Abstracts for Oral and Poster Presentation

1 Predictors of Residual FDG-PET/CT Activity in Non-small Cell Lung Cancer Lesions following Chemoradiotherapy: A Secondary Analysis of ACRIN 6668 / RTOG 0235
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Purpose/Objective(s): FDG-PET/CT is commonly used for assessing response to chemoradiotherapy for locally-advanced non-small cell lung cancer (NSCLC). Here we identify predictors of residual disease using pre-treatment imaging. Materials/Methods: In the ACRIN 6668 / RTOG 0235 study, FDG-PET scans were obtained prior to definitive chemoradiotherapy for locally-advanced NSCLC. Follow-up PET imaging was obtained 12-16 weeks following completion of radiation. On each pre- and post-treatment scan, a semi-automatic gradient-based contouring tool was used to contour every visible hypermetabolic lesion. Lesions were classified as primary tumor or by lymph node station. A maximum SUV criterion of 3.5 was used to identify malignant lesions on both pre- and post-treatment imaging. Incidence of disease in each region before and after therapy was recorded. Stepwise logistic regression was used to assess the following pre-treatment characteristics as predictors of persistent disease in a given region following chemoradiation: maximum SUV, mean SUV, metabolic tumor volume (MTV), total glycolytic activity (TGA), defined as mean SUV multiplied by MTV, and presence of multiple hypermetabolic lesions (binary variable, for nodal stations only). Results: At the time of analysis, pre- and post-treatment imaging was available for 132 patients. Prior to chemoradiation, 94% of patients had identifiable hypermetabolic tumors, and 81% had nodal disease. Patients had a mean of 3.3 hypermetabolic lesions. The incidence of disease in each nodal station ranged from 2% (prevertebral) to 48% (right paratracheal). Following treatment, 38% of primary tumors demonstrated hypermetabolic activity. Residual disease was detected in 15% of involved lymph node regions. 48% of patients exhibited a complete metabolic response. For primary tumors, increasing pre-treatment TGA was the only significant predictor (p=0.0054) of persistent hypermetabolic disease on multivariante analysis. For lymph node stations, both increasing TGA (p=0.0002) and the presence of multiple lesions (p=0.0032) were independent predictors of residual uptake. Dividing primary tumors by pre-treatment TGA into tertiles yielded post-treatment residual uptake rates of 22%, 31%, and 61%. For lymph node stations, these values were 10%, 8%, and 27%. Conclusions: NSCLC primary tumors are more likely to demonstrate persistent hypermetabolic activity following chemoradiation than involved lymph nodes. High pre-treatment TGA is an independent predictor of residual disease in both tumors and lymph node stations. Radiotracer dose escalation to primary tumors and lesions with high TGA values may be warranted. This work is supported by the National Cancer Institute CA080098 grant.

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2 Development and Characterization of 89Zr Panitumumab for ImmunoPET Imaging of the Epidermal Growth Factor Receptor
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Purpose/Objective(s): The epidermal growth factor receptor (EGFR) is overexpressed in many malignancies and has been associated with tumor aggressiveness and treatment resistance. Panitumumab, an anti-EGFR monoclonal antibody, is increasingly used with radiotherapy and chemotherapy. Currently, little is known about tumor specific uptake and overall pharmacokinetics. Non-invasive PET imaging of the EGFR may quantify EGFR expression of lesions including those inaccessible by biopsy and guide therapy selection. The purpose of this study was to develop and characterize a novel targeted imaging agent for the EGFR. Panitumumab was labeled with 89Zr, a positron emitter with a half-life of 2.77 days. The extended half-life of 89Zr is ideal for the imaging of antibodies. Materials/Methods: 89Zr was produced by a (p,n) reaction on 88Y. The chelator, Desferrioxamine-p-SCN (DFO), was conjugated to panitumumab and labeled with 89Zr. The labeled reaction was checked by TLC and HPLC analysis and serum stability studies were performed to evaluate 89Zr-panitumumab stability. Cell binding assays were performed to confirm binding of 89Zr-panitumumab to HCT116 colorectal cancer cells, which overexpress the EGFR. For biodistribution studies and microPET/CT imaging, mouse xenograft models were generated by subcutaneous injection of HCT116 cells into the hindlimbs of nude mice. T47D breast cancer tumors, which minimally express the EGFR, were utilized as a negative control. 20 μCi and 100 μCi of 89Zr-labeled panitumumab was administered via tail vein injection for biodistribution and microPET/CT studies, respectively. Imaging was performed at multiple time points and quantified by identifying regions of interest on selected tissues. Results: Panitumumab was radioabeled with 89Zr at a high radiochemical purity and specific activity (3-4 μCi/μg) and found to be stable in serum. Cell binding studies demonstrated that 89Zr-radioabeled panitumumab bound specifically with high affinity to HCT116 cells and this binding was blocked with excess unlabeled panitumumab. Biodistribution studies demonstrated increased uptake of 89Zr-panitumumab in EGFR-positive tumors in comparison to EGFR-negative tumors. MicroPET/CT confirmed the results from the biodistribution studies with elevated uptake of 89Zr-panitumumab in EGFR-positive tumors and minimal uptake in EGFR-negative tumors. Conclusion: 89Zr-panitumumab targeted the EGFR receptor with high affinity resulting in superior imaging quality of EGFR-positive tumors. This technology may be applied also to other antibodies for studying their in vivo behavior in patients.

3  A Prospective Study of $^{18}$FDG-PET with CT Scan Co-Registration for Radiation Treatment Planning of Lymphoma and Hematologic Malignancies

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**Purpose/Objective(s):** This prospective single institution study examines the impact of positron emission-tomography (PET) using $^{18}$F-fluoro-2-deoxyglucose and CT scan radiation treatment planning (TP) on target volume definition in lymphoma. **Materials/Methods:** 118 patients underwent CT/PET TP from 6/2007-5/2009. Gross tumor volume (GTV) was contoured on CT-only and PET/CT studies by radiation oncology (RO) and nuclear medicine (NM) for 95 patients with positive PET scans. Treatment plans and dose-volume histograms were generated for CT-only and PET/CT sites. Paired t-test statistics and Pearson correlation coefficients were used for analysis. **Results:** 70 (74%) patients had non-Hodgkin’s lymphoma, 10 (11%) had Hodgkin lymphoma, 12 (13%) had plasma-cell neoplasm, and 3 (3%) had other hematologic malignancies. 43 patients (45%) presented with relapsed/refractory disease. Forty-five (47%) received no prior chemotherapy. The RO-defined PET-GTV was smaller than the CT-GTV in 37% of patients by a median of 28%, the NM-defined PET-GTV was smaller than the CT-GTV in 50% by a median of 75%. The intra-observer correlation between CT-GTV and PET-GTV was higher for RO than for NM (0.94, p<0.01 vs. 0.89, p<0.01). Based on Bland-Altman plots, the PET-GTVs defined by RO were larger than those by NM. The absolute median difference in CT-GTV between RO and NM was 13.3 cc (IQ 3.8-41.2, p<0.01) whereas the median difference between RO and NM was 12.5 cc (IQ 5.3-48.5, p<0.01). Similarly, the median absolute percent difference between observers was 20% for CT-GTVs (IQ 7%-50%, p<0.01) and 24% for PET-GTVs (IQ 11%-73%, p<0.01). The clinical treatment plan for each patient was evaluated and only four (4%) patients had inadequate target coverage (D95<95%) of the PET-GTV defined by NM. **Conclusions:** Significant differences between RO and NM volumes were identified when PET was co-registered to CT for radiation planning. Despite these differences, the PET-GTV defined by RO and NM received acceptable prescription dose in nearly all patients. However, given the potential for a marginal miss, consultation with an experienced PET reader is highly encouraged when delineating PET/CT volumes particularly for questionable lesions and to assure complete and accurate target volume coverage.


4  The Importance of Recognizing Head and Neck Cancer Progression on Radiotherapy (RT) Images

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**Purpose/Objective(s):** With the increasing use of CT based treatment planning and cone-beam CT (CBCT) imaging for patient set up verification, 3D images at unique time points have been incorporated into the RT process for reasons other than tumor monitoring. We sought to determine how often tumor progression was identified on these images, and to assess the patient impact.

**Materials/Methods:** From 1997 to the end of 2009, 667 patients were treated with definitive or postoperative IMRT for previously untreated H&N cancer. The median age was 57, 80% were men, and 87% had stage III or IV disease. Tumor sites included the oral cavity, oropharynx, hypopharynx, larynx, and unknown primary. Overall, 125 patients (18%) developed a locoregional failure (LRF). In these patients, diagnostic scans showing recurrent disease were fused with the original CT simulation scan (CT-Sim). In some patients, progressive disease on the CT-Sim was not recognized initially, but in retrospect was clearly apparent based on the fusion images. Patients in whom the radiation oncologist (RO) prospectively recognized disease progression between diagnostic scans and the CT-Sim received a simultaneous integrated boost (~70 Gy equivalent) to the region of interest. Image guided radiation therapy (IGRT) with CBCT for patient set up verification became available towards the end of the study period. The subset of patients treated with this technology who experienced a LRF had the CBCT images from the first day of treatment fused with the CT-Sim received a simultaneous integrated boost (~70 Gy equivalent) to the region of interest. The overall survival (OS) was 83% (10 of 12) for patients in whom disease progression was recognized on CT-Sim, Vs 8% (1 of 12) for patients in whom progression was not recognized on CT-Sim or CBCT. Progressive disease most commonly represented a new, enlarged, or necrotic lymph node in level Ib-II on that side of the neck treated with the lower elective dose. **Conclusions:** Careful scrutiny of CT-Sim images by the RO may lead to improved survival for a subset of patients. Review of CBCT images for tumor progression may also benefit a subset of patients, particularly as the use of this technology increases. Review of these radiation therapy images by a diagnostic radiologist may increase the chance of detecting disease progression.

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5  Therapy-induced Changes In Normal-appearing Brainstem Measured With Longitudinal Diffusion Tensor Imaging

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**Purpose:** The brainstem is a critical dose-limiting organ when in proximity to the targeted volume for patients with brain and head and neck tumors receiving high dose irradiation. The long-term evolution of radiation injury and subsequent recovery has rarely been quantified but is important for the determination of brainstem tolerance. We aim to characterize therapy-induced changes in normal-appearing brainstems of pediatric brain tumor patients with serial diffusion tensor imaging (DTI). **Materials/Methods:** We retrospectively analyzed a total of 109 DTI studies from 20 pediatric brain tumor patients with initially normal-appearing brainstem who received radiation therapy between 2004 and 2008 at the age of 4-23yrs (median, 7yrs). Those with medulloblastomas (n=10) received postoperative craniospinal irradiation (23.4-39.6 Gy) and a cumulative dose of 55.8Gy to the primary site followed by 4 cycles of high-dose chemotherapy. Patients with high-grade gliomas (n=10) received cumulative dose of 55.8Gy to the primary site followed by 4 cycles of high-dose chemotherapy.
erlotinib during and after irradiation (54-59.4 Gy). Radiation was delivered at 1.8 Gy/fraction. Parametric maps of fractional anisotropy (FA) and apparent diffusion coefficient (ADC), two major DTI-derived measures of directionality and diffusivity of water diffusion within white matter tracts, were computed and spatially registered to radiation dose maps. Serving as an age-related benchmark for comparison, 37 DTI studies from healthy children, aged 6-25 years, were included in the analysis. **Results:** The mean follow-up was 3.5 years (range, 1.6-5.0). Each patient underwent a median of 5 DTI studies (range, 4-9). The median mean dose to the pons was 56 Gy (range, 7-58 Gy). Logarithmic models fitting data from healthy children indicated an increasing trend in FA and a decreasing trend in ADC with age in bilateral corticospinal tracts, bilateral medial lemnisci, and throughout the pons. Five patients showed stable or normal time trends post therapy. For the remaining 15 patients, the FA of the pons progressively declined to 65-85% of baseline values within 3 years of therapy. The time trend either subsequently stabilized or rebounded between 1.5 and 3.5 years and recovered to baseline values within 4 years. Radiation dose alone did not separate patients with and without recovery patterns. Though generally opposite to FA patterns, ADC patterns were less distinctive. **Conclusion:** We have demonstrated the feasibility of performing serial DTI for quantifying longitudinal evolution of radiation-induced changes in the pediatric brainstem. Variation in temporal DTI patterns post-therapy exists among individual patients. Although not all brainstems recovered completely from 56 Gy irradiation evaluated with DTI, for those that did, the recovery occurred within 4 years of therapy.

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6  **Comparison of 18F-FDG PET-CT versus 3T Diffusion Weighted (DWIBS) Whole-Body Magnetic Resonance Imaging in Colon Cancer Staging**  
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**Purpose:** To assess the accuracy of 3T whole-body MRI (WB-MRI) in comparison with whole-body [18F]-2-Fluoro-2-deoxy-D-glucose (FDG) PET/CT for staging newly diagnosed colon cancer. **Materials/Methods:** 40 consecutive patients with previously diagnosed colon cancer underwent 3T WBMRI (Phillips Achieva, Best, The Netherlands) and Whole-Body [18F]-2-Fluoro-2-deoxy-D-glucose (FDG) PET/CT (GE Discovery ST 16) for staging of lymph node (N) and distant metastases (M) after resection of the primary tumor. WB-MRI was performed with multi-stacks approach, in the coronal plane using morphological (T1W, T2W-STIR), Diffusion-Weighted Imaging With Background Suppression (DWIBS) and contrast-enhanced T1w 3D sequences. Evaluation was done according to the American Joint Committee on Cancer Staging classification. MR images were evaluated by two radiologists while the PET/CT images by one radiologist and one nuclear physician. Histology and a mean clinical-radiological follow-up of 6-9 months served as the standards of reference. **Results:** The mean follow-up time was 22 months. Regional lymph node involvement was correctly determined in 30/40 cases as N-positive for WB-MRI (75%, p<0.05) and in 36/40 (90% p<0.05) for PET/CT while overall M stage was diagnosed correctly in 34/40 (85%) patients for WB-MRI in comparison with 36/40 (90%) for PET/CT (p<0.05). N-stage was overstaged with WB-MRI in 4 patients (10%) and with PET/CT in 1 patient and understaged in 6 patients with WBMRI and in 2 patients with PET-CT. Distant metastases were overstaged with PET/CT in 2 and understaged in 3 patients while with WB-MRI in 1 and 4 patients respectively. **Conclusions:** WB-MRI is a fast and feasible method for staging colon cancer patients but up-to-date does not reach the accuracy of 18F-FDG-PET/CT.

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7  **Evaluation of Hepatic Tumor Response to SIRT Therapy Using Texture Feature Signatures from Contrast-Enhanced CT Images**  
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**Purpose/Objective(s):** Selective Internal Radiation Therapy (SIRT) with yttrium-90 microspheres, a locoregional procedure used for both primary and metastatic hepatic tumors, is generally reserved for patients whose advanced-stage tumors are not surgically resectable or those who have failed to respond to standard chemotherapy. While the treatment is highly effective in some cases, not all patients respond equally well. It is not currently clear why some patients respond to SIRT while others fail. Given the high treatment cost and desire for improved quality of life in these advanced cancer cases, there is a growing need to develop robust tools to predict SIRT response. Previous work evaluated potentially influential clinical features such as tumor size, grade, and CEA level and found that these factors alone do not predict whether a patient will successfully respond to SIRT. Recent studies suggest that liver texture and necrosis patterns on CT images may correlate with survival and treatment response in liver cancer patients. **Materials/Methods:** This study examines a series of 3D image texture features, computed from pre-treatment standard-of-care CT volumes, which may serve as potential indicators of SIRT response. Our dataset includes 30 advanced-stage primary and metastatic liver cancer cases that have undergone SIRT and have adequate post-treatment follow-up of changes in relevant tumor markers. Overall survival and percent change in serologic tumor marker after therapy are the primary outcomes in this study. Two types of texture signatures (texton histograms and local binary patterns (LBP)) are computed from tumor regions on pre-treatment triphasic liver CT volumes and evaluated for their ability to classify serologic response and survival. **Results:** Preliminary results indicate lesion texton signatures achieve high accuracy (93%) in binary classification of serologic response (distinguishing tumor marker increase vs. decrease / no change), using linear soft-margin support vector machines with leave-one-out cross-validation. Texton signatures also perform well on survival classification (83% accuracy) in distinguishing survival beyond the median (368 days). Texton signatures show improved survival classification performance over LBP signatures (83% texton accuracy vs. 60% LBP accuracy) but similar results for serologic response classification (93% accuracy for both texton and LBP). **Conclusion:** Hepatic lesion texture signatures from pre-treatment triphasic CT studies show high accuracy in differentiating subjects by serologic response and survival in this preliminary cohort. These texture signatures promise as potential imaging biomarkers in evaluating new patient candidates for locoregional therapy such as SIRT.

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8 Utilizing Baseline Clinical Schema and Initial Imaging Response by CT to Predict Progression Free Survival in Patients with Metastatic Renal Cell Carcinoma on VEGF-Targeted Therapy
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Purpose/Objective(s): Because of varying treatment effectiveness with vascular endothelial growth factor (VEGF)-targeted therapy in patients with metastatic renal cell carcinoma (RCC), various prognostic schema and imaging parameters have been investigated for prognostic and predictive potential. The association of clinical prognostic schema, initial post-treatment CT imaging characteristics, and combination thereof in predicting progression free survival (PFS) in patients with metastatic RCC receiving VEGF-targeted therapy was investigated.

Materials/Methods: Baseline data for metastatic RCC patients on sunitinib or sorafenib was retrospectively obtained for risk stratification by Memorial Sloan Kettering Cancer Center (MSKCC) Criteria and criteria by Heng et al. (described here as VEGF Prognostic Factors Criteria). The initial post-therapy CT was evaluated by Response Assessment Criteria in Solid Tumors (RECIST), Choi Criteria, and Morphology, Attenuation, Size and Structure (MASS) Criteria. Kaplan-Meier estimates of PFS for each patient group and overall accuracy of each method and combined criteria were calculated. Results: Eighty-two patients were identified. The MSKCC Criteria, VEGF Prognostic Factors Criteria, RECIST, MASS Criteria, and VEGF Prognostic Factors + MASS Criteria each demonstrated significant differences in PFS among patient groups (p < 0.005 for each, Log-rank test). Stratification of patient groups by Choi Criteria was not statistically significant with respect to PFS (p = 0.101). VEGF Prognostic Factors Criteria + MASS Criteria yielded the highest overall accuracy for identifying PFS > 1 year (77%) with a sensitivity of 83% and specificity of 67%. VEGF Prognostic Factors Criteria + MASS Criteria also had the highest accuracy for identifying PFS < 1 year (76%) with a sensitivity of 37% and specificity of 98%. Conclusion: VEGF Prognostic Factors Criteria in combination with MASS Criteria more effectively predicted PFS in patients with metastatic RCC on VEGF-targeted therapy than any single clinical or imaging criteria. Though external validation is needed, VEGF Prognostic Factors + MASS Criteria may prove to be a useful predictive tool in clinical trials, in planning risk-directed therapy, and in patient counseling.


9 Correlation of Morphologic response (RECIST), Tumor density (HU), Tumor Metabolism (SUV) and Perfusion for Monitoring Treatment Effect of Multidrug (Antiangiogenic+CXT) Therapy in Advanced Lung Cancer
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Purpose: To evaluate and compare between morphologic responses (RECIST), tumor density, metabolic changes on 18FDG PET CT and vascularity change on Perfusion CT (CTp) for response assessment to multidrug therapy (Antiangiogenic+CXT) and correlation to clinical outcome of progression free survival (PFS). Materials/Methods: In this IRB approved clinical trial, 23 patients (10M: 13F, mean age 49 years) with advanced lung cancer receiving multidrug therapy [Bevacizumab (BVZ) +CXT] were enrolled. CTP, whole body FDG PET and diagnostic CECT were performed at baseline, 10-12days of BVZ and then at 6 weeks and 18 weeks of initiating the chemo regimen. Tumor measurements made based on RECIST, HU (CHOI) on CECT, SUV values on FDG-PET and CTP parameters [CTP-3 (GE) (BF, BV, and MTT & PS)]. % change in various tumor parameters from baseline on each subsequent time points were estimated and compared to PFS at 6 months. Results: At 10-12 days after BVZ treatment response there was significant reduction in measurements by perfusion [mean (BF, BV, PS) change - 30-54%, p<0.05], SUV (mean -53.1%, p=0.029) and HU (-20.1%, p>0.05) and minimal change by RECIST (-11.2%, p>0.05). After 18-weeks following the completion of treatment, further reduction in tumor perfusion [mean -50 to 82%, p<0.05], SUV (-44.8%, p<0.01) and HU (-20.1%, p>0.05) and minimal change by RECIST (-11.2%, p>0.05). In patients with PFS > 6 months, the CTP values in BF, BV & PS at following the completion of treatment, further reduction in tumor perfusion [mean -50 to 82%, p<0.05], SUV (-44.8%, p<0.01) and HU (-20.1%, p>0.05) and minimal change by RECIST (-11.2%, p>0.05). After 18-weeks combined criteria were calculated. Results: Eighty-two patients were identified. The MSKCC Criteria, VEGF Prognostic Factors Criteria, RECIST, MASS Criteria, and VEGF Prognostic Factors + MASS Criteria each demonstrated significant differences in PFS among patient groups (p < 0.005 for each, Log-rank test). Stratification of patient groups by Choi Criteria was not statistically significant with respect to PFS (p = 0.101). VEGF Prognostic Factors Criteria + MASS Criteria yielded the highest overall accuracy for identifying PFS > 1 year (77%) with a sensitivity of 83% and specificity of 67%. VEGF Prognostic Factors Criteria + MASS Criteria also had the highest accuracy for identifying PFS < 1 year (76%) with a sensitivity of 37% and specificity of 98%. Conclusion: VEGF Prognostic Factors Criteria in combination with MASS Criteria more effectively predicted PFS in patients with metastatic RCC on VEGF-targeted therapy than any single clinical or imaging criteria. Though external validation is needed, VEGF Prognostic Factors + MASS Criteria may prove to be a useful predictive tool in clinical trials, in planning risk-directed therapy, and in patient counseling.


