Radiation Physics, Toronto, Canada
[2] UNIVERSITY OF TORONTO, Department of Radiation Oncology, Toronto, Canada

Purpose: To produce typical clinical time-attenuation curves (TACs) using a novel dynamic flow imaging phantom with the goal of developing a Quality Assurance protocol for DCE-CT measurement sensitivity analysis allowing the quantification and validation of DCE-CT measurements under realistic flow conditions.
Materials: The phantom is based on a simple two-compartment model and is made up of an external cylinder with an internal section containing openings to exchange mass between the compartments. The phantom was printed using a 3D printer and is made of the water-neutral polymer PC-ABS. Initial characterization of the phantom involved simple flow measurements and progressed to DCE-CT experiments in order to test the phantoms range and reproducibility. The phantom was then utilized to generate realistic input TACs in which the arterial input function has both an original bolus and secondary recirculation peak. A predictive compartmental model was generated which can accurately predict the TACs generated by the phantom given a set of control parameters (flow rate, contrast injection pulse and output flow valve positions). A DCE-CT quality assurance protocol was developed and performed using the phantom to investigate image noise, partial volume effects and CT number accuracy under realistic flow conditions. Scans were performed us-