10 Tumor Volume Change Before, During And After Stereotactic Body Radiotherapy (SBRT) For Early Stage Lung Cancer (ESLC): Evaluating The Potential For Adaptive SBRT
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Purpose/Objective(s): The primary purpose of our study is to quantify GTV change from the time of diagnosis to the end of treatment with SBRT and on first follow-up, as well as to evaluate for any predictive prognostic or risk factors related to GTV decrease. Materials/Methods: Twenty five tumors were treated with SBRT to total dose of 50 Gy in 5 fractions during October 2008 to November 2009. Median age was 72.5 yrs. Tumor stage was T1, 68%; T2, 20%; other, 12%. Tumor pathology was squamous, 24%; adeno, 24%; others, 28%; and unknown, 24%. The GTV’s were contoured on Varian Eclipse™ workstation for the initial diagnostic CT (CTp), the 5 Cone Beam CT’s (CBCT,s) obtained prior to each fraction and the CT done on first follow-up (CTpost). Results: Median time from diagnosis to initiation of RT was 64 days. All tumors...
showed a median 76% increase in GTV from CT<sub>pret</sub> to CBCT<sub>1</sub> (p=0.0012). GTV on CBCT<sub>1</sub> was the baseline and the tumor volume decreased by a mean of 7% on CBCT<sub>2</sub> (p=0.148), 11% on CBCT<sub>3</sub> (p=0.364), 19% on CBCT<sub>4</sub> (p=0.0021) and 32% on CBCT<sub>5</sub> (p=0.0004). Median time from completion of RT to the CT<sub>pret</sub> was 88.5 days. There was a 54% median decrease in GTV (p=0.0021) from CT<sub>pret</sub> to CT<sub>post</sub>. Univariate analyses of GTV shrinkage was significantly associated with ‘Time from CBCT<sub>2</sub> to CT<sub>post</sub>’ (p=0.027) and ‘T-stage’ (p=0.002). In multivariate analyses only ‘T-stage’ remained significant. No significant correlation was found between GTV shrinkage and patient’s age, KPS, COPD, oxygen dependence, pack years of smoking, pathology, peak SUV on pre-treatment PET scan, type of IMRT used or the frequency of treatments, likely due to the relatively small sample size.

**Conclusions:** Our study found a significant shrinkage in GTV between the CBCT<sub>1</sub> compared to the CBCT<sub>4</sub> and CBCT<sub>5</sub>. Adaptive SBRT could be considered after the 3rd or 4th fraction, to minimize integral dose to the surrounding normal tissues without potentially compromising GTV coverage. T2 tumors showed significantly greater GTV shrinkage than T1.


### 11 The Use of an Injectable Tissue Spacer in Conjunction With Adaptive Radiotherapy for Prostate Cancer

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**Purpose/Objective(s):** To demonstrate the efficacy of using an injectable tissue spacer, MRI imaging and adaptive radiotherapy to decrease the rectal dose during intensity modulated radiation therapy for prostate cancer. **Materials/Methods:** Between December 2009 and August 2010, 34 prostate carcinoma patients were treated with either combined high dose rate (HDR) brachytherapy plus intensity modulated radiation therapy (IMRT) or IMRT alone. The IMRT was delivered in 33 to 45 fractions of 180cGy. In conjunction with radiotherapy, the patients were administered a tissue spacer compound to increase the separation between the prostate and the rectum. The tissue spacer was injected transperineally into the prostate-rectal inter-space in order to enhance separation. In order to monitor any changes in the spacer compound throughout the course of treatment, the patients were imaged via MRI at various stages: pre-injection, post injection, and every two weeks until the conclusion of treatment. In those cases where the tissue spacer degraded significantly, adaptive radiotherapy was applied and the patients were re-planned accordingly. DVH analysis was performed for both pre and post injection anatomy. **Results:** MRI analysis revealed the tissue spacer was able to generate an additional 1.0 cm mean separation between the prostate and rectum. As a result, there was a significant reduction in rectal dose. The additional prostate rectal spacing decreased the maximum and mean rectal dose by 11.5% and 30.0%, respectively, while the rectal wall V60 and V70 decreased by 19.12% and 19.87%, respectively. Bi-weekly MRI imaging revealed that the tissue spacer separation dissipates over time. A graph of the mean separation over time reveals an initial decay of 20% over 4 weeks followed by a more rapid decay of 60% over the following two weeks. **Conclusions:** Injection of a tissue spacer in the prostate-rectal inter-space is an effective means to reduce rectal dose for prostate IMRT. MRI imaging indicates enhanced prostate-rectal spacing on the order of 1 cm is readily achievable. This spacing provides significant dosimetric advantages for treatment planning and delivery. The tissue spacer dissipates over time so the anatomy returns to its baseline state. However, given that the separation reduces over time, temporal monitoring and adaptive radiotherapy must be used in conjunction with the tissue spacer.

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### 12 Quantitative Dosimetric Consequences of Pancreatic Movement in radiotherapy treatments

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**Purpose/Objective(s):** Interval fraction movement in the abdomen can affect accurate dose delivery. We used fiducial marker seeds implanted in the pancreas to quantify the fractionation target movement in pancreatic cancer. The average movement was used to analyze dosimetric consequences in conventional 3-DCRT treatments. **Material/Methods:** 18 patients with a histologically confirmed diagnosis of pancreatic cancer deemed unresectable underwent primary chemotheraphy and radiation therapy during 5/2008 to 1/2010. Sterile marker seeds were implanted using ultrasound-guided endoscopy in the affected region. Patients were CT scanned and target contouring was performed using the Pinnacle treatment planning software. IGRT treatments were delivered with a Varian Trilogy linac where kilovoltage (kV) matched orthogonal images were taken prior to treatment to verify target positioning. A consistent reference point on a vertebral body adjacent to the seeds was selected on these images. The distance on the right-left (X), superior-inferior (Y) and anterior-posterior (Z) axes were measured for each seed in relation to the selected reference point. Interval fraction movement was calculated based on the difference between seed coordinates from the treatment plan and the seed coordinates on the kV orthogonal matched images. For each patient, interval fraction marker seed movement was calculated and then averaged to obtain a mean target motion for each individual patient. The isocenter of the patient’s treatment plan was shifted to reflect the average pancreatic movement and dosimetric changes in the target volume were analyzed. **Results:** 49 seeds in 18 patients were implanted and were used for orthogonal IGRT matching. A total of 122 fractions were analyzed. The mean isocenter shift was 4.0 mm (S.D. = 3.1 mm, range 0-13.5 mm) on the X-axis, 5.6 mm (S.D. = 3.7 mm, range 0-14.3 mm) on the Y-axis, and 3.8 mm (S.D. = 5.3 mm, range 0-19.8 mm) on the Z-axis. Prior to isocenter shift the mean V<sub>10</sub> for PTW was 89.3% ± 9.3%. After isocenter shift the mean V<sub>10</sub> for PTW was 94.9% ± 5.3%. Therefore treatment without accounting for pancreatic movement reduces V<sub>10</sub> for PTW by 5.6%. **Conclusion:** The degree of organ movement can be quantified by analysis of endoscopically implanted fiducial marker seeds. Without IGRT, the PTW for pancreatic cancer is underdosed by 5.6%. The direction and magnitude of organ motion should be considered in treatment planning.

101  Heart and Left Anterior Descending Coronary Artery Displacement during Supine and Prone Breast Radiotherapy
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Purpose/Objective(s): Given the evidence of late cardiac mortality after breast radiotherapy and the emergence of the left anterior descending (LAD) coronary artery as a likely important contributor to cardiovascular mortality, we evaluated the change in anatomic position of the heart and LAD using CT imaging between supine and prone position for breast treatment. Materials/Methods: Ninety-four CT-simulation images of 47 consecutive left breast cancer patients enrolled on NYU Protocol 05-181 (prospective trial evaluating optimal positioning for whole breast radiotherapy) were used to determine cardiac and LAD position both prone and supine. Each patient underwent CT simulation without contrast (2.5mm CT slices) in the supine and prone position. The heart was contoured from the right atrium superiorly down to the diaphragm, not including pericardium. The LAD was contoured, inferred by location with a margin of 5mm for positional and contouring uncertainty. Three axial planes were defined to evaluate cardiac position in both supine and prone positions: the superior axial plane was determined by the first pulmonary trunk segment inferiorly to the pulmonary trunk bifurcation, the inferior axial plane was defined by the superior aspect of the diaphragm adjacent to the heart and the middle plane defined mid-distance of other two. For each case prone and supine, the distance between the anterior myocardium and the anterior chest wall (CW) was measured at nine specific points for the heart; at edge of sternum, mid and lateral aspect of heart, and laterally and posteriorly from CW for the LAD. The paired differences (prone-supine) were evaluated using Student’s T-test. Results: There was systematic displacement of the middle and superior aspect of the heart closer to the chest wall in the prone vs. supine position with a mean displacement measured at the lateral aspect of the heart of 2.52 cm (95% CI 1.5cm, p < 0.001) at the superior plane and 2.82 cm (95% CI 1.2 cm, p < 0.001) at the middle plane; the inferior aspects of the heart did not show a difference among the two positions. In addition, there was systematic displacement of the LAD from supine to prone position laterally with a mean 0.95 cm (95% CI 0.9, p < 0.001) and anterior towards the CW (1.5cm (95% CI 0.89, p < 0.001). Conclusions: For breast cancer patients treated in either prone or supine position, careful anatomic delineation of the heart and LAD during treatment planning will improve the protection of these structures from radiation exposure during breast radiotherapy, hopefully impacting the late cardiovascular morbidity currently recognized after breast treatment.


102  4D-MRI Using Body Area as Internal Respiratory Surrogate: Validation and Preliminary Results
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Purpose: Tumor motion is a potential source of error in treating moving targets using radiation therapy. 4D-CT has been shown a promising technique to image lung tumor motion, but has limitations in imaging abdominal tumors due to its low soft tissue contrast. The purpose of this study is to develop a four-dimensional magnetic resonance imaging (4D-MRI) technique using body area as internal surrogate for imaging abdominal tumor motions. Materials/Methods: The proposed 4D-MRI technique consists of 1) a multi-slice 2-dimensional (2D) cine-MR sequence, and 2) a phase-based retrospective sorting algorithm using respiratory signals extracted from body area. To validate the body area as a respiratory surrogate, we retrospectively analyzed 14 abdominal cancer patients who recently underwent 4D-CT scans. Breathing signals and respiratory phases (from 0% to 100%) determined from body area were compared to those from Varian’s RPM. Absolute phase difference and correlation were determined. The 4D-MRI technique was tested on an in-house-built motion phantom and evaluated on two healthy volunteers. All 4D-MRI images were acquired in axial planes. The motion phantom was also imaged in the mid-sagittal plane using the single-slice cine-MRI. Image quality of 4D-MRI was assessed qualitatively based on image artifacts and the revelation of respiratory motion. Motion trajectories of the imaging object for the phantom and of the selected internal structures for the healthy volunteers were extracted from 4D-MRI and analyzed. Results: The respiratory phases determined from body area for 14 patients correlated well with those from RPM (mean correlation coefficient: 0.94±0.03; range: 0.88-0.98). The a mean absolute phase difference between the two was 8.61±2.59% (range: 5.4%-13.9%). No correlation was found between absolute phase difference and imaging location. For the phantom study, 4D-MRI clearly revealed the sinusoidal motion of the imaging object in all three imaging planes with minimal image artifacts. Motion trajectories of the imaging object extracted from the 4D-MRI and from the cine-MRI matched well, with a mean difference in motion amplitude of -0.3±0.5 mm. For the healthy
volunteer study, respiratory motions in both thoracic and abdominal regions were revealed by 4D-MRI. Adequate image quality was maintained even with noticeable image artifacts. Motion trajectories of the diaphragm for Subject #1 and of the left kidney for Subject #2 revealed a motion range of 1.32 cm and 0.88 cm in the superior-inferior direction, respectively. Conclusions: Preliminary results demonstrated that body area is a comparable respiratory surrogate to Varian’s RPM system, and that it is feasible to use body area to extract breathing signal for 4D-MRI.

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103 Developing Imaging Markers Of Response To Neoadjuvant Chemotherapy In Stage II/III Breast Cancer
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Purpose/Objective(s): Pathologic tumor size and the number of positive axillary nodes determines who should receive adjuvant radiation following breast surgery but how to use parameters following neoadjuvant chemotherapy is less clear. We hypothesized that serial dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) scans performed early in the course of treatment can be used to develop imaging markers of pathologic response to treatment. Tumor response to neoadjuvant chemotherapy is currently monitored by changes in tumor size as measured by physical exam, mammography and/or ultrasound. DCE-MRI scans provide information related to tumor perfusion and permeability ($K^{\text{trans}}$). The changes observed in these parameters early in the course of therapy were used to predict changes in tumor size as well as nodal status at time of surgery.

Materials/Methods: Nineteen patients with Stage II/III breast cancer were enrolled in an IRB-approved clinical trial that obtained MRI scans pre-treatment, 7-14 days following initation of chemotherapy and pre-surgery. Sixteen patients were scanned at 3 time points: pre treatment ($t_0$), 7-14 days following initiation of chemotherapy ($t_1$) and pre-surgery ($t_2$). Three patients were scanned only at the first two time points. Pathologic determination of tumor sizes as well as nodal status was compared to the enhancing volume at MRI on $t_2$. The volume of enhancing tumor was calculated by detecting the voxels in which the signal increased 50% post-contrast. The change of mean $K^{\text{trans}}$ from $t_0$ to $t_1$ was compared with the change of volume of enhancing voxels from $t_0$ to $t_1$ and compared to pathologic tumor sizes. Results: The 6 patients who showed an increase of $K^{\text{trans}}$ from $t_0$ to $t_1$ had residual tumor burden at time of surgery. Only 2 of the 13 patients who showed a decrease of $K^{\text{trans}}$ from $t_0$ to $t_2$ had residual tumors at surgery. The group with $|K^{\text{trans}}(t_1)-K^{\text{trans}}(t_0)|$ had a much higher median tumor burden at the time of surgery. The Wilcoxon rank sum test also indicated the tumor size of this group was significantly different (p=0.0002). In this limited patient set there was no correlation with primary tumor MRI characteristics to number of positive nodes at time of surgery. Conclusions: We found a strong correlation between the early change in $K^{\text{trans}}$ and residual tumor burden, as well as the change in the enhancing volume of tumor tissue at conclusion of therapy. The ability to use pretreatment tumor characteristics to predict pathologic outcome would allow us to better plan radiotherapy fields for patients undergoing neoadjuvant chemotherapy.

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104 Surface Dose Measurements of a Carbon-nanotube Tomosynthesis Device Used for IGRT
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Purpose/Objective(s): Image guided radiation therapy (IGRT) can be necessary for accurate daily patient set-up, however imaging dose is always a concern. The ability to perform image guidance while the radiation beam is on, is currently lacking. Nanotube stationary tomosynthesis (NST) is a new IGRT system that uses 52 carbon-nanotube (CNT) x-ray sources to perform patient imaging during beam delivery. We herein present preliminary phantom surface dose measurements using the NST system. Materials/Methods: A head and neck and thorax phantom (RANDO) were imaged using the NST system at a clinically relevant SSD. The anode voltages were 60 and 75kV, which were chosen to current IGRT methods. Future studies will address adjusting the voltage of the NST system and number of CNT x-ray sources used in order to decrease imaging dose and improve IGRT. Results: When using the NST system at a clinically relevant SSD, the applied anode voltages were 60 and 75kV, which were chosen to current IGRT methods. Future studies will address adjusting the voltage of the NST system and number of CNT x-ray sources used in order to decrease imaging dose and improve IGRT.

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105 Altered Functional Network Connectivity in Patients With Brain Tumors: A Resting-State fMRI and Graph Theory Investigation
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Purpose/Objective(s): Previous studies have demonstrated altered global brain network connectivity in patients with brain tumors using graph theoretical analysis of resting-state magnetoencephalography (MEG) data. To date, no studies have investigated similar graph theoretical analysis methods applied to resting-state functional magnetic resonance imaging (RS-fMRI) BOLD signal acquired from patients with brain tumors, such as glial cell malignancies. The purpose of this study, therefore, was to evaluate the impact of brain tumors on whole-brain network connectivity using RS-fMRI. We hypothesized that some network metrics in these patients may differ from those of healthy controls.

Materials/Methods: An institutional ethics committee approved this study. Four patients with brain tumors were scanned in a 1.5 T GE scanner using an 8-channel head coil (GE Medical Systems, Milwaukee, WI, USA) for collection of structural anatomic (3D SPGR) MRI and RS-fMRI BOLD data as part of routine presurgical fMRI motor and language mapping, and compared to 30 healthy normal control subjects. All data was motion-corrected and normalized to a standard template using SPM. A binarized adjacency matrix for each subject was generated at a network cost of 0.3 from
which graph theory metrics (clustering coefficient, C; characteristic path length, L; local efficiency; global efficiency; and small-worldness) were computed. **Results:** Tumor patients included a 69 y.o. female with right frontoparietal glioblastoma multiforme (GBM) (Grade IV), 42 y.o. female with left temporal astrocytoma (Grade II), 37 y.o. male with left frontal oligodendroglioma (Grade II), and 45 y.o. male with right frontal oligodendroglioma (Grade II). C and L were significantly decreased in patients with brain tumors, as compared to healthy controls. There was also a slight decrease in global efficiency and small worldness, as well as a slight increase in local efficiency in these patients compared to healthy controls. **Conclusions:** Graph theoretical analysis of RS-fMRI data from individuals with brain tumors demonstrates associated abnormalities in global brain network connectivity. In particular, the decreases in C and L replicate similar findings described using MEG, which suggest that global brain networks in these patients may function more randomly than those of healthy controls. Decreases in L identified in this and the prior MEG study suggest excessive brain synchronization, which may help to explain epileptic seizures commonly associated with brain tumors. Further characterization of global brain network characteristics in patients with glial tumors could potentially lead to novel functional imaging markers with which to study disease progression, guide therapy and predict outcomes.

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106 **Graph Theory Network Metrics Computed from Clinical Task-Based fMRI Acquired During Presurgical Motor and Language Mapping of Patients With Brain Tumors**

**C. T. Whitlow,** J. A. Maldjian, *Wake Forest University School of Medicine, Winston-Salem, NC*

**Purpose/Objective(s):** The standard imaging method for evaluating global brain network connectivity relies upon graph theoretical analysis of resting-state functional magnetic resonance imaging (RS-fMRI) BOLD data, which is not routinely acquired in clinical tumor imaging. To date, no studies have investigated the acquisition of graph theory metrics from task-based fMRI (T-fMRI) BOLD data acquired during presurgical brain mapping of patients with brain tumors. The purpose of this study, therefore, was to determine if accurate graph theory network metrics could be computed from clinical T-fMRI of patients with brain tumors. We hypothesized that there would be no difference between graph metrics computed from T-fMRI and standard RS-fMRI BOLD data. **Materials/Methods:** An institutional ethics committee approved this study. Four patients with brain tumors were scanned in a 1.5 T GE scanner using an 8-channel head coil (GE Medical Systems, Milwaukee, WI, USA) for collection of structural anatomic (3D SPGR) MRI, routine clinical presurgical T-fMRI using motor (finger-tapping) and language (verbal-recall) tasks, and RS-fMRI BOLD data. All data was motion-corrected and normalized to a standard template using SPM. T-fMRI data was further processed to remove task-associated temporal interdependencies. A binarized adjacency matrix for each subject was generated at a network cost of 0.3 for the T-fMRI and RS-fMRI data from which graph theory metrics (clustering coefficient, characteristic path length, local efficiency; global efficiency; and small-worldness) were computed. **Results:** Tumor patients included a 69 y.o. female with right frontoparietal glioblastoma multiforme (GBM) (Grade IV), 42 y.o. female with left temporal astrocytoma (Grade II), 37 y.o. male with left frontal oligodendroglioma (Grade II), and 45 y.o. male with right frontal oligodendroglioma (Grade II). There were no differences between graph theory network metrics computed from RS-fMRI and clinical T-fMRI BOLD data. **Conclusions:** Graph theory network metrics can be accurately computed from clinical T-fMRI BOLD signal acquired during routine presurgical motor and language mapping of brain in patients with glial cell malignancies. These data are concordant with prior studies demonstrating similar graph theory metrics computed from T-fMRI and RS-fMRI in basic science research paradigms. Importantly, these methods can be immediately applied to clinical databases of presurgical functional brain mapping for hypothesis testing. The translation of this approach into clinical practice may potentially lead to the discovery of novel functional imaging markers with which to study disease progression, guide therapy and predict outcomes in patients with brain tumors.

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107 **Distinguishing Physiologic Variation from Malignancy: A PET/CT Study of Pediatric Neck Structures**

**R. Kotecha,** H. A. Jackson, A. Panigraphy, *Department of Radiology, Los Angeles, CA*

**Purpose/Objective(s):** In the clinical management of oncologic disorders, PET/CT imaging is critical to the initial identification of neoplastic tissue and classification of tumor staging. In children, the complexity of head and neck anatomy combined with the physiologic variability in intensity in the neck makes imaging in this region challenging. The objectives of the present study were to: (1) quantitate normal physiological variation in SUVs of the tonsils, thyroid, parotid and submandibular glands in a pediatric population; and (2) identify potential age-dependent changes in these anatomic structures. **Materials/Methods:** 34 pediatric oncology patients (25 M and 9 F; age range: 4-30 y, average age: 14.5 y) who had undergone prior PET/CT evaluations between 10/1/2008 and 6/30/2009 were retrospectively reviewed. The patients were being evaluated for Hodgkin lymphoma, non-Hodgkin lymphoma, acute lymphoblastic leukemia and other malignancies. The PET/CT logbook was used to identify the cases; images were reviewed on the PET/CT workstation and the hospital Synapse PACS system. Clinical information was obtained from the patients’ charts. The blood glucose levels in these patients before FDG injection was normal (range: 60-118 mg/dl, average: 91.6 mg/dl). The studies were performed on a Phillips Gemini PET/CT. For the quantitative analysis of the SUVs, regions of interest (ROI) were drawn around the following structures using axial images: thyroid gland, palatine tonsils, submandibular glands and parotid glands. ROIs were drawn manually around each of the structures from the superior border to the inferior border as identified on multiple axial slices. The maximum SUVs (SUVmax) were recorded for each of the structures. The SUVmax of the ROIs were provided by the manufacturer. Statistical analysis was performed using Pearson’s correlation. **Results:** The metabolic activity (SUVmax) increased slightly with age in the parotid glands (p < 0.05) and submandibular glands (p < 0.05). In contrast, there was no significant change related to age in the thyroid gland or tonsils. The widest range of SUVs were seen in the tonsillar tissue with a SUVmax ranging from 1-20 when
compared to the parotid, submandibular and thyroid glands which ranged from 1-6. Biopsy of the tonsils with the highest SUVmax demonstrated reactive follicular lymphoid hyperplasia with no signs of malignancy. **Conclusion:** Age dependent changes occur in the parotid, submandibular and thyroid glands in pediatric patients. In comparison, the metabolic uptake within the tonsils is relatively stable over age, but has the widest range of SUVs. Knowledge of physiological variation in the pediatric population will help with the interpretation of pediatric oncologic head and neck cases.

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### 108 4D-MRI for Radiotherapy of Mobile Tumors

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**Purpose/Objectives:** 4D-CT captures a single-cycle snapshot of breathing motion. Normal breathing fluctuations across multiple breathing cycles result in slice-to-slice anatomic inconsistencies. Consequently, single-cycle sampling with 4D-CT can result in an over-simplification of motion. Whereas frequent, repeat or longer imaging sessions could address this sampling deficiency, this is not feasible with 4D-CT because of patient exposure to ionizing radiation. MRI is not encumbered by this limitation. Variations in respiratory motion can be captured by imaging longer and/or more frequently. Dynamic 2D, multi-slice MRI acquisitions achieve the highest frame rates with good SNR and resolution characteristics over a large field-of-view. The aim of this work was to develop a robust 2D-to-4D sorting technique for dynamic MRI sequences for radiotherapy applications. **Materials/Methods:** Our methodology was developed using a balanced steady-state free precession sequence on a 1.5T MRI system (MAGNETOM Espree, Siemens AG, Germany). 3D volumes were scanned in sagittal or coronal planes by changing the slice location per frame. Voxel sizes were 2 mm × 2 mm (in plane) × 5 mm (between planes) and imaging parameters were adjusted to achieve repetition times of approximately 300 ms. Using three healthy volunteers, the thorax and/or abdomen was scanned for 10-30 minutes continuously. Simultaneously, a respiratory signal was acquired with a pneumatic belt. Our two-step sorting technique (MATLAB, The Mathworks, Inc., Natick, MA) is based on the respiratory signal, which is descretized, per cycle, into equal-time-weighted phase bins. In the first step, all frames per slice location for each phase bin were averaged, producing an “average 4D-MRI.” In the second step, raw frames were compared to the set of images per slice location from the average 4D-MRI: a normalized cross-correlation scoring criterion over a user-selected rectangular ROI indicated the best matching phase anatomically. The subset of best-matching raw frames per slice location and phase were then averaged to produce an “ideal 4D-MRI” image. **Results and Conclusions:** Processed 4D images depict the “average breathing cycle” over the MRI session. Frame-averaging produces images which have much-improved SNR. Depending on variability in patients’ breathing and positioning over time, the number of phase bins and the phase of interest, the “average 4D-MRI” can be noticeably blurry. The second-pass sorting tends to mitigate this, at the expense of SNR. The degree of “sharpening” and SNR reduction depends on the availability of frames with the anatomy of interest at the “average” location and the number of frames selected for secondary averaging. This “ideal 4D-MRI” may be better suited for certain applications such as deformable image registration. Further work is ongoing to compare this technique with 4D-CT.

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### 109 Volumetric Quantitative CT Scan-based Finite Element Modeling to Detect Rapid Loss of Proximal Femur Bone Strength and Density After Pelvic Irradiation

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**Materials/Methods:** Volumetric Quantitative CT (vQCT) scan-based finite element (FE) modeling, an engineering structural analysis technique, was developed to estimate bone strength and fracture risk. Because FE modeling accounts for the 3-dimensional mechanical properties of the osseous architecture of the femur on a patient-specific basis, this technique offers greater predictive power than the more widespread 2-dimensional densitometric techniques such as dual energy X-ray absorptiometry (DXA). The present study utilizes vQCT scan-based FE modeling to assess changes in proximal femur strength, bone mineral density (BMD) and bone mineral content (BMC) due to pelvic radiation therapy (RT). **Results:** Quantitative CT scans of the hip were obtained with a calcium hydroxyapatite calibration phantom one week before starting and at the completion of 50.4 Gy to the pelvis in 8 patients with gynecological cancers. Mean dose to the proximal femurs was 29.3 Gy (2.7 - 57.8 Gy). Patient-specific FE models of the left proximal femur generated from each QCT scan evaluated pre- and post-treatment proximal femur fracture locations under two loading conditions: 1) Single-limb stance (SL) - force applied to femoral head at 20° to shaft axis within the coronal plane and 2) fall onto posterolateral greater trochanter (fall load, FL) - force applied to femoral head at 60° to shaft axis and 25° to coronal plane; opposing surface of greater trochanter restrained in opposite direction. The change in fracture load for each loading condition was analyzed by 2-t test. Volumetric BMD (vBMD) and BMC were calculated via vQCT for the spongy trabecular bone (Tr), dense cortical (Co), and integral (Tr+Co) compartments of the proximal femur. Significance was determined by paired t-test. **Results:** All patients lost proximal femur strength for both SL and FL conditions (means, -5% and -10%, p<.05). vBMD was reduced in both Tr and integral but not Co compartments. BMC was reduced for all three regions; Tr -24%, Co -14% and integral -16% (p<.01). Co BMC decline was accompanied by loss of Co volume (-14%, p<.01) indicating cortical thinning. **Conclusions:** RT caused rapid decline of bone strength, vBMD, and BMC over the five weeks of treatment. Only an early activation of bone resorbing osteoclasts can account for this rate of decline (i.e. BMC decline >2% per week). Future studies will assess longitudinal, long term changes and possible dose response dependencies.


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**110  RECIST for Radiation Oncologists [RO-RECIST]**

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Purpose/Objective(s): To modify RECIST criteria to make it more suitable for radiation oncology practice. Materials/Methods: There have been a number of guidelines since the 1960s to help the practicing cancer specialists carry out such a task. [Zubrod et al, 1960; Gehan and Schneidermann, 1990; Therasse et al, 2000]. As technology advanced, the guidelines had to be changed to keep up with the changing clinical practice. Most of these guidelines were specifically developed for clinical trials. However, their relevance and importance to daily clinical practice should not be neglected. The first of these guidelines - World Health Organization (WHO) Handbook - originated to bring uniformity of tumor response assessment methods among different co-operative clinical groups so that comparisons could be made among different clinical trial results. However, clinicians often used such criteria in their daily clinical practice. As the Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) emerged as dominant technologies, the WHO criteria had to be redefined with new guidelines in 2000 [Therasse et al, 2000]. Named ‘RECIST’ for Response Evaluation Criteria in Solid Tumors, these guidelines emerged as a result of large international collaborative efforts. Initiated by EORTC (European Organization for Research and Treatment of Cancer), NCI (National Cancer Institute) of the United States, and NCIC of Canada Clinical Trials Group, a Task Group was created that developed the initial draft over three years. This was followed by Consensus Meeting with representatives from academia, drug development industry and regulatory bodies, the RECIST guidelines were made available in the public domain in the year 2000. In 2009, RECIST version 1.1 was recommended. The purpose of the update was to clarify many questions that arose with the use of RECIST over the about 10 years of its use as well as to add the following: (a) How to include Positron Emission Tomography in the response assessment. (b) To have methods to assess lymph nodes which were not included in RECIST version 1.0. (c) How to apply RECIST to cytostatic agents and targeted molecular agents that are not necessarily cytotoxic. RECIST 1.0 and 1.1 versions have been developed with a focus on cytotoxic and cytostatic drugs. At this time no such criteria more applicable to radiation oncology exists. Results: We have developed - based on RECIST criteria - specific recommendations for radiation oncology. These criteria - Radiation Oncology-RECIST (RO-RECIST) will be presented. Conclusions: There is a need for RO-RECIST. A first step is being taken to remedy the void that exists currently.

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**111  Characterization of Glial Cell Intratumoral fMRI Resting-State Networks Using Graph Theoretical Analysis**

C. T. Whitlow, J. A. Maldjian, Wake Forest University School of Medicine, Winston-Salem, NC

Purpose/Objective(s): Previous studies have demonstrated that graph-theoretical analysis of tumor histologic tissue-architecture can provide clinical prognostic information. To date, no studies have investigated similar graph theoretical analysis methods applied to resting-state functional magnetic resonance imaging (RS-fMRI) BOLD signal acquired from tumors, such as brain glial cell malignancies. The purpose of this study, therefore, was to determine if graph theory network metrics can be acquired from glial cell tumors using RS-fMRI. We hypothesized that some network metrics might vary according to glial tumor grade. Materials/Methods: Four patients with brain tumors were scanned in a 1.5 T GE scanner using an 8-channel head coil (GE Medical Systems, Milwaukee, WI, USA) for collection of structural anatomic (3D SPGR) MRI and RS-fMRI BOLD data as part of routine presurgical fMRI motor and language mapping evaluation. In order to evaluate network metrics within each patient’s tumor, a region of interest was manually drawn around the lesions and the remaining brain masked out. A binarized adjacency matrix for each tumor was generated at a network cost of 0.3 from which graph theory metrics were computed. Results: Patients included a 69 y.o. female with right frontoparietal glioblastoma multiforme (GBM) (Grade IV), 42 y.o. female with left temporal astrocytoma (Grade II), 37 y.o. male with left frontol oligodendroglioma (Grade II), and 45 y.o. male with right frontal oligodendroglioma (Grade II). Intratumoral network metrics were similar in magnitude to global network measures reported for the brain. Intratumoral measures of clustering coefficient, characteristic path length, local efficiency, global efficiency and small worldness were similar between tumor grades. The GBM, however, demonstrated greater betweenness centrality and lower modularity compared to the lower grade tumors. Conclusions: Intratumoral graph theory network metrics can be computed from RS-fMRI BOLD signal. Intratumoral networks from glial cell malignancies were similar to those of the brain, which is also composed of glial cells. Network metrics may vary according to tumor grade, with the high grade GBM demonstrating lower betweenness centrality, indicating a more equally distributed pattern of internodal connectivity, which could confer resistance to network destruction within these clinically aggressive lesions. The lower modularity associated with the GBM suggests that these lesions are more homogeneous, which could reflect underlying differences in histologic organization. Further characterization of network characteristics of glial tumors could potentially lead to novel functional imaging markers with which to study disease progression, guide therapy and predict outcomes.

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**112  Gadolinium-Enhanced MRI Characteristics of Liver Metastases Treated with Imaging-Guided Radiation Therapy (Cyberknife)**

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Purpose/Objective(s): Pictorial essay illustrating MRI appearance and treatment related changes of liver lesions treated with imaging-guided radiation therapy (Cyberknife technology). Materials/Methods: Twenty patients with liver metastases were followed with gadolinium-enhanced MRI to assess changes in appearance of the lesions, their size, signal characteristics and treatment specific changes and outcomes related to imaging-guided radiation therapy (Cyberknife technology). Results: Cyberknife is a new technology in cancer treatment which offers precise radiation delivery system to every part of the body. It has been offered as an alternative to surgery, and in many cases is the only option for treatment or cure due to location of the tumor or functional status of the patient. Long term follow up studies with imaging outcomes are not yet available. Few studies have described short term imaging follow up utilizing CT and/or PET/CT in assessing tumor treatment response. At our institution, a cohort of twenty patients with liver metastases has been followed with gadolinium-enhanced MRI examinations. Pre and post treatment appearance of the lesions is described and illustrated with depiction of changes of liver lesion size, signal characteristics, treatment
related changes and outcome. **Conclusions:** Imaging-guided radiation therapy is a new treatment related option for cancer patients with liver metastases. Gadolinium-enhanced MRI allows excellent follow up of liver lesions treated with Cyberknife technology in assessment of treatment related changes and therapy outcome.

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### 113 Feasibility of a Prone, Chin-up (Direct Coronal) PET/CT Acquisition Protocol for Head and Neck Cancer Patients. A Technique Designed to Alleviate Problems Posed by Dental Amalgam Metallic Artifact

**C. G. Guglielmo,** R. Pyzalski, M. McNall, B. Peters, C. Jaskowiak, S. Perlman, *University of Wisconsin, Madison, WI*

**Purpose/Objective(s):** Metal artifact produced by dental amalgam during PET/CT scans for head and neck cancer patients limits accurate anatomic localization of PET abnormalities on CT images and results in propagation of artifacts into reconstructed PET images, which can lead to false positive findings and inaccurate quantification. The addition of a prone, chin-up PET/CT imaging acquisition limited to the head/neck region (direct coronal PET/CT), as part of a standard whole body PET/CT imaging scan, is proposed as a method for evaluating patients with head and neck cancer in an effort to move the plane of metallic artifact produced by dental amalgam into a plane that minimizes these problems and allows for improved diagnosis, staging, and restaging of these patients. The purpose of this study is to examine the feasibility of a direct coronal PET/CT imaging protocol. **Materials/Methods:** CT scans were performed using a RANDO head phantom in which dental amalgam material has been placed to simulate direct coronal PET/CT acquisitions on patients with metallic artifact. The plane of metallic artifact produced during CT acquisition was determined using both the standard axial and direct coronal acquisitions. Further, subjective assessment by volunteers of the tolerability of prone, chin-up positioning lasting 5 minutes (without scanning) while using various measures to maximize comfort was performed. The dose of a single additional low dose, attenuation scan of the head and neck is also calculated to determine the added radiation exposure associated with this protocol. **Results:** The plane of metallic artifact using a direct coronal technique was shifted to parallel the axis of the ramus of the mandible away from the area of the oropharynx and level II nodal station. With adequate comfort measures the prone, chin-up position employed is felt to be tolerable for the expected 5 minute duration of this scan. The added radiation dose of a single limited low dose, non-contrast CT of the head and neck with this technique is less than 1/5 of that received with a standard diagnostic quality CT. **Conclusions:** A direct coronal PET/CT acquisition of the head and neck will move metallic artifact generated by dental amalgam out of the oropharynx and level II nodal station, key areas to assess in patients with head and neck cancer as demonstrated by this phantom study. This technique should be tolerable for patients during an expected 5 minute scan duration when efforts to maximize patient comfort are employed. The added radiation dose of a second limited low dose CT of the head/neck is considered to not exceed the potential for improved scan interpretation. Further evaluation of this technique on clinical patients is warranted.

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### 114 An Interactive Anatomic Atlas Generated Utilizing a Computerized 3-Dimensional Radiation Oncology Treatment Planning System

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**Purpose/Objective(s):** A radiation oncology treatment planning tool has proven to be a powerful tool for self-instruction in anatomy and cross-sectional imaging, but a professionally reviewed, virtual prossection to compare a student’s work to a standard would be useful, either for verification of the student’s work, or for testing. In the absence of such a prossection, an attending physician or anatomist must review all of the student’s work to assure accuracy. **Materials/Methods:** Using de-identified patient image sets, a student contoured organs on sequential CT images, based on correlations with several anatomy textbooks and review with radiation oncology physicians and oncologic surgeons. Labeled and unlabeled axial and resultant 3-Dimensional images have been created. All completed structure sets have been reviewed by an oncologic surgeon specializing in the treatment of that body section for accuracy of structures and labels. Within this institution, the image sets will be available for additional students to use for contouring, with comparison to the labeled prossections after completion. **Results:** Students report that this tool is the most effective way of learning to read CT scans they have found, and comparison of their drawings to these virtual prossections will allow for testing of accuracy. The system is simple enough that a reasonably computer literate student or physician can learn to draw structures with less than an hour of orientation and training, with the use of a cross sectional anatomy book and occasional supervision from an experienced physician. Learning is greatest when students draw themselves. Images from the atlas will be displayed in the presentation. **Conclusions:** A modern radiation therapy treatment planning system provides a tremendously powerful instructional tool for anatomy and diagnostic radiology, for testing of knowledge in these subjects, and for self instruction, particularly in the advanced imaging technologies. The virtual prossection provides the opportunity for interactive testing.

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### 115 Individual Fraction Re-planning with Three-Dimensional CT for Single Channel Vaginal Cylinder High-Dose-Rate Brachytherapy: Imaging Technology Overkill?

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**Purpose/Objective(s):** Vaginal cylinder high-dose-rate (HDR) brachytherapy is currently one of the most common procedures performed in the treatment of early stage endometrial cancer. Current recommendations by the American Brachytherapy Society (ABS) regarding the fractional re-planning for HDR vaginal cuff brachytherapy are ambiguous. Additionally, recent investigations of the utility of fractional re-planning using two-dimensional simulations for vaginal cylinder HDR brachytherapy have had conflicting conclusions. To date, there has not been any analysis of the utility of three-dimensional computed tomography (CT) simulations in the treatment planning process for single channel vaginal cylinder
HDR brachytherapy. Materials/Methods: Nine consecutive women treated at our institution, representing a total of 29 administered vaginal cylinder HDR brachytherapy fractions between 2009 and 2010, had three-dimensional CT simulations performed prior to every HDR fraction. A unique and customized treatment plan for a single channel HDR vaginal cylinder was then generated for every HDR fraction administered. Total dose to critical organs was calculated based on the customized treatment plans for every fraction and compared to the calculated organ doses if the first treatment plan had been applied unchanged to all subsequent fractions. Paired, two-tailed Student's t-tests were used to statistically compare fractional re-planning vs. a single plan. Three-dimensional organ interfractional motion was also measured and correlated to fractional differences in calculated critical organ dose. Results: All patients received HDR brachytherapy fraction doses to the upper 2/3 of the vagina of either 6 Gy prescribed to the surface or 7 Gy prescribed to 0.5 cm of depth. Comparing fractional re-planning vs. a single plan, mean 2cc bladder doses were 8.70 Gy vs. 8.38 Gy (p = 0.42), rectal doses were 13.06 Gy vs. 12.99 Gy (p = 0.70), and bowel doses were 3.38 Gy vs. 3.41 Gy (p = 0.21), respectively. Maximum bladder interfractional motion was observed in the transverse plane and measured to be 1.56 cm with a mean of 0.93 cm. Maximum rectal interfractional motion was observed in the transverse plane and measured to be 2.04 cm with a mean of 0.81 cm. Maximum bowel interfractional motion was observed in the sagittal plane and measured to be 5.15 cm with a mean of 2.09 cm. Conclusion: Given the minimal and statistically insignificant differences in critical organ dose between fractional re-planning and the use of a single plan, three-dimensional CT simulations prior to every fraction cannot be justified for single channel vaginal cuff HDR brachytherapy administrations in a medical economy and practice environment with limited resources and time.


116 Comparison of Imaging Modalities Used in Brachytherapy Treatment Planning for Cervical Cancer
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Purpose/Objectives: Brachytherapy, in conjunction with external beam radiotherapy (EBRT), has been the mainstay for treatment of cervical cancer for many decades. Traditionally, point doses to the cervix have been based upon the location of a treatment applicator as identified on orthogonal plain films. Tumor size and shape have historically not been considered in dosimetric treatment planning. In 2005 GEC ESTRO published recommendations regarding 3D imaged based treatment planning for cervical carcinoma. In particular, they encouraged the use of MRI for accurately identifying the extent of the tumor volume. Herein we analyze tumor volumes as defined on both CT and MRI for patients treated with high dose rate brachytherapy for cervical cancer. One aim is to investigate whether CT may suffice in specific situations to replace MRI.

Materials/Methods: We obtained CT images prior to treatment and at the time of each tandem and ovoid (T&O) brachytherapy insertion. Beginning in July 2009, MRI images were also obtained prior to treatment and at the time of the first T&O insertion. For this analysis, gross tumor volume (GTV) and high-risk clinical tumor volume (HR-CTV) volumes were contoured on MRI images, and the CTV was contoured on CT images. Volumetric data was analyzed with a paired t-test. Results: Since July 2009 a total of seven patients have been treated with MRI based brachytherapy treatment planning. One patient did not undergo an MRI prior to beginning EBRT and therefore is excluded from this comparison. Volumetric analysis revealed that the MRI HR-CTV was significantly larger (mean tumor volume (MTV)=60.06 cc) than the CT CTV (MTV = 25.75 cc) at diagnosis (p = 0.02) but not at the time of first T&O (MTV 19.03 cc v. 16.0 cc, p = 0.44). The MRI GTV was significantly larger than the MRI HR-CTV at diagnosis (p = 0.07) and at the time of first T&O (p = 0.04). The decrease in MTV from the time of diagnosis to the time of first T&O was significantly greater for MRI HR-CTV than for the CT CTV (p = 0.005). Conclusion: MRI is useful in evaluating tumor response to EBRT at the time of first T&O insertion. There was a significant difference between the MRI GTV and HR-CTV MTV at the time of first T&O compared to the MTV prior to treatment however there was no difference in the CT CTV mean tumor volume. Since volumetric analysis revealed that the MRI HR-CTV was not significantly different than the CT CTV at the time of first T&O it may be reasonable to use CT based planning in many cases of image guided brachytherapy after the first implant.

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117 Interfractional Target Volume Changes With the Use of 3-Tesla MRI for Cervical Intracavitary Image-Guided Brachytherapy
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Purpose: Magnetic resonance imaging (MR)-guided brachytherapy (IGBT) for cervical cancer facilitates delineation of target volumes and organs at risk (OAR). The GEC-ESTRO guidelines define contouring volumes used for dose specification based on lower strength MR images. We assessed the consistency of these volumes over the course of IGBT by determining whether significant interfractional target variations occur using a higher strength 3T MRI for IGBT. Materials/Methods: From 2008-2010, 12 women with Stage IB-IV cervical cancer had MR imaging for at least 3 fractions of tandem and ring (T&R) intracavitary HDR after 45 Gy external beam radiation. MR imaging was performed to define OARs and to adjust the dose specification from point A to the high risk-CTV (HR-CTV). 3T images were acquired using commercial phased-array coils. Non-fat-suppressed, T2-weighted images were acquired using a 3D-TSE sequence optimized to produce images with 1 mm^3 voxels. Gross tumor volume (GTV) and HR-CTV were contoured for each fraction by one physician, and target volumes were analyzed. Results: MRI-contoured volumes were normalized to the first fraction volume. The range of normalized volumes was 0.12-1.29 for GTV and 0.59-1.65 for HR-CTV. In 4 patients (33%), the GTV was not visualized. Mean visualized GTV was 0.75 and mean HR-CTV was 0.94. Standard deviations for GTV were 0.30 and for HR-CTV were 0.18. HR-CTV volume change per day was usually small (-0.01 on average), but ranged from -0.08 to 0.12. There was a statistical difference in the interfractional volumes for both the GTV and HR-CTV (p < 0.05). The cervix/uterus and cervix/parametria interfaces were not always as distinct as with lower strength MR.

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Conclusions: 3T MRI acquisition for T&R brachytherapy for cervical cancer demonstrates that interfractional GTV and HR-CTV changes occur. This may be secondary to physiologic and MRI-protocol parameters, patient motion, and/or window and level variations, leading to poor visualization of the cervix-uterus and parametrial-cervical borders. Further studies with high Tesla MRI will be valuable to assess determinants of interfractional target volume changes, as well as intensity changes of the target volumes.

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118 Radiation Delivery for Systemic Disease; Targeted Radionuclide Therapy (TRT) and non-Hodgkin Lymphoma
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TRT is a form of systemic radiotherapy that utilizes various radionuclides, conjugated to antibodies or antibody fragments, specifically designed to systemically target malignancies. The radiation is delivered in a continuous, exponentially decreasing low dose and low dose-rate fashion. Depending upon the type of targeting construct that is used, the immune system may or may not have a significant synergistic impact on cell kill. The LQ model predicts that radiotherapy delivered by TRT should be less effective than standard high dose-rate external beam radiotherapy. TRT however, appears to be very effective. Although there is emerging data for TRT used to treat solid tumors, radiolabeled anti-CD20 antibodies (ibrutinomab tuxetan/ tositumomab), used to treat NHL, are moving into the adjuvant setting (FIT trial). It is imperative that radiation oncologists understand and embrace this technology in order to expand their boundaries.

This presentation will review tumor microenvironment, antibody penetration into tumors, pharmacokinetics of targeting constructs, selection of radionuclides, radiobiology of TRT, clinical data supporting the use of TRT for NHL, and the concept of the systemic cure of cancer using TRT. For example, the linear quadratic formula can quantitate cell kill when using TRT. If a dose rate 10-15 cGy/hr, an effective half-life of 4 days, half-time repair of 1.5 hours, α/β equal to 10, and an absorbed tumor dose of 15-20 Gy are delivered by a single instillation of TRT, a 2-3 log cell kill should result. Today, genetic engineering has allowed the use of fully human monoclonal antibodies so that multiple instillations of TRT agents are now possible, hence avoiding the development of anti-globulin antibodies. The successful treatment of 106-109 cells (mm-em size) with TRT may now be within reach.

Author Disclosure Block: T.W. Speer: D. Speaker's Bureau/Honoraria; Spectrum Pharmaceutical.

119 The Use of Dynamic Contrast Enhanced (DCE) Endorectal Magnetic Resonance Imaging (MRI) in the Evaluation of Patients with Rising or Persistently Elevated PSA after Radical Prostatectomy
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Purpose/Objective(s): To evaluate the use of dynamic contrast enhanced (DCE) endorectal magnetic resonance imaging (MRI) in staging of patients with a rising or persistently elevated PSA after prostatectomy. Materials/Methods: The charts of prostate cancer patients who were treated with radiation therapy between January of 2004 and October of 2010 for a rising or persistently elevated PSA after prostatectomy at the M.D. Anderson Cancer Center were reviewed. Of the 389 postprostatectomy patients treated, 143 patients had DCE MRI of the pelvis with an endorectal coil before starting their salvage treatment. 113 patients had an undetectable PSA (defined as being <0.1 ng/mL) after surgery. 30 patients had a detectable PSA after surgery with a median PSA of 0.2 ng/mL (range 0.1 - 1.7 ng/mL). On the MRI scans, a focal area of enhancement with contrast in the prostate/seminal vesicle fossa was defined as suspicious for local recurrence. Results: The median PSA at the time of the MRI scan was 0.3 ng/mL (range 0.1 - 8.0 ng/mL). Out of the 143 patients, there were 35 patients with MRI findings suspicious for a local recurrence. 26 of these patients underwent ultrasound-guided biopsy of the prostate/seminal vesicle fossa. 23 patients had a pathologically proven local recurrence. One patient had residual prostate tissue seen on pathology. The positive predictive value (PPV) of DCE endorectal MRI for cancer was 88.5%. Out of the 9 patients who were treated with salvage radiation therapy to the prostate/seminal vesicle fossa without pathologic confirmation of their suspicious MRI findings, 8 patients remain disease free (7 patients with PSA <0.1 ng/mL and 1 patient with PSA of 0.1 ng/mL) after a median follow-up of 22 months (range 5 - 63 months). The median PSA value for patients with a biopsy-proven local recurrence was 1.35 ng/mL (range 0.3 - 8.0 ng/mL). 8 patients with a biopsy-proven recurrence had a PSA less than 1.0 ng/mL at the time of their biopsy (4 patients with PSA of 0.3 ng/mL, 1 with 0.4 ng/mL, 1 with 0.5 ng/mL, and 2 with 0.8 ng/mL). There were 9 patients with prostate/seminal vesicle fossa biopsies performed without any suspicious findings on the MRI. Of these patients, only one patient had a pathologically proven local recurrence. The negative predictive value (NPV) of DCE endorectal MRI was 88.9%. Conclusions: Dynamic contrast enhanced (DCE) endorectal MRI of the pelvis offers an effective method of assessing for local recurrence of prostate cancer after prostatectomy. In this study, DCE endorectal MRI was able to detect local recurrences in patients with PSA's as low as 0.3 ng/mL.


120 Diffusion Weighted and Dynamic Contrast Enhanced MRI in Patients with Low Risk Prostate Cancer: Correlation with Pathological Findings
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Purpose/Objective(s): To evaluate the performance of multiparametric MRI for cancer detection and staging in patients with suspected low risk prostate cancer. Materials/Methods: Fifty eight consecutive patients with low risk prostate cancer and unilateral cancer involvement on standard biopsies were included prospectively. All patients underwent multiparametric endorectal MR examination prior to radical prostatectomy, including T2-weighted (T2W), diffusion-weighted (DW) and dynamic contrast enhanced (DCE) sequences. On MRI and histological surgical specimens, the peripheral zone (PZ) and transition zone (TZ) were each divided into quadrants, thus yielding 8 octants per gland. In each octant,
suspected unilateral low risk prostate cancer, multiparametric MRI can accurately predict large volume and bilateral tumors. It should be thus detected in 80% (16/20) of cases. Accuracy of tumor detection was not significantly influenced by Gleason score. Optimal MR combinations, tumor size was correctly estimated in 77% of tumor foci involving more than one octant and bilateral tumors were significantly better than T2W+DWI and T2W alone (p<0.001). In the TZ, only T2W+DWI performed better than T2W alone (p=0.02). With optimal MR combinations, tumor size was correctly estimated in 77% of tumor foci involving more than one octant and bilateral tumors were detected in 80% (16/20) of cases. Accuracy of tumor detection was not significantly influenced by Gleason score. Conclusions: In patients with suspected unilateral low risk prostate cancer, multiparametric MRI can accurately predict large volume and bilateral tumors. It should be thus recommended before considering active surveillance or focal therapies.


121 Changes in Treatment Intent Following PET/CT Simulation in Previously Staged NSCLC Patients
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Purpose/Objective(s): Multimodality therapy for locally advanced lung cancers involves a combination of chemotherapy and radiation therapy and PET/CT scanning is the most accurate non-invasive method of staging lung cancers. Few investigations have examined the role of disease progression in treatment naive candidates for radical radiotherapy and this investigation was performed to determine whether appropriately staged patients undergoing PET/CT simulations on a hybrid unit had either staging or treatment intent changes despite having PET/CT scans performed within the prior three months. Materials/Methods: 93 consecutive patients underwent PET/CT simulation for NSCLC at the University of Pennsylvania between 4/29/09 - 7/31/10. All included patients had accompanying diagnostic nuclear medicine interpretations. Of these, 31 patients had previous PET/CTs in the three months immediately preceding their simulation and all had been appropriately staged without any evidence of distant metastatic disease. Patients had to be stage II or greater to be included in the examined cohort. Results: 31 patients were eligible for inclusion. The median age was 69. At the time of CT simulation for definitive radiotherapy intent, re-staging following simulation found new nodal disease or metastatic disease in 14 (45%). Of these, 9 (29%) had evidence of new metastatic disease with the remaining 5 (16%) diagnosed with nodal disease requiring substantial alteration of treatment fields. Seven patients (23%) were not treated with radiation and received systemic therapy or best supportive care alone. A reverse Kaplan-Meier plot was generated to determine the mean and median time to upstaging, which was 65, and 74 days, respectively. At a scan interval of 30 days, the rate of upstaging was 10%. Further numerical analysis was performed with the Penn-only cohort of patients (n=9). Non-upstaged patients had a mean SUV velocity of 0.072 units compared to a SUV velocity of 0.126 in patients that were upstaged by their second PET/CT scan (p=0.0115). For all patients, the median interval between PET/CT scans was 43 days. Conclusions: Radiation treatment planning with PET/CT scans repeated within 3 months of an initial staging PET/CT resulted in the identification of significant new findings that altered treatment intent in a high percentage of patients. For a subset of patients who underwent both scans at our institution, SUV velocity predicts for upstaging within the examined period and is statistically significant. Overall, 23% of patients had interval progression changing treatment intent from curative to palliative and nearly one half overall progressed in N or M stage. Without the planning PET/CT, a substantial proportion of patients would have received inappropriate treatment for metastatic disease.


122 Comparison Study: 3.0 T MRI versus 3 D Endoscopic Ultrasound in Preoperative staging of Colorectal Cancer.
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Purpose/Objective(s): Colorectal cancer is the third most common cancer. Depth of tumor invasion, lymph node status, tumor grade and involvement of the circumferential resection margin are the most important prognostic factors. An accurate preoperative assessment of rectal cancer is essential for appropriate patient management decisions and to detect patients at high risk of recurrence because the treatment strategies need to be individualized according to the extent of tumor invasion depth. The preoperative assessment of rectal cancer mostly depends on endorectal ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI). To our knowledge, no studies have been published on rectal cancer staging comparing 3.0 T MRI and 3D endoscopic ultrasound. The purpose of this study is to evaluate the diagnostic performance of 3T MRI and 3-D endoscopic ultrasound imaging in local staging of rectal cancer (for evaluating the invasion to muscularis propria and perirectal tissue). Materials/Methods: 26 consecutive patients (14 men and 12 women), with a mean age of 59 years (range 45-78 years) with biopsy proven rectal cancer underwent 3.0 T MR Imaging and endorectal sonography. The sensitivity, specificity, positive predictive value and negative predictive value of each staging technique were calculated with reference to the histologic findings. Results: 3T is more sensitive and accurate than endoscopic ultrasound for evaluating the invasion depth to perirectal tissue. There is no difference between 3T and endoscopic ultrasound for evaluating the invasion depth to muscularis propria. Conclusion: To conclude, our study suggests that endoscopic ultrasound and 3.0 T MRI provide similar results in assessing the muscularis propria invasion. In addition, MRI permits good assessment of tumor penetration into perirectal tissue, permits good visualization of rectal wall layers, is less operator dependent than endoscopic ultrasound, and is not influenced by the tumor size or location. 3-T MRI derives benefit mainly from the improvement of single to noise ratio and spatial resolution. 3T MRI is non invasive and offers better diagnostic value over 3-D-endoscopic ultrasound for evaluating the invasion depth of rectal cancer. 3.0 T MRI seems to be the single preoperative staging examination that most accurately predicts the pathologic stage of rectal cancer.

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Utility of the Interval Mammograms after Breast Conserving Therapy

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Purpose/Objective(s): At our institution, we perform a post-BCT mammogram on the anniversary of the patient’s annual mammogram and then yearly thereafter. However, frequently radiologists recommend a six-month interval study on the treated side to assure stability of these findings even though no specific worrisome findings were identified. Upon completion of this interval mammogram (IM) patients may often return to their annual diagnostic mammograms. In this retrospective study we will look at the clinical relevance and utility of this IM.

Materials/Methods: Four hundred and sixty-seven patients were identified and treated with BCT at Abington memorial hospital (AMH) between Jan 1, 2007 to April 2010. Of those patients we indentified patients that had an interval mammogram, and identified the clinical relevance, utility and yield of these IM which was determined by the number of biopsies and number of breast cancer recurrences identified from the IM. We define three post BCT mammograms; the first follow up mammogram (FFM), which is the first mammogram obtained at any time upon completion of BCT. Next we define a routine follow up mammogram (RFM) which is the annual mammogram, one year from the FFM. Last, we define the IM as a mammogram that was recommended at a 6 month interval between the FFM and RFM. Results: Of the 467 patients treated for breast cancer with BCT over the 3 year 4 mo study period, 131 patients did not receive their post BCT mammograms at AMH and were thus excluded from the results, leaving 336 patients for evaluation. 88 patients were requested to have an IM. The median time from the completion of radiation therapy to the FFM was 6 months. 3 patients had suspicious findings on the IM prompting a biopsy, all of which were benign. 60 patients after receiving an IM went back to their RFM after having stable post treatment changes with no clinical relevance, BIRAD 2. 28 patients after receiving their IM were felt to have continued suspicious post operative changes, with BIRAD 3, prompting additional follow up and eventually returning to the RFM. Also of note, 15 patients had suspicious finding on their IM prompting a biopsy, all of which were benign.

Conclusions: Of the 88 patients who were requested to have an IM, all returned back to their RFM without any clinical relevance or yield, with noted stable post treatment changes. The IM lead to 3 biopsies and yielded no recurrent or new breast cancers. Based on these results, the IM following BCT represents an unnecessary procedure that, if eliminated, would result in reduced healthcare costs without significantly impacting outcomes. The annual diagnostic mammogram should be considered adequate following BCT.

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Usefulness of Prebiopsy Multi-functional and Morphologic MRI Combined with the Free-to-total PSA Ratio in the Detection of Prostate Cancer

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Purpose/Objective(s): The purpose of the study was to assess the predictive value for prostate cancer of magnetic resonance (MR) using morphological (T2-weighted [T2WI]) and functional (MR spectroscopy [MRSI], diffusion-weighted [DWI], and dynamic contrast-enhanced [DCE]) sequences and the free-to-total PSA ratio (%fPSA) alone and combined. Materials/Methods: This retrospective study included 70 patients [PSA>4 ng/ml; %fPSA<20%] who underwent endorectal MR at 1.5T prior to biopsy. We graded the likelihood of cancer on a five-point scale. Imaging data were compared with histology on prostatectomy. Accuracies were estimated from the area under receiver operating characteristic (ROC) using the hemiprostate as the unit of analysis. A p value <0.05 denoted statistical significance. Results: The model combining all variables was more accurate than each variable alone [95% versus 73.5% (T2WI), 76% (MRSI), 82% (DWI), 76% (DCE), 79% (%fPSA)]. The complete model had similar accuracy than combining two imaging variables with %fPSA, especially %fPSA+T2WI+DWI and %fPSA+DVI+MRSI (94%); with a negative predictive value of 91% and 89.5%, respectively. The best models combining two imaging variables [MRSI+DWI (86%), T2WI+DWI (85%)] had similar accuracy than the combination of all imaging variables (87%), higher accuracy than the best individual imaging variable (DWI, 82%) but lower than the complete model. Conclusions: The combination of at least one functional technique with %fPSA is more accurate than combining only imaging variables in cancer detection. Use of more than two imaging variables does not increase the detection rate. Functional MRI has potential for avoiding a large number of negative biopsies.


The Role of Postoperative Radiation Therapy (PORT) For Stage I/II Endometrial Cancer: A Single Institution Ten-Year Experience

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Purpose/Objective(s): Recently published data from phase III multi-institutional randomized trials for patients with pathological stages I/II endometrial cancer (EC) have demonstrated a relapse-free survival benefit favoring postoperative radiation therapy (PORT) versus observation (OBS) for at risk patients. In addition, the use of adjuvant vaginal brachytherapy (VBT) has recently been shown to be as effective as postoperative external beam irradiation (EBI) in maintaining these patients’ overall survival. This current study reports one institution’s experience with PORT for patients with early stage EC. Materials/Methods: We retrospectively reviewed 72 consecutively treated patients with pathological stages I-II EC from January 1997 through December 2007 with minimum follow-up (F/U) of 6 months for those who were recommended for consideration of PORT. After multi-disciplinary review, patients either had PORT or were delegated for OBS. Post-operative therapy was generally pelvic EBI until late 2005 at which time VBT (usually with 4-6 cycles of carboplatin/paclitaxel CT) became the recommended mode of adjuvant treatment. The data was analyzed in March 2010. Results: Of this study group, 41 were placed into OBS, 22 had EBI and 9 VBT. Median age for all patients was 65 years (range: 29-89 years) with median F/U of 39 months (range: 6-139 months). There
were 45 stage I and 27 stage II EC patients. There were 58 adenocarcinoma variants and 14 high grade cell types, such as papillary serous, clear cell carcinoma or uterine sarcomas. Tumor grading revealed 27 well, 26 moderately and 19 poorly differentiated lesions. Of the OBS group, 24/41 (58.5%) were alive at last known contact versus 12/22 (54.5%) having EBI and 8/9 (88.9%) with VBT. Most fatalities were not due to disease progression and none were attributed to adjuvant therapy. Locoregional relapse occurred only for those having OBS (3 patients). Distant failures occurred in all groups (6 OBS, 4 EBI, and 1 VBT). **Conclusions:** Our results support the use of PORT to reduce the risk of loco-regional relapse in selected patients with early stage EC. The patterns of failure in this study support ongoing investigations in the use of PORT with or without CT to optimize control of this disease.


126 Interval PET Scan Restaging For Radiation Treatment Planning in Endometrial Cancer

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**Purpose/Objective(s):** The purpose of this study was to assess the role of interval staging with PET scan in radiation treatment planning in patients with advanced stage or loco-regional (L-R) recurrent endometrial cancer. **Materials/Methods:** At our institution, locally advanced endometrial cancer patients undergo postoperative chemotherapy and radiation therapy. Chemotherapy and radiation therapy are administered in a "sandwich" plan starting with three courses of chemotherapy, then radiation therapy, followed by chemotherapy. PET scan restaging is obtained following the initial chemotherapy to assess disease status and for radiation planning. Restaging PET scans were also performed in patients with L-R endometrial cancer recurrence. We performed a review of the frequency with which the treatment volume and doses are modified in radiation planning. The IRB approved the study review. **Results:** Twenty-six patients with advanced stage (n=15) or L-R recurrent endometrial cancer (n=11) had interval PET scan performed. Stage distribution of the 15 patients with advanced stage endometrial cancer was 12 with Stage IIIA, 12 with IIC, and one with Stage IVB. Seven of 15 patients had abnormal PET scan findings that led to modifications of treatment fields to encompass the FDG-avid lesions and consideration of boost doses. Ten of the eleven patients with L-R recurrences had abnormal PET scans. Three of these eleven patients had systemic disease and were treated with palliative therapy. Eight patients with limited recurrences were treated with curative intent and two of these eight with oligometastases received regional radiation therapy followed by SBRT boost. Thus 7 of 15 patients with advanced disease and 10 of 11 patients with recurrent endometrial cancer had treatment modifications. **Conclusion:** While conventionally, the radiation treatment volumes and doses are based on the initial surgical pathologic findings, interval PET scan after chemotherapy and prior to radiation therapy influenced radiation treatment planning in 17 of 26 (65%) endometrial cancer patients with advanced stage or loco-regional recurrence. Interval PET scan restaging should be considered for radiation treatment planning in patients with endometrial cancer receiving pre- radiotherapy chemotherapy, advanced stage or loco-regional recurrence.

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127 Role Of Diffusion Weighted Sequences With Background Body Signal Suppression (dwibs) In Diagnosis, Staging And Recurrence Of Oncologic Disease In Pediatric Patients

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**Purpose/Objective(s):** Pediatric neoplastic diseases are metastatic at diagnosis in 20% of cases, thus a whole body staging is mandatory in the diagnostic phase. Moreover recurrence of disease are frequent, thus a whole body surveillance is needed in the follow up. Conventional whole body MRI sequences (STIR,T1 and Gd-enhanced T1 sequences) provide detailed morphological information about tumors while diffusion-weighted sequences yield qualitative and quantitative information about water molecular motion that is expected to be restricted in tumors as in metastases. Our purpose was to assess the diagnostic role of DWIBS sequences along with conventional whole body sequences in detecting primary tumors and secondary metastases for diagnosis and staging and for recurrence of disease in pediatric oncologic patients. **Materials/Methods:** All consecutive pediatric patients with a biopsy-proven neoplastic disease untreated and all consecutive oncologic pediatric patients already treated for disease (postsurgery, postchemotherapy or postradiotherapy) both scheduled for a whole-body staging with nuclear medicine techniques prospectively underwent a whole-body MRI study at our institution with conventional and DWIBS sequences. WB images were compared with nuclear medicine images and lung-CT scans considered as standard of reference and diagnostic accuracy was assessed stratifying for organ and parenchyma. **Results:** 31 untreated Pediatric oncologic Patients with 21 solid tumors and 10 lymphomas and 39 treated pediatric oncologic patients with 30 solid tumors and 9 lymphomas were imaged. 25 skeletal and visceral sites were examined and recorded for all patients and for all sequences. Both STIR and DWIBS had high sensitivity for depicting bone and liver metastases but DWIBS provided better tissue contrast in detecting lymph nodes metastases. A fewer accuracy was obtained for lung parenchyma metastases with all sequences. **Conclusions:** DWIBS sequences have several pitfalls due to potential false positive images, overlap between benign and malignant features and technical limits. Nevertheless they enhance the conspicuity of tumor and metastases in whole body MRI both in staging and follow up setting. **Author Disclosure Block:** S. Savelli: None. M. Di Maurizio: None. M. Mortilla: None. A. Tamburini: None. M. Aricò: None. C. Fonda: None.

128 Volumetric Analysis Of Tumor Response To Neoadjuvant Chemotherapy (GTX) and Radiation Therapy In Borderline Resectable Pancreatic Cancer

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**Purpose/Objective(s):** Neoadjuvant GTX (Gemzar, Taxotere, Xeloda) followed by radiation therapy has shown promising results in downstaging borderline resectable pancreatic cancer patients to resectability. Assessing treatment response has traditionally been performed using 1- or 2-
dimensional measurements. Three-dimensional tumor response, however, may be more accurate based on previously reported experiences. Therefore, we quantified tumor volumes at various intervals during neoadjuvant GTX-RT and compared tumor response according to 1-, 2-, and 3-dimensional methods. Materials/Methods: This retrospective review included 14 borderline pancreatic cancer patients treated with a neoadjuvant regimen of GTX followed by 5-FU chemoradiotherapy. All patients ultimately underwent surgical resection. The GTX regimen included gemcitabine 750 mg/m² on days 4 and 11, docetaxel 30 mg/m² on days 4 and 11, and capecitabine 750 mg/m² on days 1-14. This was repeated every 21 days for a median of 3 cycles (range, 2-10). Patients were treated using 3D conformal (21%) or intensity-modulated radiation therapy (79%) to a median dose of 50 Gy (range, 45-52 Gy) in 1.8-2.0 Gy fractions along with concurrent infusional 5-FU. For patients treated with IMRT, simultaneous integrated boost delivered 45 Gy to the CTV and 50 Gy to the GTV in 25 fractions. The gross tumor volume was contoured on 3 CT scans obtained at the following time points: A) initial staging prior to neoadjuvant therapy, 2) CT simulation, and 3) restaging. One- and 2-dimensional measurements were made using these contours. Results: All patients in this study experienced an overall decrease in pancreatic tumor volume after completing neoadjuvant therapy. The median volume decrease between time points A and C was 6.72 cm³ (range, 0.53-15.47), corresponding to a decrease of 48.7%. The majority of volume change occurred after CT simulation. With respect to the pretreatment volumes, the decrease prior to and after simulation was 0.42 cm³ (range, -9.12-12.47) and 5.32 cm³ (range, -2.06-15.93), respectively. There was concordance between all assessment methods in 13 of the 14 patients. One patient had a partial response by the 1- and 2-dimensional techniques, but stable disease by volumetric analysis. Conclusions: This is the first study to evaluate volumetric tumor response in borderline resectable pancreatic cancer patients undergoing neoadjuvant GTX and radiation therapy. Our data suggest that radiation therapy plays an important role in downstaging these patients to resectability. With respect to radiographic tumor response, our data demonstrate no significant difference based on 1-, 2-, or 3-dimensional criteria.


129 Interval PET/CT Scan During Chemoradiation for Squamous Cell Carcinoma of the Anus To Guide Radiation Therapy Dosing

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Purpose/Objective(s): PET/CT is useful in staging, managing, and predicting the outcomes of anal cancer. At our institution, we obtain an interval PET/CT scan during chemoradiation and use the degree of PET/CT response to prescribe the total RT dose. Such use of PET/CT has not been reported in the literature. Materials/Methods: This single institution retrospective review includes 18 patients with T1-4N0-3M0 squamous cell carcinoma of the anus who underwent definitive chemoradiation with concurrent 5-FU and mitomycin C. A PET/CT scan was obtained during the initial staging process. For node negative patients, IMRT with compensators was used to deliver a simultaneous integrated boost by which the gross tumor volume (GTV) received 40 Gy in 2 Gy fractions and the regional lymphatics received 36 Gy in 1.8 Gy fractions. For node positive patients, IMRT with compensators was used to deliver 50 Gy in 2 Gy fractions to the GTV and 45 Gy in 1.8 Gy fractions to the regional lymphatics. All patients received a GTV boost for a total dose of 50-62 Gy. The boost dose was based on treatment response according to an interval PET/CT scan obtained within a week of starting the boost. Results: All anal tumors were PET avid upon initial staging, with a median SUV maximum of 10.5 (range, 7.7-24.9). An interval PET/CT scan was obtained at a median treatment dose of 45 Gy (range, 30-54). The majority of patients had a significant decrease in PET avidity; the median SUV maximum was 5.4 (range, 0-11.8). The median reduction in SUV maximum was 46.2% (range, -3.4-100). Two patients had no visible 18FDG uptake on the interval PET/CT. Fourteen patients have undergone a restaging PET/CT scan approximately 3 months after completing chemoradiation, with 11 demonstrating no visible hypermetabolic activity. The median SUV maximum was 3.8 (range, 3.7-5.8). Conclusions: This is the first reported use of determining treatment dose based on PET/CT response during definitive chemoradiation for squamous cell carcinoma of the anus. Despite beliefs that RT-induced inflammation can obscure tumor response assessment, we observed a dramatic decrease in PET avidity during chemoradiation. Our data should be evaluated with respect to cancer-related outcomes.

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130 Comparative Studies Using 99mTc-ECG Versus 18F-FDG For Diagnosing, Staging And Assessing Therapy Efficacy In Patients With A Confirmed Diagnosis Of Non Small Cell Lung Cancer

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Purpose/Objective(s): 99mTc-ethylcysteine-glucosamine (ECG) is a SPECT agent developed as an alternative to 18F- fluorodeoxy-D-glucose (FDG) for cancer imaging. Thymidine incorporation studies show intranuclear localization of ECG with presence in all three phases of cell proliferation. Glucose loading studies for macrophage and neutrophil uptake show minimal ECG uptake whereas FDG has avid uptake and competes directly with glucose. Imaging studies compare ECG SPECT/CT and FDG PET/CT for diagnosing, staging and assessing therapy efficacy for patients with non small cell lung cancer (NSCLC). Materials/Methods: Twenty one patients with NSCLC, not receiving therapy, and seven patients with NSCLC receiving chemotherapy had comparative imaging with FDG-PET/CT and ECG-SPECT/CT. Results: Objective comparative image interpretation on non-therapy patients resulted in 1:1 concordance for both primary and metastatic lesions. Comparative interpretation for therapy patients resulted in three false studies for PET secondary to infection and inflammation. Conclusions: The results suggest ECG-SPECT/CT may provide an alternative to FDG-PET/CT for diagnosing, staging and assessing therapy efficacy in patients with NSCLC.

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INTRODUCTION: Computed Tomography (CT) and positron emission tomography (PET) have been used as gold standard for staging and evaluating therapy on Hodgkin lymphoma. The development of whole-body MR imaging (WBMRI) with short tau inversion recovery (STIR) technique brought a new angle of assessment regarding ALARA principles. Purpose/Objective(s): Evaluation by WBMRI of IOP-GRAACC-UNIFESP, Sao Paulo, Brazil patients with Hodgkin lymphoma comparing with CT, PET or scintigraphy findings when available. Materials/Methods: 15 patients from the last two years with Hodgkin lymphoma with a medium age of 16.0 years (range 6-21) that could perform a WBMRI along with CT, PET or scintigraphy. Image findings were compared with Bone Marrow Biopsy (BMB) and clinical findings. Results: WBMRI agreed with clinical findings on most patients (86.7%). A substantial agreement between WBMRI and BMB was found. WBMRI disagreed with clinical findings in only two patients due to remaining high T2 lesions after treatment. One WBMRI positive finding with negative BMB was treated as positive according to clinical findings, considering, as described in the literature, that the biopsy site did not reach the ill bone marrow. Scintigraphy, less sensitive, could not find secondary lesions in one patient. The disagreement along with CT was about residual masses that lost its signal on MR studies and could be found on CT, considered negative. This study has significant findings helping determine its value as part of the diagnostic and follow-up of Hodgkin lymphoma following ALARA principles. Author Disclosure Block: J.L.O. Schiavon: None. H.M. Lederman: None. F.A.V. Luisi: None. R. Regacini: None.

132 Use Of Gadoxetate Disodium In The Diagnosis Of Pediatric Hepatic Lesions
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Purpose/Objective(s): Gadoxetate disodium (Gd-EOB-DTPA, Eovist, Bayer HealthCare) is a relatively new, hepatic-specific Magnetic Resonance Imaging (MRI) contrast agent. Gadoxetate disodium is unique among MRI contrast agents in that in patients with normal liver and kidney function, approximately 50% of the administrated dose is excreted via the hepatobiliary system. This property has made the contrast popular in the adult setting to help diagnose multiple hepatic abnormalities including focal nodular hyperplasia, hepatic adenoma, hepatocellular carcinoma, and metastases. There is little published on the use of gadoxetate disodium in children. The purpose of this presentation is to describe our pediatric MRI protocol as well as the imaging appearance of pediatric liver lesions using gadoxetate disodium. Materials/Methods: The radiology report system at our institution was queried for all patients who underwent a liver MRI with administration of gadoxetate disodium contrast agent. The patients ranged in age from 4 days to 28 years. Tumors imaged included many diagnoses unique to pediatric patients: hepatoblastoma, undifferentiated hepatic embryonal sarcoma, hemangioendothelioma, and congenital hemangioma. As well as, many diagnoses common to both adult and pediatric patients: simple cyst, focal nodular hyperplasia, hepatic adenoma, dysplastic/regenerative nodules and hepatocellular carcinoma. Conclusions: As a hepatocyte specific MRI contrast agent, gadoxetate disodium has the potential to improve the diagnosis, characterization, staging, and follow-up of pediatric liver masses.

133 CT-based Assessment of Visceral Adiposity and Outcomes in Esophageal Adenocarcinoma

Purpose/Objective(s): Our group has previously reported that BMI >25 is associated with lower grade tumors and increased overall survival in patients with esophageal adenocarcinoma. With data suggesting that computed tomography (CT) defined visceral adiposity in patients with esophageal adenocarcinoma is increased compared to controls, we sought to evaluate whether there was a similar correlation using these CT defined measures with oncologic outcomes. Materials/Methods: We reviewed the Moffitt Cancer Center database evaluating patients who underwent esophagectomy for adenocarcinoma from 1994 to 2008. Patients were excluded if they had a pre-operative BMI <20. Using the preoperative CT scan, we calculated the visceral (VFA), subcutaneous (SFA), and total abdominal fat areas (TFA). The primary endpoints were overall survival (OS) and disease-free survival (DFS), which were analyzed using the Kaplan-Meier method and log-rank analysis. Multivariate analysis was performed using Cox proportional hazard regression model. Results: We identified 126 patients who met inclusion criteria. The median VFA, SFA, TFA, and VFA/SFA were 182 cm², 280.99 cm², 526.84 cm², and 0.66 cm², respectively. For patients with VFA/SFA > or ≤ 0.66 cm², there was no significant difference between 5-year OS (51.3% vs. 41.6%, p=0.25) or 5-year DFS (50.1% vs. 35.9%, p=0.66). In the univariate analysis, VFA > 182 cm² was associated with fewer involved lymph nodes (p=0.047), larger tumor (p=0.016), male gender (p=0.042), and longer operating time (0=0.032). The ratio was not prognostic on multivariate analysis (HR = 0.49; 95% CI: 0.21-1.13). Conclusions: We found no association between OS or DFS and VFA/SFA. While VFA >182 cm² was associated with larger tumors, there was also a fewer number of lymph nodes harvested in this group. Further studies evaluating the impact of SFA, TFA, VFA and oncologic/operative outcomes are warranted to further clarify their significance in this cohort. Author Disclosure Block: M.D. Cuong: None. J. Choi: None. J. Weber: None. S.E. Hoffe: None. R. Shridhar: None. J.S. Barthel: None. K. Almhanna: None. E.A. Eikman: None. M.C. Biagioli: None. K.L. Meredith: None.
Purpose/Objective(s): To present an illustrative guide of different stages of squamous cell carcinoma of the head and neck and with specific emphasis on the crucial role imaging plays in clinical staging. Materials/Methods: Various cases of pathologically proven squamous cell cancer and their imaging appearance. Results: Squamous cell carcinoma is the most frequent malignancy of the head and neck region, arising from the squamous mucosa that lines the upper aerodigestive tract. The upper aerodigestive tract is divided into several major sites which include: (1) Oral cavity, (2) Oropharynx, (3) Hypopharynx, (4) Larynx, (5) Nasopharynx, and (6) Nose and Paranasal sinuses. Squamous cell carcinoma is a malignant tumor of epithelial origin, whose behavior depends on the site of origin and the histological grade. We present an illustrative guide of different stages of squamous cell carcinoma of the head and neck and with specific emphasis on the crucial role imaging plays in clinical staging. Conclusions: The extent or stage of cancer at the time of diagnosis is a key factor that defines prognosis and is a critical element in determining appropriate treatment based on the experience and outcomes of groups of prior patients with similar staging. Staging is historically based solely on the anatomic extent of cancer and remains primarily anatomic. The most clinically useful staging system is the tumor, node, metastasis (TNM) staging system maintained collaboratively by the American Joint Committee on Cancer (AJCC) and the International Union for Cancer Control (UICC). Three categories comprise the system: the T component is defined by the size of contiguous extent of the primary tumor. The N component is defined by absence or presence and extent of cancer in the regional lymph nodes. The M component is defined by the absence or presence of distant spread or metastases. The specific TNM status of each patient is then tabulated to give a numerical status of Stage I, II, III, or IV. Radiologic imaging plays a vital role during clinical staging and is often applied in the evaluation of the extent of the primary tumor, including local invasion, nodal involvement and distant spread.

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Imaging findings of recurrent Malignant Peritoneal Mesothelioma

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Purpose/Objective(s): To describe the CT imaging findings of recurrent malignant peritoneal mesothelioma in patients who underwent debulking surgery. Materials/Methods: The history, clinical and laboratory data, and imaging studies of 13 patients with histologically proven diagnosis of Malignant Peritoneal Mesothelioma (MPM) and their recurrence following cytoreductive surgery were reviewed. CT studies were reviewed for presence of ascites; peritoneal, mesenteric and omental involvement, presence of solid abdominal viscera involvement, gastrointestinal involvement, presence and location of enlarged lymph nodes and extra abdominal sites of involvement. Results: The most common finding at recurrence was ascites (n=6). Peritoneal thickening was seen in 5 patients; infiltration of the peritoneum resembling omental caking was seen in one patient and low density implants mimicking pseudomyxoma peritonei was seen in another patient. None of the peritoneal implants showed calcification. Three patients had large discrete soft tissue masses in the omentum and/or peritoneum. Multifocal serosal implants were seen in four patients; one had low grade small bowel obstruction which was managed conservatively. Three patients had evidence of intra thoracic disease seen as soft tissue pericardial mass and malignant pleural effusions. Conclusion: CT findings of recurrent malignant MPM resemble primary MPM, metastatic or granulomatous diseases. Radiologist should be aware of its appearance and forms of recurrence which may be seen at extra abdominal sites.

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Clinical Utility of Image-guided Chest Wall Mass Biopsy: Results In 28 Patients
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Purpose: To determine test characteristics of percutaneous image-guided biopsy of chest wall masses. Materials/Methods: Retrospective study of 28 patients who underwent image-guided biopsy of chest wall masses from 2006 to 2008 was performed. In 19 (68 %) patients, the mass was detected as part of a staging evaluation in patients with known malignancy; 9 (32 %) patients had no known malignancy. Biopsy results were classified as diagnostic (malignant or benign) or non-diagnostic (atypical and insufficient). Sensitivity, specificity and negative predictive value were calculated for all patients, and the Fisher-Freeman-Halton exact test was used to determine if test characteristics varied in patients with and without history of cancer, masses smaller and greater than 5 cm, or according to needle size. Results: Overall diagnostic rate was 71%. Of these, there were 20 TP, 3 TN, 5 FN and no FP results [sensitivity 80% (20/25), specificity 100% (3/3) and negative predictive value 37% (3/8)]. There were no differences between patients with and without cancer. Among 19 patients with known cancer, 10 (36%) had metastatic disease from their known primary; in three (11 %) patients, the result yielded a specific benign entity. Biopsy test characteristics did not differ with respect to mass or needle size. Minor complications were seen in 7% of patients. Conclusion: Image-guided chest wall mass biopsy is a sensitive and specific procedure, which is clinically important in the care of patients both with and without a known primary cancer.

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Occult Findings Revealed At Radiation Treatment Planning Simulation: The Importance Of Review And Re-evaluation
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Purpose/Objective: The importance of careful scrutiny of simulation images cannot be underestimated. Materials/Methods: Case review of clinical situations where previously unsuspected simulation findings impacted on subsequent care. This presentation will review four cases including lung cancer, cancer of the uterine cervix, breast cancer and bone metastases where previously unsuspected findings were identified at time of radiation treatment planning simulation that dramatically impacted on the course of treatment. Conclusions: Always carefully scrutinize radiation treatment planning simulation images for information that may impact on treatment decision making.

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Fiducial-Based Image Guided Radiotherapy for Accelerated Partial Breast Irradiation
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Purpose/Objective(s): The RTOG 0413 trial of whole breast versus partial breast irradiation requires a 10 mm PTV in the accelerated partial breast irradiation (APBI) group. Image Guided Radiation Therapy (IGRT) may allow for more accurate targeting and positioning, thereby reducing this generous PTV margin, improving local control and reducing normal tissue toxicity. The goal of this prospective study was to validate the use of intraparenchymal textured gold fiducials for use in IGRT in breast cancer patients receiving 3D conformal (CRT) APBI.

Materials/Methods: Twenty-seven patients were enrolled on this IRB approved prospective trial. Each had three or four gold fiducials placed at the periphery of the lumpectomy cavity and were treated with 3D CRT APBI. Free breathing 4D CT image sets were obtained pre- and post-treatment. Intrafraction respiratory motion was assessed by comparing the position of the fiducials’ center of mass (COM) between end-inspiration and end-expiration. Interfraction respiratory motion compared the position of the fiducials‘ COM between pre- and post-treatment CTs. Seromas were contoured on end-expiration and end-inspiration phases of both CTs and their position compared to the fiducials‘ COM. The distance of fiducials to the isocenter and of the isocenter to bony reference points were measured on megavoltage (MV) images taken prior to each treatment. Fiducial migration was determined by comparing the relative displacements of each marker to one another from the daily MV image sets.

Results: The average intrafraction respiratory motion was -0.3 mm (standard deviation, SD = 0.7 mm, range -2.1 to 1.2 mm). The average interfraction variation in respiratory motion was 0.0 mm (SD = 1.0 mm, range -2.5 to 2.2 mm). The average change in seroma position relative to the fiducial COM over the course of treatment was 1.7 mm (SD = 0.9 mm, range -1.6 to 3.9 mm). The average variation in daily separation between the fiducial pairs from daily MV images compared to the reference position at simulation was 2.4 mm (SD = 2.2 mm). The PTV margin required to account for this variation 95 percent of the time (two times the standard deviation of this variation) was 4.4 mm. As measured on daily MV image sets, the PTV margin that would be required to account for 95% of the variation in fiducial motion without image-guided alignment to the fiducials was 8 mm.

Conclusions: Textured fiducial markers are stable throughout the course of APBI. There was minimal intrafraction or interfraction respiratory motion, or variation in position of the fiducial markers. The position of fiducials relative to the seroma showed minimal variation. These data confirm the efficacy of fiducial markers for IGRT daily localization in APBI. PTV margins can be reduced to 5 mm with the use of fiducial-based IGRT.

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Uptake on Post-Ablation I-131 Whole Body Scan as a Predictor of Repeat Radioactive Iodine Treatment in Differentiated Thyroid Cancer
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Purpose/Objective(s): Following thyroidectomy for differentiated thyroid cancer (DTC), radioactive iodine treatment (RAIT) is administered to completely ablate residual thyroid tissue to reduce risk of local and distant recurrence. A proportion of patients require multiple doses of radioiodine to achieve this. Here, we evaluate the extent to which uptake on post-ablation whole body scan (WBS) can predict the requirement for
repeat doses of radioiodine. **Material/Methods:** We retrospectively identified patients given RAIT following surgical resection of DTC between June 2006 to March 2010 in the Oxford Cancer Centre, Churchill Hospital. Uptake on post-ablation WBS and number of RAIT delivered in patients following a first dose of 3.1Gbq were compared. Statistical significance was assessed by Fisher’s exact test. **Results:** In the entire cohort of 120 patients, 89% (n=107) were successfully ablated following a single dose of RAIT. The mean uptake was 1.78% (range 0 - 10.8%). The remaining 13 patients who required multiple doses of RAIT had a mean uptake of 8.03% (range 0.12 - 34%). The proportion of patients receiving multiple treatments was higher where uptake was ≥3% (single versus multiple RAIT, 19% vs 46%, p=0.034) with an odds ratio of 3.7 (95% CI 1.13-12.30). **Conclusion:** When uptake on post-therapy WBS is higher or equal to 3%, patients are almost 4 times more likely to need repeat RAIT. A more complete thyroidectomy may lead to less repeat treatments.

**Author Disclosure Block:** S. Teoh: None. J. Statham: None. A. Weaver: None.

141 Cone Beam CT (CBCT) Matching for Spinal Radiosurgery: Is it Accurate Enough?
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**Purpose:** Radiosurgical treatment of cranial or extracranial targets demands accurate positioning of the isocenter at the beam and table isocenter and immobilization of the target during treatment. For spinal radiosurgery the standard approach involves matching of cone-beam CT (CBCT) in-room images with the planning CT (pCT) to determine translation and yaw corrections. The purpose of this study was to assess the accuracy of these techniques compared to advanced automatching using mutual information metrics both with a volume of interest (VOI) and optimizing translations and rotations in all axes. The dosimetric consequences of our current standard matching techniques were also evaluated.

**Materials/Methods:** Ten consecutive spinal radiosurgery patients treated in the last year were subjected to analysis. For purposes of this analysis the automatch using mutual information and a VOI was considered to create “the true isocenter” for positioning the patients. Review of the imaging from this automatch confirmed perfect superimposition of the two datasets within the VOI. Matching the CBCT to the pCT using the automatch allowed assessment of the rotations which had been previously ignored. Recalculation of the dose volume histogram was undertaken for each patient assuming displacement of the true isocenter to the treated isocenter. Comparisons between the delivered doses and the intended doses were made. **Results:** The mean absolute lateral/vertical/longitudinal translations and vector displacement between the manual CBCT-pCT matching isocenter and the true isocenter were 0.13, -0.05 and -0.39 mm with a minimum and maximum vector shift of 3.2 and 8.1 mm. The mean pitch, yaw and roll correction for automatch was -0.30, 0.25 and 0.97 degrees with a maximum of 1.65, 2.92 and 1.43. Four of ten patients had a significant change in the coverage of the tumor due to lack of correction of translational and rotational errors. The largest errors were observed in patients with small and irregular target volumes. **Conclusion:** Precise positioning for spinal radiosurgery cannot be accomplished with manual pCT-CBCT matching without a clinical strategy to compensate for rotations. In the absence of this significant underdosing of the tumor may occur.

**Author Disclosure Block:** I. Crocker: None. E. Schreibmann: None. T. Fox: None.

142 Limited Projection Image Based Deformable Three-dimensional Registration For Lung And Head And Neck
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**Purpose/Objective(s):** To provide within-treatment deformable registration between the 3D planning CT images and few treatment radiographs in tomosynthesis-based IGRT approaches using cone-beam CT (CBCT) and the novel carbon nanotube stationary tomosynthesis (NST) devices.

**Materials/Methods:** Our method uses a machine learning strategy that has a two-stage process: training and IGRT. In the training stage we perform a patient-specific training that generates sample images from a range of potential treatment deformations. Potential treatment deformations are generated from the principal variations of deformation, which are calculated between the planning images and their intrinsic mean image by diffeomorphic registration. For each such sample image we generate 2D projections by re-projecting on the image volume. We compute multi-scale linear regressions between the deformation parameters and the differences between the projections of the deformed CT images and those of the intrinsic mean CT image. In the IGRT stage, the learned regressions are applied iteratively to the successive residues between the radiographs and those of the current estimated CT deformed by the previously predicted parameters. This iteration yields an accurate deformation field for treatment-time 3D image generation. The re-projection process is implemented on GPUs to speed up the real-time image guidance that will be enabled by the carbon nanotube based stationary tomosynthesis IGRT system NST. **Results:** We tested our method by both the simulated and the real radiographs for lung and head-and-neck (HN) IGRTs. The simulated radiographs are generated by re-projecting on the transformed planning images and adding Gaussian noise. We test our method by using 2 radiographs, 22 degrees apart for NST and 5 radiographs, 5 degrees apart for CBCT. For lung study, the planning images we used are 10-phase RCCT images. The mean error displacements (MEDs) are reduced from 2.96 mm to 0.06 mm for simulated NST and to 0.23 mm for simulated CBCT. For HN study, we model the mandible deformations by thin-plate spline with landmarks. Our method can detect the treatment-time mandible tip shift with less than 0.1 mm error for both simulated NST and CBCT. For the rigid transformation of HN, a total of 180 test cases are ranged from -2 to 2 cm in translation and -5 to 5 degrees in rotation. The MEDs are 0.52 mm and 1.09 mm for simulated NST and CBCT, respectively; the MEDs and the computation time for using 2 real NST radiographs are 2.5 mm and 5.81s with laptop GPU acceleration.

**Conclusions:** Our method has the potential to provide within-treatment rigid and non-rigid transformation correction by using few limited-angle treatment radiographs, which is important for image-guidance during treatment delivery and the reduction of imaging radiation dose.

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Use of Image-Guidance, Rectal Balloon, 4D-CT, and MRI for Treatment Planning Allows for Vast Improvement in Dosimetry of Radiotherapy for Prostate Cancer

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Purpose: IMRT allows for higher doses to the prostate while minimizing toxicity. Dose escalation has been shown to improve PSA control of prostate cancer (PC). New approaches have been developed that when combined, may improve the therapeutic ratio even more. This study evaluates the dosimetric results of combining 4D-CT, image-fusion MRI, and daily image-guidance with fiducial markers and a rectal balloon in the treatment planning and delivery of IMRT for PC. Materials / Methods: Patients (pts) treated at MUSC with IMRT for PC from July 2008 to July 2010 were evaluated after IRB approval. Pts treated on experimental protocols were excluded. All had 3 fiducial markers placed via TRUS followed ~1 week later by CT/MRI simulation with custom rectal balloon in place. 4D-CT was performed and the magnitude of the motion of the fiducial markers measured in all-dimensions. Treatment planning was then performed with fused MRI to delineate the prostate and gross disease. Low risk CTV1 was the prostate only. Intermediate risk CTV1 was the prostate+3mm expansion for extracapsular disease (ECE) and proximal 2.5cm of seminal vesicles (SV). High risk CTV1 was the prostate+3mm for ECE, lower nodes (below the roof of the acetabulum) and SV, and the pelvic lymph nodes (PLN) to mid L5. CTV2 was prostate/gross disease for all pts. Patient-specific CTV-to-ITV conversions were made by expanding the CTV by the magnitude of the motion of the fiducial markers. ITV-to-PTV expansions were 2mm for setup error with daily portal image-guidance using computerized analysis of the centroid of the triangle formed by the fiducial markers, for all ITVs except for the PLN. The PLN CTV1-to-PTV1 expansion was a 1cm expansion in all dimensions. PTV1 received 45 Gy/25 fx followed by 34.2 Gy boost to PTV2 (total dose 79.2 Gy/44 fx). IMRT treatment planning was based on objectives derived from the literature. Results of the final plan were tabulated and compared to planning objectives. Results: 89 pts’ dosimetry was analyzed: 15 low risk, 33 intermediate risk, and 41 high risk. All ITV dose objectives were achieved. Vast improvements in actual achieved parameters were seen compared to historical planning objectives. For example, the planning objective for rectal wall D50% was ≤75.6 Gy, while the median achieved D50% was 44.2 Gy for low risk, 57.8 Gy for intermediate risk, and 56.5 Gy for high risk pts. The historical planning objective for bladder wall D53% was ≤47 Gy, while the median achieved D53% was 3.6 Gy for low risk, 14.4 Gy for intermediate risk, and 38.1 Gy for high risk pts. Conclusions: Combining patient-specific CTV-to-ITV conversions, MRI fusion, fiducial marker image-guidance, and a rectal balloon results in substantial improvements in dosimetric outcomes.

The Impact Of PET/CT In Defining The GTV In Radiation Therapy Planning Of Various Sites

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Purpose/Objective(s): The use of PET/CT in radiation therapy planning is gaining great interest. Several reports incorporated its use in radiation planning based on its value and practicality. However, there is still no consensus among users on the exact definition of gross target volume (GTV) delineation using FDG PET/CT. We studied the applicability of the Anatomical Biological Halo; a distinct halo that was observed in several cancers as a GTV delineating method in four sites namely; head and neck, lung and neck, and rectal cancers comparing the GTV delineated by two independent Radiation Oncologists. Materials and Methods: Eighty seven patients with various cancer sites underwent PET/CT radiation therapy planning. 25 head and neck, 19 lung, 23 cervical, and 20 rectal cancers. Immobilization devices required for conformal radiation therapy or IMRT were custom fabricated for the patients prior to the injection of 18F-FDG. Integrated, coregistered PET/CT images were obtained and transferred to the radiation planning workstation (Xeleria). While the PET data remained obscured, a CT-based gross tumor volume (GTV-CT) was delineated by two independent observers. Later on GTV-PET [Anatomical Biological Contour (ABC)] was delineated by the two independent observers. Results: The anatomical biological halo was identified in all cancer sites by its distinct color at the periphery of all areas of maximal SUV uptake. The mean halo SUV is 1.83 ± 0.6. The mean halo thickness was 1.96 ± 0.2 mm. The halo is used by the two observers to contour the ABC. A clinically significant (~25%) tumor volume modification was observed by using PET/CT. Fifty four cases (62%) had a >25% modification in the mean GTV after using PET/CT. The largest mean absolute difference between PET and CT planning was encountered among cervical cancers followed by lung, neck and least among rectal cancers. Interobserver GTV variability decreased from 23.7 cm3 (SD 25.9) in CT-based planning to 7.1 cm3 (SD 6.2) with the use of PET/CT planning (P < 0.0001). The concordance among observers was increased using PET/CT planning; 15 cases (17.2%) had ≤10% volume discrepancy using CT compared to 48 (55%) utilizing PET/CT (P < 0.0001). The best concordance was encountered among lung cases and the least was among rectal cancers. Conclusions: PET/CT radiation based planning is a valuable tool to reduce interobserver variability in contouring GTV. The anatomical biological halo is observed in several cancer sites and provides a uniform method of contouring among observers.

Stereotactic Radiosurgical Ablation of Renal Tumors: Initial Experience

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Purpose/Objective(s): Surgical resection remains the gold standard for treatment of localized renal tumors. We determine the effectiveness and safety of radiosurgical ablation (RSA) with fiducial markers and respiratory gating for treatment of localized renal tumors. We examine radiographic changes on CT of the treated renal lesion. Materials/Methods: HIPAA compliant IRB approved study from Phase I/II Clinical Trial. Total enrollment of 5 patients (M:3:F:2; Mean age 55.4, range 41-69), without prior history of abdominal radiation or therapy, who had pathologically proven renal neoplasm less than 4 cm, underwent CT-guided intra-tumoral placement of gold fiducial markers, followed by 3D conformal radiation therapy with respiratory gating of renal tumor. Four equal fractions of 4 Gy each were delivered with BID regimen over 2 days. Eight week later the tumor was surgically excised into determine pathologic response. Pre- treatment and post-treatment tri-phasic CT scans were compared to determine radiographic changes of the lesion. Results: Total 5 lesions (mean size: 1.8 cm, range 1.3-3.3 cm) were treated. All
patients tolerated fractionated dosing without adverse clinical outcome or evidence for radiation toxicity. There was no significant change in renal function at 8 weeks post RSA. Two of 5 lesions (40%) had no residual noplasm at pathology. Post-treatment CT showed no significant change in lesion size or contour. Both high attenuation enhancing lesion became hypointenating and without significant enhancement, with no viable tumor on pathology. **Conclusions:** Radiosurgical ablation appears to be a safe and effective no-invasive treatment for localized renal tumors. Triphasic CT shows promise in predicting tumor viability after RSA.

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### 146 Megavoltage Imaging: Patterns of Tumour Regression and Predictive Factor for Non-Small Cell Lung Cancer Undergoing Radiation Therapy on Tomotherapy

**Purpose/Objective(s):** Recent advances in image-guided radiotherapy (eg., cone beam CT and megavoltage CT (MVCT) on tomotherapy) have allowed us to monitor changes in tumor/target during the course of fractionated radiotherapy. The objectives in this study are to assess patterns of tumor response in patients with non-small cell lung cancer observed by daily megavoltage imaging during treatment on tomotherapy and to explore patient and tumor specific characteristics as predictive factors correlating to response. **Materials/Methods:** A total of 666 daily MVCT studies for 25 patients were reviewed for outlining the gross tumor volume (GTV). No MVCT study was discarded. The quality of the MVCT was acceptable to monitor GTV and associated normal tissues. Relevant patient age, stage, performance status, weight loss, smoking habits, histology subtype, hemoglobin level, initial GTV, treatment time and overall tumor regression and survival were considered. **Results:** Based on anatomical changes in the GTV/tumor response as seen on MVCT imaging, three groups (A,B,C - early, intermediate and delayed) of patients were identified through the course of the radiation. A correlation between age, initial GTV, overall percent regression and regression rate were observed in each group. Groups A, B and C were significantly (<0.001) associated with Stage IIIA, IIIB and IV patients respectively. No patient had a complete response. No significant difference was noted in the overall survival between the three response groups. Smoking during radiation therapy did not significantly affect the tumor response. **Conclusions:** Image based tumor regression through the standard courses of radiotherapy may be classified into three groups; A, B and C. Each group may be associated with patient and tumor specific characteristics for predictive/clinical significance. MVCT imaging can be used as in vivo surrogate as biomarker, useful for adaptive radiation with potential of improving therapeutic ratio via tumor dose escalation and will be further discussed.

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### 147 Effect of Rotational Setup Errors Using Cone-Beam CT Localization on CTV Coverage for Intrathoracic Tumors

**Purpose/Objective(s):** While technology exists to correct for all six degrees of positioning errors identified by cone-beam CT (CBCT), some systems correct only for translational errors. The impact of unrecovered rotational errors has been investigated for head and neck and pelvic treatment sites, but there is limited data for intrathoracic tumors where the treatment volumes are often large and irregular. Our objective was to analyze the effect of uncorrected rotational positioning errors on clinical treatment volume (CTV) coverage for intrathoracic tumors. **Materials/Methods:** Patients were treated with intensity-modulated or 3D-conformal radiotherapy using either stereotactic body radiotherapy (SBRT) or non-SBRT (conventional dose and fractionation) with an Elekta Synergy-S linear accelerator and XVI CBCT system. Analyses included 235 CBCT scans from ten patients undergoing non-SBRT and 29 CBCT scans from three patients undergoing SBRT. Co-registration of the CBCT and planning CT images was performed and six degrees of positional setup errors were recorded. After correcting for translational errors, volumetric comparison of rotated CTVs with regard to planning treatment volume (PTV) margins were made. In order to calculate the volume of the rotated CTV that was outside of a given PTV margin, the volumetric union of all interfractional rotational setup errors was used. **Results:** For non-SBRT, the mean interfraction rotational setup errors were -0.1° ± 1.9, 0.4° ± 2.0, and -0.5° ± 1.8; the mean magnitude of the interfraction rotational setup errors were 1.6° ± 1.0, 1.6° ± 1.3, and 1.4° ± 1.1; and the maximal rotational errors were -4.8°, 7.4°, and -5.9° in the lateral, superior-inferior, and anterior-posterior dimensions, respectively. For SBRT pre-treatment, the mean interfraction rotational setup errors were -0.8° ± 2.2, 0.4° ± 1.3, and -0.6° ± 2.0; the mean magnitude of the interfraction rotational setup errors were 1.7° ± 1.5, 1.2° ± 0.7, and 1.5° ± 1.4; and the maximal rotational errors were -4.9°, 2.3°, and -4.5° in the lateral, superior-inferior, and anterior-posterior dimensions, respectively. SBRT post-treatment rotational setup errors were similar in all directions. The rotated CTV volumes exceeding 1 cm³ beyond PTV were recorded in 6% of fractions with a 3 mm PTV, 1.7% with a 4 mm PTV, and 0.9% with a 5 mm PTV. The average percent of union CTV volume beyond PTV was 1.1% ± 2.1, 0.4% ± 1.1, and 0.2% ± 0.5 for 3, 4, and 5 mm PTV margins, respectively. No correlation was found between the union CTV volume outside any PTV margin and the number of treatment fractions, the volume of CTV, or the greatest distance from the isocenter to tumor edge. **Conclusion:** While seemingly significant rotation setup errors were observed, our results indicated that 5 mm PTV margins offer adequate CTV coverage for intrathoracic tumors.

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148 Inter And Intra Observer Variation In Gross Tumor Delineation On MVCT Images In Patients Undergoing Tomotherapy Based IGRT For Postoperative Vault Recurrences.
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Purpose/Objective(s): This study was designed to evaluate inter and intra-observer concordance in gross tumor volume (GTV) delineation on megavoltage CT (MVCT) images. Materials/Methods: Three observers delineated GTV on MVCT and CECT and two observers recontoured on MVCT images. Tumor volumes were calculated and correlated using spearman correlation. The standard deviation of centre of mass was averaged on per patient basis. The ratio of common volume and encompassing volume was used to determine intra and inter-observer spatial concordance for observer variability on MVCT & CECT image datasets of same patients. Lack of difference in spatial concordance ratio between MVCT and CECT images was used as an index of usability of MVCT images. Forty-five image datasets were available for 8 patients. Results: High intra-observer GTV correlation was recorded for observer 1 and 2 (r=0.93 & r=0.98; p= 0.03 and 0.0001). The average intra observer spatial concordance ratio was 0.57 and 0.62 respectively. The mean GTV of observers 1, 2 and 3 were 30.96c (17.9-52.2); 29.86c (15-51.8) and 40.86c (16.7-104.1) respectively. Average standard deviation of centre of mass of all observers was less than 5mm in either direction. Largest inter-observer discordance was observed in anterior, inferior and lateral direction. The inter-observer spatial concordance of GTV on MVCT and CECT images was 0.35 and 0.36 (p = 0.24) respectively. The intra-observer spatial concordance of GTV on MVCT and CECT images was 0.56 and 0.63 (p value not significant) respectively. Conclusions: Moderate to good inter and intra-observer GTV correlation was observed on MVCT images however was associated with low inter-observer spatial concordance on both MVCT and CECT images. Strategies to improve contouring reproducibility on MVCT and KVC images are desirable.


149 The Effect of Cyber knife Therapy on Lung Cancer on Pulmonary Function Test: A Retrospective, Observational Cohort Pilot Study
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Purpose/Objective(s): Background - The current standard of care for early stage Non Small Cell Lung Cancer (NSCLC) for operable patients is invasive local control through surgical resection and for inoperable patients external beam radiotherapy. Both these modes are associated with significant decrease in lung function. Radiotherapy can also cause pneumonitis. There have been significant advances in treatment technology in recent years that will reduce damage to healthy lung tissue during NSCLC treatment. One such treatment is Cyberknife which has the unique ability to track dynamic targets that moves with breathing which in turn limits radiation exposure to normal tissue. No previous studies have specifically documented Cyberknife’s effect on pulmonary function tests (PFTs). This study aims to confirm that in treatment of lung cancer, especially early stage, Cyberknife preserves lung function better than the current standard of care. The objective is to compare pre and post lung function parameters of patients treated with Cyberknife for lung cancer. Materials / Methods: This is an IRB approved, retrospective, observational cohort study of patients diagnosed with lung cancer to determine if there are differences in lung function before and after Cyberknife radiosurgery. PFTs were performed on the group before and after radiosurgery. We included patients of any sex or age diagnosed with primary or metastatic lung cancer who opted for cyberknife treatment and had pre and post treatment PFTs. Data analysis included generation of descriptive statistics to adequately describe the sample. We conducted paired t-tests to determine differences in PFT data pre-operatively and post-operatively. We also conducted subgroup analysis based on gender, location and stage of tumor. We compared eleven components of PFTs including: FVC, FEV1, FEV1/FVC ratio, FEF 25%-75%, FIVC, SVC, IC, ERV, DLCO, DLVA and VA. Results: Thirty-seven patients were included. The mean age of the group was 72.2 years. Paired t-tests indicated that there is no statistical difference between mean PFT measurements in pre-Cyberknife and post-Cyberknife for the overall group and for subgroups based on gender and tumor location. Conclusion: Cyberknife treatment has been shown to be very effective for stage I cancer in multiple studies published in last few years. In our study we observed that Cyberknife is successful in preserving lung function status as was measured by PFTs. In our study we did observe that cyber knife preserves lung function better than the current standards of care and also has better side effect profile. With further studies we hope that cyber knife will come up as better choice and could become the standard of care in the future.


150 Onboard Radiotracer Imaging Via Emerging Region-of-Interest Technologies
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Purpose/Objective(s): Target localization for radiation therapy has been greatly enhanced by onboard transmission imaging, including conebeam CT. However, CT is sensitive primarily to electron density. Higher contrast between tumor and normal tissue - and greater biological relevance - is provided by imaging with radio-labeled biological molecules, as in Single-Photon Emission Computed Tomography (SPECT). SPECT however is generally noisy and requires long scan times. An opening that may allow for markedly enhanced onboard SPECT is that it need image only a small region about the approximately known target location. Notably, such regional imaging is supported by recent developments in principles of truncated imaging. Herein we utilize these principles to design multi-pinhole-collimated SPECT systems and detector trajectories that can substantially out-perform conventional SPECT. Two hardware challenges then are first to achieve the completely sampling trajectories and second to maneuver the detectors about a patient in position for radiation therapy. Herein we propose a novel approach utilizing a robotic arm. Materials/Methods: Projection data are computer simulated for a SPECT system involving a 43cm by 43cm detector and a 3x3 array of pinholes. A 5cm-diameter region in the thorax is considered. A detector trajectory is designed to satisfy complete-sampling principles for the 5cm
region, to maintain 3 cm clearance about the patient, and to otherwise achieve best possible proximity to the 5 cm region. Also considered is a single parallel-hole-collimated detector. In addition, resolution and sensitivity are computed for the 5 cm region. Implementation with a robotic arm is evaluated by computer-aided-design (CAD) programs using realistic models for robot, parallel-hole-collimated detector, therapy linac, and patient table. **Results:** As compared to the single parallel-hole-collimated detector, the 9-pinhole system shows much better visualization and contrast-recovery for structures within the 5 cm region. These results are supported by the resolution and sensitivity calculations, which show the 9-pinhole system to have almost 3 times better resolution at the same sensitivity. The CAD studies demonstrate a parallel-hole-collimated trajectory. **Conclusions:** For regions that are around 5 cm in diameter, SPECT imaging of those regions can be markedly improved by concentrating the available detector surface area around those regions. Simulation studies suggest that a robotic arm is a feasible approach to achieving the completely-sampling regional-imaging trajectories and to maneuvering SPECT detectors about the patient in position for radiation therapy. Taken together, these results imply a substantially enhanced outlook for biological imaging onboard radiation therapy machines via SPECT.

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### 151 Anatomical Dose Tracking for Adaptive Radiation Therapy

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**Purpose/Objective(s):** To introduce a method that allows for inter-fraction modifications to a treatment plan so as to compensate for tumor shrinkage, patient weight loss, and anatomical shifts during a radiation treatment course. This method may lead to reduced morbidity and improved survival for certain patients compared to a therapy course designed using treatment plans produced days or weeks before treatment start. **Materials/Methods:** During the design of a radiation treatment plan, tissue volumes of interest (VOIs) are delineated on CT-simulation images. These delineated initial VOIs that are transferred from the planning-CT to cone-beam CT (CBCT) image volumes serve as the starting point for creating the corresponding VOI structure sets in the CBCT images. In addition, CBCT volumes are registered to the planning-CT volumes by the therapists on the daily basis. The daily change in shape, volume, and position of the VOIs is determined by employing elastic mutual information technique. An electronic portal imaging device (EPID) used for acquiring daily CBCT images of the patient also allows collection of exit fluence images from the patient during the treatment. Actual daily 3D dose distribution delivered to the patient may then be computed from these measured exit fluences by back-projection onto the CBCT volumes. Comparison of the 3D dose distribution in the daily CBCT volumes with each other and the planning-CT allows the attending radiation oncologist to decide whether any change to the course of treatment is required. Temporally integrated dose to each individual voxel is needed in order to assess the tumor control probability and normal tissue complication probability due to damage of organs at risk (OARs), especially serial type OARs. Optical flow and fluid dynamic models are employed to quantify the temporally evolving target and OAR dose voxels. **Results:** Ten patients with various cancers were selected for this study. Visualization of the results included velocity vector maps, time-dose curves, and movie techniques. Noticeable anatomical and dosimetric changes were observed in some patients, especially for lung and head and neck treatments. On the basis of these observations, it is estimated that at least 10% and possibly 40% of patients will benefit from inter-fraction modification of radiation treatment plans. **Conclusions:** Daily CBCT dosimetry using measured exit fluence provides a direct and non-invasive means of determining anatomical imparted dose to VOIs. This information is valuable to assess whether OAR dose needs to be reduced or critical spots in the target corrected. Modification of treatment plans is warranted based on this limited study; however, the technique used to evaluate the importance of adaptive radiation therapy requires more extensive study.


### 152 Six Degrees of Freedom CBCT-Based Positioning System for Frameless Stereotactic Radiosurgery

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**Purpose/Objective(s):** We present a positioning approach for frameless radiosurgery treatment based on in-room volumetric imaging coupled with an advanced six degree of freedom (DOF) image registration technique. The procedure improves accuracy and comfort by avoiding use of a bite block with optical guidance system, making it especially feasible for pediatric patients as well as patients with dental issues. **Materials/Methods:** Patient motion during setup and treatment is restricted by a custom thermoplastic mask. Accurate positioning is achieved by matching an in-room cone-beam CT (CBCT) to the planning CT (PCT) using a 6 DOF rigid registration method customized to use mutual information metric in Mattes’s formulation. In addition to couch shifts, the 6 DOF registration calculates the spin, tilt and couch angles required for precise target positioning. The spin and tilt are applied using a customized couch mount while couch translations and rotation are applied using the treatment console. A second CBCT is acquired to verify positioning with the clinical system before treatment delivery. **Results:** Twenty eight patients consisting of a total of 38 targets and 63 treatment fractions have been delivered at our institution using this advanced positioning approach. To verify system accuracy, an anthropomorphic pediatric phantom test was performed using 4 DOF (Varian 3D review system) and our 6 DOF registration process. The isocenters of delineated targets were computed by our system with an average accuracy of (0.7, 0.2, and 0.5) mm in the vertical, lateral and longitudinal directions. The angular errors were (0.01, 0.2, and 0.01) in spin, tilt and couch rotation. An additional test was performed using the phantom in which known shifts were introduced. Mislalignments up to 10 mm shifts and 3 rotations were recovered to an ideal alignment with differences of 0.2 mm in the anterior-posterior direction, 0.3 mm in the lateral direction and 0.5 mm in the longitudinal direction, and angular shifts of less than 0.3 on any axis. All these values were less than couch motion precision. In clinical patient positioning, mean error in the shifts predicted by the system was 0.5 mm and 0.35, as assessed by a confirmation CBCT scan.

**Conclusions:**
Conclusions: Accurate and efficient SRS positioning without the use of optical guidance is achievable using our 6 DOF registration method. This system is relatively inexpensive compared to a couch-based 6 DOF system, increases patients comfort and allows the treatment of pediatric patients without the need for anesthesia.


153 Proton Radiography for Pediatric Malignancies; Development and Enhancement of a Proton Imaging Technique
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Purpose/Objective(s): Pediatric patients are more susceptible to radiation induced malignancies and toxicities from therapeutic and diagnostic radiation. Proton radiography (PR) is being investigated as a tool for daily set up prior to proton radiation treatment, which would provide improved imaging capabilities along with reduced radiation dose. Furthermore, PR can provide daily pre-treatment in-vivo measurements of proton stopping powers which would reduce proton range uncertainties and improve the accuracy of proton fields delivery with a decrease in the radiation dose compared to diagnostic x-rays and cone beam CT. Materials/Methods: A group of 5 pediatric patients with 1) neuroblastoma, 2) spinal malignancy, or 3) thoracic tumors were used to evaluate the ability of proton radiography to allow real-time tumor tracking, while the tumor is moving within the lung with the patient respiration. Proton radiographic images were generated using a Monte Carlo imaging tool, PR-Imaging, developed at Massachusetts General Hospital and compared with both diagnostic quality x-ray portal images and digitally reconstructed radiographs from CT data. Results: Radiographic images of the lung tumors were generated with simulated PR-Imaging using a scanned proton pencil beam (PBS) at 230 MeV and 490 MeV, and compared to diagnostic X-ray digitally reconstructed radiographs (DRR). Whole body radiographic images for the pediatric patients with conventional X-ray radiograph, and simulated PR-Imaging using a scanned proton pencil beam were also generated and compared. PR images with high resolution comparable to that of a diagnostic x-ray were generated. The X-ray portal images and the X-ray radiographs present better edge detection, while lung tissue to soft tissue boundaries of the tumor were better distinguished in PR images. The imaging tool kit allows the oncologist and radiologist to change windowing level and tumor contrast level relative to soft tissue background. Conclusion: PR-Imaging prior to therapy allows for high quality images that can provide information on range degradation of the proton therapy beam. PR-Imaging during therapy allows for daily quality assurance and tumor tracking during radiation to guarantee that it has been appropriately treated with radiation. PR-Imaging in pediatrics patient can allow the reduction of proton range uncertainties which can affect the therapy. PR- imaging delivers a decrease in the amount of radiation compared to diagnostic x-rays and cone beam CT.

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154 F-18 FDG PET-CT and Bremsstrahlung SPECT-CT in Predicting Survival in Patients with Unresectable Metastatic Melanoma to Liver Undergoing Yttrium-90 (Y-90) Radioembolization: A Preliminary Study
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Purpose/Objective(s): Malignant melanoma is an aggressive cancer with frequent systemic metastases to the liver associated with poor prognosis. We investigated PET-CT and Bremsstrahlung SPECT-CT prognostic factors for survival in patients with unresectable metastatic melanoma to liver undergoing Y-90 radioembolization. Materials/Methods: Patients with unresectable metastatic melanoma to liver who underwent F-18 FDG PET-CT prior to Y-90 were studied. Pretreatment PET-CT scans performed on a Discovery LS system (GE, Waukesha, WI) were analyzed using Mim 5 (Mim Software Inc, Cleveland, OH). The three largest FDG-avid tumors with minimum long axis diameter of 1 cm and minimum max SUV of 2.5 were identified as target tumors. The target max SUVs, total glycolytic activities and volumes were summed. Target metabolic tumor burden was calculated by dividing the summed target volume by total liver volume. Treatment Y-90 Bremsstrahlung SPECT-CT scans performed on a Symbia system (Siemens, Germany) were analyzed using Mim 5. Mean counts per mL of the target tumors and a background region were determined and the ratio of target-to-background mean counts was calculated. Statistical analysis was performed with SPSS 16.0 using Kaplan Meier estimator and Cox proportional hazards methods. Results: Thirteen patients (5 women and 8 men; mean age of 55.1 years) were studied, 5 with cutaneous primary melanoma and 8 with ocular primary melanoma. Overall survival rates from 1st Y-90 at 30 days, 6 months, and 1 year were 92%, 74% and 21%, respectively, with median survival of 305 days (95%CI 214-395). Mean target metabolic tumor burden was 9.7% and mean target TGA was 2115.9 SUV*mL. Target metabolic tumor burden (p=0.02) was found to be a significant predictor of survival from 1st Y-90 on univariate analysis and total glycolytic activity (p=0.09) showed a trend towards significance. Overall max SUV (p=0.21) and sum of target max SUVs (p=0.26) were not found to be significant. The ratio of target-to-background mean counts on Bremsstrahlung SPECT-CT was not found to be significant (p=0.19). Conclusion: Our preliminary study shows metabolic tumor burden based on the three largest FDG-avid lesions on pretreatment F-18 FDG PET was found to be a prognostic marker of survival after Y-90 in the treatment of metastatic melanoma to liver. Total glycolytic activity showed a trend towards significance.

155 Guiding Therapy by Repetitive Measurements of Tumor Oxygen
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The level of oxygen in a tumor is one of the most important factors that affect the response to therapy. The level of tumor oxygen changes with disease progression and with therapy in a complex and unpredictable manner, so that direct measurements are needed to follow it repeatedly under clinically applicable conditions. With such information available it should be feasible to enhance and individualize therapy by delivering single or multimode therapy at the times of most favorable oxygen levels in the tumor. We have developed an approach, based on electron paramagnetic resonance (EPR) that now makes it feasible to make such measurements in the clinical setting under conditions compatible with clinical routines. These in vivo measurements are made using low frequency (1.2 GHz) EPR spectroscopy and surface loop resonators, which enable measurements to be made in vivo at superficial sites, providing direct, non-invasive (after placing the ink in the tissues), repeatable measurements of tissue $pO_2$. Ongoing EPR oximetry studies in human subjects include oximetry in tumors during courses of radiation and chemo-therapy, where hypoxia can limit efficacy and measurement of subcutaneous $pO_2$ in the feet of healthy volunteers to develop procedures that could be used in the treatment of peripheral vascular disease. In each case, we aim to provide quantitative measurements which will aid physicians in the characterization of disease status and the effects of therapeutic measures, so that treatments can be applied with optimal effectiveness by taking into account the oxygen-dependent aspects of the therapy. The overall goal is to enhance clinical outcomes. Tumor oximetry measurements have been performed in tumor tissues of 12 patients during courses of radiation and chemotherapy. Tumor types include melanoma, basal cell, soft tissue sarcoma, and lymphoma, and measurement sites have ranged from the feet to the scalp. Oximetry measurements of subcutaneous tissue on dorsal and plantar foot surfaces have been made in 12 volunteers, with measurements ongoing for each and the longest set of measurements carried out successfully over the last 5 years. These studies demonstrate the feasibility of EPR oximetry in a clinical setting and the potential for more widespread use in the treatment of these and other oxygen dependent diseases. Ongoing developments include the expansion of the technique to determine $pO_2$ in operative fields after irradiation, in wound healing, and in restorative oncological surgery; extension of the technique to measure at greater depths using implantable resonators; and the development of capabilities to make the measurements at the bedside and in the operating room. Extensive measurements are planned in head and neck, breast, cervical, and prostate cancers.


156 Integrated Interventional Oncology and Implanted Fiducial Marker Image Guided Intensity Modulated Radiation Therapy for Spinal Metastases
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Purpose: Interventional oncology and radiation oncology can sometimes be conceived as separate or competing treatment modalities; however, disciplinary models emphasizing rivalry are seldom productive. We present a new treatment strategy for the palliation of spinal metastases integrating radiologic spine instrumentation for radiofrequency ablation (RFA), cement vertebroplasty, and implantation of fiducial marker seeds with image guided radiation therapy (IGRT) and intensity modulated radiation therapy / radiosurgery (IMRT / IMRS). Methods: Spinal targets in patients with metastatic malignancy were identified as potential targets for integrated RFA, cement vertebroplasty, implanted fiducial marker seeds, and IGRT-IMRT. RFA created a cavity within affected vertebra so that the risk of hematological dissemination during cement vertebroplasty could be minimized. In lesions with neural canal impingement, RFA cavity creation can prevent retropulsion of tumor/bone debris posteriorly. Vertebroplasty improves spinal stability and strength resulting in early pain relief for all patients. Implantation of fiducial marker seeds for IMRT can be performed either immediately before or after vertebroplasty. IGRT-IMRT / IMRS was initiated 2 weeks after interventional oncology procedures. A patient with cord impingement by epidural tumor resolves completely after the combined therapy. There was no major complication seen. There was no tumor recurrence at any of the treated levels up to the present time. Results: Ten vertebral levels in seven patients were treated with the integrated methodology. All patients achieved durable pain relief. A patient with cord impingement by epidural tumor resolved completely after the combined therapy. There was no major complication seen. There was no tumor recurrence at any of the treated levels up to the present time. Conclusions: This combined treatment strategy utilizes the disciplinary strengths of both radiology and radiation oncology departments. Imaging localizes the target lesions and provides direct anti-tumor action through percutaneous RFA while also providing bone strength through vertebroplasty. Fiducial marker seeds are implanted in the same sitting to guide IMRT or IMRS. Targeted radiation therapy (IMRT / IMRS) then provides long term durable control for excellent palliation.

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157 Dose Perturbation in the Presence of High Z inhomogeneity in External Beam Radiotherapy
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Purpose/Objective(s): Treatment planning of the pelvic area for patients with artificial hips has remained a challenge in conventional radiotherapy as the commercial treatment planning systems (TPS) are not able to model the dose perturbations at the interfaces. Monte Carlo based TPS are expected to account for the dose increase near a high-Z inhomogeneity. The purpose of this study is to compare the results of Monaco, a Monte Carlo based TPS (CMS), with the Superposition and Convolution algorithms employed in XiO (CMS). The calculated central depth dose curves were also compared with the experimental measurements. Materials/Methods: A simple solid water phantom was designed that comprised a 7x7x3 cm³ stainless steel cast in wax with its proximal surface positioned at 5cm depth. Central axis percentage depth dose curves (PDD) were measured using a NACP chamber and a PTW diamond detector. The simplicity of the phantom enabled manual creation of identical geometry in the TPS and relative electron densities were forced to the corresponding structures. Central depth dose curves were
calculated for two energies (10 and 15MV) and two field sizes (5x5 and 10x10cm²). **Results:** The standard non MC algorithms do not calculate the dose perturbation at the high-Z interface showing a 14% difference with measurements at 10MV. The MC algorithm was the only software able to compute the dose perturbation and backscatter at the boundaries with an overall difference of 5% with the experimental results. However, the peak of the backscatter simulated by Monaco appears to be slightly shifted with respect to the measurements. Similar results were obtained with a 15MV photon beam. **Conclusions:** A preliminary study comparing measured with modeled dose perturbations in the presence of high-Z inhomogeneity has been presented. The MC algorithm models the dose perturbation at the solid water-metal interface more accurately than the conventional TPS algorithms. Due to the over-response of the NACP chamber at the inhomogeneity interfaces, further experimental measurements are required to be performed with a single array prototype dosimeter (DOSI) to assess the performance of Monaco at high-Z material interfaces.

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### 158 Single Institution Experience with Drug Eluting Bead Chemoembolization for Hepatocellular Carcinoma

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**Purpose:** To evaluate lesion response and survival in patients in a single institution treated for hepatocellular carcinoma with doxorubicin drug eluting bead (DEB) embolization. **Materials/Methods:** Data on patients undergoing drug eluting bead chemoembolization for hepatocellular carcinoma at a single tertiary care institution from October 2005 through August 2008 were collected in an institutional database. Patient data collected pre-procedure included Childs classification, mean lesion size, hepatitis status and other risk factors, and ethnicity. Lesion response was evaluated using the RECIST criteria. Patient outcomes, including survival and peri-procedural complications, were recorded. **Results:** 125 patients underwent a total of 203 treatments, with a median follow up of 9 months. Lesion response rates were as follows: complete response (CR) of target lesion 38/203 (18.7%); partial response (PR) of target lesion 47/203 (23.1%); stable disease (SD) 79/203 (38.9%); progressive disease (PD) 28/203 (13.8%). Total liver response rates were: CR 18/203 (8.9%); PR 53/203 (26.1%); SD 85/203 (41.9%); PD 54/203 (26.6%). **Conclusions:** Drug eluting bead chemoembolization has largely replaced standard triple drug therapy trans-arterial chemoembolization with ethiodized oil. Our data demonstrate that the target lesion response rates with DEB chemoembolization are excellent. While the majority of responses were favorable for both target and non target lesions, progressive disease occurred with nearly twice the frequency in non target lesions when compared to target lesions, reflecting the underlying disease state.

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### 159 Interactive 3D Visualization for Radiation Treatment Planning

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**Purpose/Objective(s):** The goal of radiotherapy treatment is to deliver a lethal radiation dose to target tissue regions while limiting exposure to nearby critical structures. Planners must understand spatial relationships between 3D image data, beam configurations, segmented anatomic structures, and dose distributions. Current planning tools typically rely on 2D visualizations such as slice-by-slice views with contour overlays, which make 3D relationships difficult to interpret. When 3D views are available, they lack interactivity, speed, and the ability to show relationships between multiple data sources such as CT and MRI. Hardware-accelerated multi-source volume rendering is a new technology capable of providing interactive 3D views of complicated radiotherapy planning scenes. Such visualizations create a rapid and more complete understanding of 3D spatial relationships when compared to traditional 2D views. The goal of this research is to leverage interactive 3D visualizations to improve efficiency and accuracy in a number of identified clinical planning tasks. **Material/Methods:** We integrated an interactive 3D visualization system into our standard clinical radiation therapy planning software, PLanUNC. The rendering engine is novel and unique in its capabilities. It is optimized to produce displays that are conditioned on information from multiple data sources, such as serial and cross-modal 3D images, radiation dose distributions, beam shapes, and the boundaries of anatomic structures. The system uses an object-order rendering framework along with graphics shader programs to produce interactive displays of multi-source scenes on commodity graphics hardware. In particular, this enables novel 3D views of radiation treatment plans with dose overlays painted onto anatomic surfaces and throughout the volume images. **Results:** Our enhanced 3D planning software is being evaluated for clinical application in chart round review, anatomic structure segmentation, beam design, image-to-image registration, and dose distribution evaluation. In an initial case series of six patients, the system has successfully integrated and illustrated anatomy of the head and neck, male pelvis, lower extremities, and thorax across multiple imaging modalities. **Conclusions:** Enthusiastic initial feedback from the pilot suggests that interactive 3D visualizations are likely to improve planning efficiency and will be readily adopted at our institution as standard of care in radiation treatment planning. Future research will quantify the value of this system for planning efficiency and quality assurance. Further applications such as volume animation to assess the effect of daily anatomic variation on dose accumulation have been prototyped.

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### 160 Comparing Prostate only 3DCRT and IMRT: Dosimetric Gains Using CT versus CT-MRI Fusion and DMPO

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**Purpose/Objective(s):** MRI is believed to improve prostate contour delineation. This study explores the advantage of CT-MRI fusion versus CT alone along with DMPO and its dosimetric gains. **Materials/Methods:** 5 patient pelvic data sets (CT & MRI for each) were acquired using a Phillips Brilliance Big Bore CT scanner and SONATA MRI scanner (1.5 Tesla). The data sets were imported in to the Pinnacle 8M version 8
TPS. The CT was fused with its corresponding MRI using a mutual information algorithm. 10 data sets were available (5 CT & 5 CT-MRI fusion). Each data set was used to construct the following volumes of interest: Gross tumor volume (GTV), clinical target volume (CTV), planning target volume (PTV), rectum, bladder, penile bulb and femoral heads. Contouring was jointly evaluated by a radiologist & radiation oncologist. Intensity modulated radiotherapy (IMRT) & 3 dimensional conformal radiation therapy (3DCRT) plans were generated for each data set thus creating a total of 20 plans targeting the prostate and seminal vesicles only. The prescription dose was 79.2 Gy in 44 fractions. Direct machine parameter optimization (DMPO) was utilized during IMRT planning. Volume based dosimetric comparisons were done using dose volume histograms. Monitoring units were also calculated for each plan. The results were analysed statistically using the student’s t’ test & Mann-Whitney test where appropriate. Results: The median PTV & CTV V98 were 99.9% & 100% respectively for all plans. Median values for the CT-MRI fusion IMRT: bladder (cc) V15: 81.04, V25: 66.63, V35: 53.65, V50: 40.36; rectum (cc) V40: 24.48, V50: 21.44, V65: 17.39, V70: 16.39, V75: 14.79; femoral head dose maximum: 47.14 Gy, bulb of penis: dose maximum: 74.13 Gy, mean dose: 32.22 Gy, D30: 54.08 Gy, D50: 27.34 Gy, D70: 14.81 & monitoring units: 291.40 MUCT-MRI fusion IMRT was superior to 3DCRT for the bladder (V15, p=0.023; V25, p=0.022; V35, p=0.022; V50, p=0.015). CT-MRI fusion IMRT was superior to CT-MRI fusion 3DCRT for the rectum & femoral heads (V40, p=0.043; V50, p=0.043; V65, p=0.043; V70, p=0.043; V75, p=0.016 for the rectum & p=0.005 for the femoral heads). The monitoring units were significantly less for CT-MRI fusion IMRT vs. CT-MRI fusion 3DCRT & 3DCRT (p=0.01) whereas there was a trend observed for superiority over CT-IMRT (p=0.073). No difference was observed for the bulk of penis (dose maximum, mean dose or D30, D50 & D70, p=NS). Conclusions: While dosimetric coverage of CTV and PTV were comparable among each of the 4 plans created for each patient, considerable sparing of organs at risk was achieved with IMRT using CT-MRI fusion as compared with 3DCRT alone. DMPO based IMRT planning allowed reduction in monitoring units which was greatest for CT-MRI fusion IMRT.


161 Investigation of 4DCT-based Functional Images for Function-Guided Radiation Therapy
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Purpose/Objective(s): Ventilation-guided treatment planning may suffer from the problem that tissue damage at one place may impact ventilation function in remote regions. In this study, we will present a method to calculate the compliance of the local alveoli and tissues in the lung, and show that the resultant compliance images are not sensitive to the mechanical variations and can be potentially used for assessment of radiation injury. Materials/Methods: Six 4DCT images were investigated in this study: one previously used in the generation of a POPI model, and the other five acquired in our institute. A tetrahedral geometrical model was created and scaled to encompass each of the 4DCT image domains. Image registrations were performed on each of the 4DCT images using a multi-resolution Demons algorithm. The images at the end of exhalation were selected as a reference. Images at other exhalation phases were registered to the reference phase. For the POPI-modeled patient, each of these registration instances was validated using 40 landmarks. The displacement vector fields (DVF) were used first to calculate the ventilation images. With the computed DVF, a finite element framework was developed to compute the stress images of lung tissue. The regional compliance was then defined as the ratio of the ventilation and stress values, and calculated for each phase. The effect of the parameter variations on the computed stress distributions was estimated using Pearson correlation coefficients. Results: For the POPI-modeled patient, five exhalation phases from the start to the end of exhalation were denoted by i=1,...,5 respectively. The average lung volume variation relative to the reference phase (P) was reduced from 18% at P1 to 4.8% at P5. The average stress at phase P was 1.42, 1.34, 0.74, 0.28 kPa, and the average regional compliance was 0.19, 0.20, 0.20, and 0.24, for i=1,...,4, respectively. For the other five patients, their average R, value was 21.1%, 19.6%, 22.4%, 22.5% and 18.8%, respectively. The regional compliance averaged over all six patients is 0.2. For parameters chosen from the potential parameter range, the resultant stress distributions were found to be similar to each other with Pearson coefficients greater than 0.81. Conclusions: In this study, we have presented a deformable mesh-based method to calculate three-dimensional ventilation and stress images. Their ratio represents the compliance of local ventilation units (alveoli) in the lung. Changes in compliance reflect potential radiation injury in lung tissue. Therefore the compliance images may be useful for function-guided radiation treatment planning.

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162 Usefulness of Implanted Markers for Set Up of Lung Cancer Patients: Interfractional Positional Variability of Fiducial Markers in Locally Advanced Non-Small-Cell Lung Cancer
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Purpose: Current set-up of lung cancer patients for radiotherapy is based on bony anatomy and does not account for variations in tumor motion, deformation, or volume changes which may result in geographical miss. The present study investigates the usefulness of implanted markers as a surrogate for tumor-based set up during image-guided radiotherapy. Materials and Methods: Seven patients with locally advanced non-small cell lung cancer were implanted with gold coils bronchoscopically. Patients underwent same day 4D fan beam computed tomography (4D FBCT) imaging for confirmation of marker placement and treatment planning and daily 4D cone beam CTs (4D CBCTs) prior to each treatment session. Markers, tumor, and a reference bony structure (vertebra) were contoured for all 10 phases of the 4D FBCT and weekly 4D CBCTs. The interfractional displacement of the mean marker and tumor centroid position relative to bony anatomy and markers relative to tumor were determined using the 4D FBCT as a reference. Results: The systematic/random interfractional marker-to-bone displacement was 1.5/3.4, 4.3/4.5 and 3.6/4.3 mm in the x (lateral), y (anterior-posterior), and z (superior-inferior) directions. The systematic/random tumor-to-bone displacement was 2.2/3.2, 7.4/5.8 and 6.2/5.5 mm in the x, y, and z directions. The systematic/random marker-to-tumor centroid displacement was 2.3/2.6, 2.2/2.4 and 4.9/3.3 mm in the x, y, and z directions.
Conclusion: Marker position relative to tumor remained comparatively stable throughout treatment and was smaller than tumor-to-bone displacement. Although fiducial marker based image guidance may decrease the risk for geometric miss of the tumor, displacements between markers and tumor centroid still require a safety margin of 11.3 mm for this patient cohort.

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163 Quality Assurance (QA) Methods For Deformable Image Registration: Measures For Evaluating Displacement Fields In Clinical Settings
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Purpose/Objective(s): Deformable registration migrated from a research topic to a widely adopted clinical tool that describe the motion and soft tissue deformation of in vivo imaging datasets. While various mathematical formulations have been reported in literature and implemented in commercial software, we lack a straightforward method for quality assurance of a given deformable image registration solution. Our aim was to develop quantitative metrics of registration quality that are algorithm-independent, labor-efficient, and precisely identify errors in a given displacement field. Materials/Methods Proposed quality assurance (QA) framework uses concepts derived from vector analysis to identify unrealistic anatomical motion in a displacement field. Our central theme is identification of vortexes in the displacement field that do not correspond to the underlying anatomical changes. Vortexes are detected and their intensity quantified using the CURL operator and presented as a vortex map overlaid on the original anatomy for rapid identification of problematic regions. Additionally, complementary features of the displacement field such as regions of compression/expansion are identified through the determinant of the Jacobian matrix. Results: We show application clinical scenarios of adaptive radiotherapy and treatment response assessment, where the CURL operator quantitatively detected errors in the displacement field and identified problematic regions that were invisible to classical voxel-based evaluation methods. These unrealistic deformations are not visible when using the standard voxel-based solution evaluation methods. However, they produce erroneous results when the deformable solution was applied on a secondary dataset such as dose matrix in adaptive therapy or PET data for treatment response assessment. Conclusions: The proposed QA framework for deformable image registration provides increased usability and accuracy in detecting unrealistic deformable registration solutions when compared to standard intensity-based approaches. It is computationally efficient and provides a valuable platform for the clinical acceptance of deformable image registration in image-guided radiation therapy.

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164 CT Perfusion As A Surrogate Biomarker In Predicting Tumor Biology And Response To Anti-Angiogenic Therapy In Soft Tissue Sarcoma: Comparing With Tumor Size, Tumor Density, Tissue Biomarkers, Circulating Biomarkers And Gene Expression
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Purpose/Objective(s): To evaluate the role of CT perfusion in predicting tumor biology and monitoring response to antiangiogenic therapy in soft tissue sarcomas in correlation with tumor size, tumor density, tissue biomarkers, circulating biomarkers and gene expression. Materials/Methods In this ongoing clinical trial, 20 patients (13M: 7F, age range 25-75, mean 55 yrs) with STS underwent CTp and diagnostic CECT on 16-MDCT at baseline and 10 days after treatment with antiangiogenic (Bevacizumab) treatment alone as well as after completion of 6 weeks of antiangiogenic and XRT. CTp parameters (BV, BF, PS and MTT) were estimated (GE Perfusion 3). The tumor size and density measurements (HU units) were also recorded on the diagnostic CT images. The percentage change in tumor attenuation and CTp parameters was estimated comparing the baseline and post treatment values. Correlation of the CTp was also performed with microvessel density, circulating biomarkers (VEGF, PlGF and TNF). Results: At day 10 following antiangiogenic therapy, significant change in CTp parameters and tumor density was observed (pre-55±22 HU and at 10 days-45±18 HU, mean HU change -16.2%, p=0.001 and mean CTp change (17-30%)=p=0.05) and similar findings were noted after completion of treatment (6 wks) (pre-55±22 HU and post-30.9±20.4 HU, mean HU change -25.4 (44.1%), p=0.003 and mean CTp change (17-30%)=p=0.01). Higher grade tumors had higher baseline perfusion compared to lower grade tumors (p<0.01). The drop in CTp during antiangiogenic therapy correlated with fall in tissue biomarkers (MVD, r=0.5) and elevation of circulating biomarkers (VEGF and PlGF levels). Tumors with higher baseline perfusion values showed superior response to treatment and atleast 20 different genes were differentially expressed between the patients with high perfusion and low perfusion tumors. Conclusion: CT perfusion is a robust method for monitoring early and late treatment response to antiangiogenic and radiation therapy comparing to tumor size and tumor density. The tumor vascularity changes depicted by CTp correlate with changes in tissue and circulating biomarkers. Baseline tumor perfusion correlates with genetic expression which can predict treatment response.


165 Three-component Molecular Composition Map of the Breast using Dual Energy Mammography: Distinguishing Findings in Benign and Malignant Lesions
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Purpose/Objective(s): To investigate the relationship between diagnosis and breast composition map in women with abnormal findings in their breast. The long-term goal of this project is to develop a technique that will improve the specificity of mammography diagnosis. Materials/Methods: Following prior work using a phantom model and IRB approval, a pilot study of 9 women who had previously undergone mammography with a BI-RADS 4 classification underwent an additional custom high energy/low dose scan as part of a pilot study investigating the use of breast composition mapping in mammography. We used the standard low energy mammography image, the custom high energy image, and a thickness map of a custom phantom to derive the pixel-by-pixel water, lipid, and protein thicknesses of the breast. These
estimates were calibrated using custom phantoms containing varying thicknesses of solid water (water-equivalent), machinable wax (lipid-equivalent), and Delrin (protein-equivalent). The resulting blinded images were compared to the diagnosis of a trained radiologist and the local variation in the estimated water/lipid/protein content was measured. All images were taken using a Hologic Selenia Digital Mammography System (Hologic, MA). Truth was ascertained by a sample of the biopsy tissue being broken down into the three components. **Results:** The women participating in the study displayed a variety of breast abnormalities, both benign and malignant. These abnormalities were clearly distinguishable in the molecular composition map because they displayed distinctive compositional signatures. For example, a woman diagnosed with a small invasive carcinoma Gd 2 with mucinous features displayed strong increase in water content in combination with strong decrease in lipid and protein content. Breast composition maps of women with other breast abnormalities showed different signatures. Examples of the findings will be demonstrated. Updated data will be presented since this was first presented at RSNA 2010. **Conclusion:** Breast compositional imaging provides unique information beyond the standard presentation mammogram that further distinguishes breast abnormalities. Unusual compositional signatures are emerging for different types of breast abnormalities. This technique is relatively easy to implement on standard full-field digital mammography systems. **CLINICAL RELEVANCE/APPLICATION:** This technique is clinically relevant because it is expected to improve the specificity of mammography diagnosis and reduce the number of false positive results requiring biopsy.

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**166 Perfusion and Diffusion-weighted MR Imaging for Characterization of Recurrent Gliomas Before and After Treatment with Stereotactic Radiosurgery and Bevacizumab**

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**Purpose/Objective(s):** High grade gliomas have increased vascular permeability, perfusion, and levels of interstitial fluid compared to surrounding normal tissue. Dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) interrogates tumor vasculature, while diffusion-weighted magnetic resonance imaging (DW-MRI) evaluates microscopic water diffusion. This prospective pilot study uses DCE-MRI and DW-MRI to investigate whether changes in tumor vasculature and diffusion restriction occur following treatment of recurrent gliomas with stereotactic radiosurgery (SRS) and bevacizumab (BVZ). **Materials/Methods:** Human subjects with recurrent high grade gliomas up to 5 cm in maximum dimension were eligible (accrual goal: 15). Patients with lesions <3 cm were treated with single fraction SRS per RTOG 90-05 guidelines. Patients with 3-5 cm lesions received five 5-Gy SRS treatments. All received BVZ within 24 hours before and two weeks after their first SRS treatment. Patients underwent DCE-MRI and DW-MRI 24-96 hours before BVZ (“baseline”), 7 days after SRS (“post1”), and 2 months after SRS (“post2”). MRI data were analyzed to evaluate treatment-related changes in perfusion indices (Ktrans, AUC, EVF) and apparent diffusion coefficient (ADC), with gross tumor volume as the region of interest. Paired two-sample t-tests determined whether significant changes in perfusion indices or ADC occurred with treatment. **Results:** Eleven subjects have been enrolled. Ten have undergone baseline and post1 imaging, and six have undergone imaging at all three time points. Median baseline mean Ktrans, mean AUC, mean EVF, and mean ADC were 160 min\(^{-1}\), 127 mmol/kg/s, 51, and 318x10\(^{-6}\) mm\(^2\)/s, respectively. Mean Ktrans, mean AUC, and mean EVF did not change significantly from baseline to post1 imaging, but decreased from baseline to post2 imaging (Δmean Ktrans = -97 min\(^{-1}\), p = .03; Δmean AUC = -304 mmol/kg/s, p = .05; Δmean EVF = -83, p = .04). Mean ADC did not change significantly from baseline to post1 or post2 imaging. **Conclusion:** Treatment of recurrent gliomas with SRS and BVZ results in decreased Ktrans, AUC, and EVF by two months posttreatment, implying reduction in tumor permeability and perfusion. ADC does not seem to change with treatment. This study continues to accrue.

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**167 AdC Values Of Diffusion Weighted 3T MRI for Diagnosis Of Different Histotypes In Malignant Renal Tumors. Correlation With Cellularity.**

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**Purpose/Objective(s):** To correlate AdC value of diffusion-weighted (DW) MRI at 3 Tesla (3T) with tumour cellularity in different histotypes of malignant renal tumors. **Materials/Methods:** 10 normal volunteers and 28 Patients with histologically proven malignant renal lesion (18 clear cell Ca, 4 papillary variant Ca, 3 chromophobe cell Ca, 1 sarcomatoid Ca, 2 transitional cell Ca) underwent MRI of kidney by using a 3 T superconductive magnet (Phillips Achieva, Best, The Netherlands). Diffusion Weighted (DW) images were obtained in the axial plane during breath-hold (19 seconds) with a SE-EPI single shot sequence (TR 2275 ms; TE 58 ms; FA 90°; EPI Factor 53; Thickness 5 mm) with max b factor of 500 s/mm\(^2\). Axial dynamic contrast-enhanced 3D T1 FFE fat-sat sequence was performed in all patients. All lesions were surgically resected and the mean tumor cellularity was calculated as the number of tumour cell nuclei in 10 high-magnification fields in area without regressive phenomena. Comparison between tumour cellularity and the mean AdC value were performed using simple linear regression analysis. **Results:** Mean AdC value in normal renal parenchyma was 2.35 ± 0.31 x 10\(^{2}\) mm\(^3\)/sec, while mean AdC value in malignant renal tumours was 1.69±0.24 x 10\(^{2}\) mm\(^3\)/sec. In our series there wasn’t a statistically significative difference between AdC values of different histotype (1.73 ± 0.8 clear cell Ca, 1.84 ± 0.4 papillary variant Ca, 1.67 ± 0.9 granular cell Ca, 1.71 ± 0.3 sarcomatoid variant Ca, 1.46 ± 0.6 transitional cell Ca). The analyses of mean AdC values showed an inverse linear correlation with cellularity in malignant renal tumours with a Pearson’s correlation coefficient r = -0.71 (p<0.01). **Conclusion:** 3T DW MRI seem to be a feasible and reliable technique to differentiate different histotypes of malignant renal tumors on the basis of tumour cellularity.

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Hepatic Perfusion in Cancer Patients Measured with Free Breathing Dynamic Contrast Enhanced (DCE) CT Protocol


Purpose/Objective(s): Determine perfusion values in liver tumor and normal tissue using a free breathing DCE CT protocol with a posteriori automatic motion correction. Materials/Methods: 14 patients with hepatomas were scanned with a free-breathing axial shuttle CT perfusion protocol. The scan was performed by imaging two contiguous 4 cm sections of liver using the axial shuttle mode to cover an 8 cm volume; each section was scanned at least 40 times alternately while 40 ml of contrast agent was injected at a rate of 4 ml/sec1. Z-axis respiratory motion correction (RMC) was performed with an iterative correlation algorithm, matching high contrast organ features such as organ edge, tumor edge or hilum. The raw and corrected images were processed with CT Perfusion 5 to generate the temporal average, hepatic arterial fraction (HAF), total blood flow (BF), blood volume (BV), arterial blood flow (ABF), portal venous blood flow (PVBF) and permeability surface product (PS) maps. Tumor functional values were measured in automatically segmented ROIs, normal values were measured in ROIs drawn manually at least 1 cm from nearest tumor edge on time averaged anatomic CT. Results: Using two-tailed paired students t-test we found tumor BV to be significantly lower than healthy tissue by 23% with RMC and 26% without RMC (p<0.01). Tumorous tissue had significantly higher PS (32% with RMC, 65% without RMC), HAF (57% with RMC, 55% without RMC) and ABF (37% with RMC, 27% without RMC) than normal tissue (p<0.01). PVBF showed no difference between tumor and normal tissue, in scans with and without motion correction. Tumor BF trended higher than normal tissue (p=0.06 and p=0.04 with and without motion correction). Only BF and PVBF in tumor changed noticeably due to motion correction, both decreasing after motion correction, BF by 8% (p=0.05) and PVBF by 9% (p=0.08). The coefficient of variation did not change significantly in any functional parameter due to motion correction, although in PS it decreased by 26% (p=0.09) and in PVBF increased by 16% (p=0.08). Conclusions: Our findings suggest that liver tumors undergo rapid angiogenesis which selectively increases the arterial blood supply to the liver. Tumor blood vessels are more permeable than normal liver blood vessels, which is similar to other tumor sites. Liver tumors have low blood volume but a high rate of flow which may indicate local hypertension. Motion correction did not change the mean value of the calculated functional parameters nor did it change significance or trends when comparing cancerous and normal tissue. No significant drop in variance relative to mean in any functional values indicates that motion correction may not be necessary in most cases with proper choice of algorithm parameters when calculating liver perfusion maps.


Single Photon Emission Computed Tomography (SPECT) and Computed Tomography (CT) Registration for Liver Stereotactic Body Radiotherapy (SBRT).

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Purpose/Objective(s): Describe a method to register 99mTc sulfur colloid SPECT with SBRT treatment planning CT imaging to identify normal functioning liver and splenic parenchyma with increased precision for liver SBRT. Materials/Methods: Eleven liver SBRT patients underwent SPECT and respiratory gated 4D-CT using a custom VacLoc bag for immobilization. To reduce uncertainty in registration, up to nine radiopaque markers, 1 mm in diameter, were placed on the patient’s surface prior to the 4D-CT. To minimize potential anatomical changes due to stomach, bowel or bladder filling, patients were positioned in the VacLoc bag for the SPECT scan within 2 hours of completing the CT scan. The markers on the patient’s surface were replaced with 99mTc labeled markers showing as 1.5 mm diameter circles on the SPECT image. To enable contouring of the photogenic normal liver parenchyma, the SPECT 3D liver image was converted to slices using MatLab (Natick, MA). Once the slices were obtained, the free breathing CT and SPECT images were registered by two methods using the LEONARDO multi modality workplace software (Siemens Inc., Malvern PA). First, the markers were ignored and registration was based on identifying the liver on the SPECT and CT images. In the second registration method the markers were first used to obtain a global registration, which was then fine-tuned using the liver information. The average distance between the centers of the SPECT and CT markers was recorded after each registration. The physician then contoured volumes of photogenic SPECT normal liver parenchyma (SPECT-NLV) on the registered images and the contours were incorporated into 3D-conformal treatment planning. Results: The mean SPECT-to-CT markers distance over all patients was 8.6 mm (range 28.05/2.20) for the liver-only registration method and 6.3 mm (range 20.14/1.10) for the markers and liver combination method. While the data appears to show that both registration methods yield similar results, there are inherent difficulties in fusing a non-anatomic image such as SPECT to a CT scan without the use of external markers. In some cases the lesions in the liver can be identified on both images and can be used as ideal landmarks. However in most cases, using the markers gives a greater degree of confidence in the fusion process. Additionally, the use of the markers as a starting point for the registration results in a significant decrease in the registration time. Conclusions: Due to the inherent problems encountered when trying to fuse a non-anatomic image to a CT scan, the use of 99mTc markers allowed for a more robust registration in a shorter amount of time.


Deformable Imaging Capability for the Three-dimensional (3D) CT Atlas of the Brisbane 2000 System of Liver Anatomy

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Background: With the increasing use of stereotactic radiosurgery and brachytherapy techniques by radiation oncologists, there is an increasing need for useful radiologic correlation with surgical anatomy. Purpose/Objective(s): Herein, we display deformable imaging capability for the

Materials/Methods: The International Hepato-Pancreato-Biliary Association has formulated a terminology to deal with confusion in the nomenclature of hepatic anatomy and liver resections, The Brisbane 2000 Terminology of Liver Anatomy and Resections, which is anatomically and surgically correct. Hepatic surgeons rely on the Brisbane 2000 terminology as the descriptive gold standard. We applied this anatomic terminology by contouring the Brisbane segments as well as hepatic vessels on axial slices of a portal venous phase diagnostic CT of a normal liver. Software was used to reconstruct these images into a 3D data set. Anatomic accuracy was confirmed by a multidisciplinary panel with representatives from radiology, hepatic surgery, and radiation oncology. A proprietary deformable registration algorithm is used to transform the Brisbane system atlas to the patient specific planning volume thereby providing detailed anatomical segmentations within the patient space. Results: Hepatic segments (I, II, III, IVa, IVb, V, VI, VII, and VIII) were successfully produced by first considering the three functional livers: the right, the left and the caudate. The relevant hepatic vessels (inferior vena cava, left hepatic vein, left portal vein, middle hepatic vein, portal vein, right hepatic vein, and right portal vein) as well as the relevant anatomic planes were contoured. Deformable image registration technology allows for pretreatment contouring as well as post-treatment response evaluation. Conclusions: The surgical gold standard Brisbane 2000 system of liver anatomy has now been successfully adapted into a 3D atlas for imaging and radiation treatment planning with deformable registration used to transform the atlas into the patient specific planning volume. This model creates a common system for defining extent of anatomic disease that can facilitate contouring, treatment planning, and follow-up response evaluation enhancing standards of communication and reporting.


171 Stereotactic Body Radiotherapy (SBRT) for Patients with Unresectable Liver Tumors Utilizing Single Photon Emission Computed Tomography (SPECT) Co-Registered with Computer Tomography (CT) for 3-D Conformal Treatment Planning A. V. Kirichenko, K. Kotinsley, E. Day, K. Baxter, D. Werts, W. McWilliams, D. Parda, Allegheny General Hospital, Pittsburgh, PA

Purpose/Objective(s): SPECT provides functional imaging of the liver parenchyma through uptake of radioactive colloid by Kupffer cells in proportion to vascular perfusion. We incorporated liver SPECT-CT imaging for SBRT 3-D conformal treatment planning in order to minimize irradiation of well perfused volumes of normal liver parenchyma. Materials/Methods: 14 patients with unresectable metastatic (13) or primary (1) hepatic tumors completed liver SPECT with 99mTc sulfur colloid for treatment planning and have been evaluated for response after > 2 months from completion of SBRT (median 6.8 months, range = 2.5-13.5 months). Using body surface markers, SPECT images were co-registered with CT using the Leonardo multi-modality workplace software (Siemens, Malvern PA). Contoured volumes of photogenic SPECT normal liver parenchyma (SPECT-NLV) were incorporated into 3D-conformal treatment planning. CT and SPECT-based dosimetry was compared and predicted normal liver volumes were calculated. Planned target volume (PTV) included 4D-CT-defined internal target volume (ITV) with an additional 0 to 5 mm margin. The cumulative mean PTV was 285cm³ (range 15-1265cm³). The dose per fraction ranged from 6Gy to 12Gy with a mean total SBRT dose of 45Gy (range, 30-50Gy) prescribed to the isodose line encompassing the PTV. Megavoltage cone-beam CT was used for image-guidance. Results: In 6 of the 14 patients, there was no detected SPECT-NLV reduction. However, in the remaining 8 patients with chemotherapy induced hepatic injury including one with recent major hepatectomy there was reduction of the SPECT- NLV /CT compared to CT only imaging by a mean of 27% (range 21-50%). For most of these patients, < 40% of the predicted SPECT-NLV (mean of 26.5%, range, 9.5%-54%) received ≤ 18Gy (BED = 40Gy), by using 3D-conformal treatment planning, dose intensity modulation, and/or reduction of the total dose. Two patients with reduced SPECT-NLV who received ≥ 18Gy to 41% and 54% of predicted SPECT-NLV respectively developed Grade 2 elevation of liver enzymes. Otherwise, no incidence of > Grade 1 radiation induced liver disease was observed. Patients with larger tumors who completed palliative SBRT experienced improvement in performance or/and pain control. To date, the overall in-field local control for palliative and definitive SBRT is 93% with no incidence of liver failure. Conclusions: Our data present a novel and simple method of SPECT/CT registration for SBRT 3-D conformal treatment planning. It allows identification and conformal avoidance of functional normal liver parenchyma from high radiation doses thus facilitating safety of SBRT in patients with preexisting liver disease.


172 Dependence of Locoregional Lung Ventilation Estimation Methods on Image Registration Technique K. Latifi1, K. Forster1, G. Zhang1, T. Dilling1, C. Stevens1, M. Stawicki2, W. van Elmpt1, A. Dekker2, 1Moffitt Cancer Center, Tampa, FL, 2MAASTRO, Maastricht, Netherlands

Introduction: Radiation therapy currently does not consider local lung function in treatment plan optimization. Dose levels that cause toxicity have been reported but there have been few publications examining the dose levels that result in reduced lung function. In order to accomplish a deeper understanding of the dose effects on local lung, robust ventilation imaging is required. This study investigates the influence of deformable image registration on two previously validated ventilation algorithms. This study examines the dependence of the derived ventilation images on the registration algorithms used. Materials/Methods: Image registration of the normal end expiration and inspiration phases of the 4D CT images was used to correlate the voxels between the two respiratory phases. Ventilation was calculated using the Jacobian and the ΔV methods. The Jacobian method is a mathematical representation of the volume change that uses the first derivative to approximate the change in volume of voxels. The ΔV method is a direct geometrical calculation of the volume change of each voxel. Two different registration algorithms, Optical Flow [OF] and Diffeomorphic Morphons [DM], were used. 4D CTs from 20 patients (10 lung and 10 esophageal) were retrospectively analyzed. Differences between the ventilation images generated by the Jacobian method using DM vs. OF registration were examined using voxel to voxel differences. This analysis was repeated using the ΔV ventilation method. Results: Average difference between the ΔV with OF registration and ΔV with DM registration was -0.19 with a range of -3.14 to 10.95 and standard deviation of 0.75. Average difference between the Jacobian with OF registration and Jacobian with DM registration was -0.19 with a range of -3.04 to 10.34 and standard deviation of 0.72. A small number of
peripheral SaO2 measurement. Retinal oxygen extraction is measured using RO and is defined as the difference between the arteriolar oxygen saturation (SaO2) and the venule oxygen saturation (SvO2). Retinal function is assessed with Goldmann Visual Fields (GVF). Each retina is divided into 4 regional quadrants using the optic nerve or disc as the central reference point, and the radiation plan and the results of RO and GVF are registered onto one another for analysis. The primary and secondary objective is to evaluate potential changes in retinal oxygen extraction using RO and functional changes using GVF. Exploratory objectives include correlating changes in retinal physiology (RO) to retinal function (GVF) and to assess for a radiation dose response. To assess reproducibility of RO in irradiated patients, 5 repeated optic disc centered images of each eye were obtained for the first 5 patients. In each retina, the SaO2 and SvO2 were calculated for two first degree arterioles and two venules. 6 retinas and 24 vessels with 5 repeat measurements of each are available for review (120 total observations). The reproducibility between repeated measurements was determined by the restricted maximum likelihood (REML) method. Results: 5 patients have enrolled. The median peripheral SaO2 is 98% (range, 98-100%). For all 24 vessels analyzed, the mean arteriolar SaO2 is 96.3% (SD 5.8%). Variance between repeated measurements of the same vessels is 0.00021 for arterioles and 0.00023 for venules. This accounts for only 5% (arterioles) and 3.5% (venules) of the total variability. Conclusions: RO is a novel imaging technology that evaluates retinal oxygenation and is highly reproducible in irradiated patients.

Quantitative Evaluation of Radiation-induced Vocal Cord Injury using Dynamic Ultrasound
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Purpose/Objective(s): Curative radiation for oral cavity, oropharyngeal, hypopharyngeal and nasopharyngeal cancers can injure the vocal cords which can adversely affect speech and quality of life. Vocal cords are hard to image with conventional MRI, CT or ultrasound. Currently, no imaging tool is available in the clinic to visualize and evaluate such injury. The purpose of this study is to develop a dynamic ultrasound technology to quantify radiation-induced vocal cord injury. Materials/Methods: Eight healthy volunteers and four post-radiation patients (one with clinically-identified vocal cord injury) were enrolled under IRB approval. Each participant was scanned using a clinical ultrasound scanner (Sonic Touch, Ultrasonix, Richmond, B.C., Canada) with a 14-MHz linear array transducer. Ultrasound probe was placed in the transverse plane, approximately parallel to the vocal fold’s mucosal wave propagation. Each participant was asked to phonate the vowel sound “a” and sustain the phonation for 5 seconds while 315 dynamic (consecutive) ultrasound images of the right vocal fold were recorded. The vocal cord vibration patterns were obtained through these consecutive images. The vibration frequency and 2-D dimensions were computed to measure the vocal cord performance. Results: Vocal cords were clearly visualized using dynamic ultrasound in all participants. The vocal cord vibration patterns of healthy volunteers revealed smooth sinusoidal wave propagation; while the patterns of post-radiation vocal cords presented irregular wave propagation. The 2-D dimensions of the maximum vertical and horizontal displacements decreased for patients with vocal cord injury. The vocal cord vibration pattern was most disrupted in the patient with clinically-identified vocal cord injury. Conclusions: In the effort to develop a noninvasive imaging technique for evaluating vocal cord injury post radiotherapy, we identified dynamic ultrasound as a promising tool. Ultrasound is safe, simple, and cost-effective. This study demonstrated its feasibility in imaging the vocal cords and quantifying vocal cord condition.


Evaluating Vaginal Fibrosis Following Radiotherapy for Gynecologic Malignancies: A Feasibility Study Using Quantitative B-mode Ultrasound
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Purpose/Objective(s): Vaginal fibrosis is a common toxicity following radiotherapy to the pelvis, yet no imaging tool exists to readily identify this toxicity, and no intervention exists to aid in symptom relief. The purpose of our investigation is to develop a noninvasive imaging method to help evaluate radiation-induced vaginal fibrosis. Materials/Methods: Five patients with successfully treated gynecologic (GYN) cancer enrolled in the study. The mean age of the patients was 61 years (range: 52 to 67). Previous radiotherapy treatment following hysterectomy included brachytherapy (1 patient), external radiotherapy (1 patient), and combination treatment (3 patients) with a median follow up of 21 months (range 12 to 38 months). Clinical assessment data was collected from patient interview, examination, toxicity assessment by common toxicity criteria v3.0, and Female Sexual Function Index survey. Ultrasound data was acquired using a clinical ultrasound scanner with a 7.5 MHz biplane probe. Transverse images of the anterior vaginal wall were acquired step-wise from the apex (vaginal cuff) to the introitus (vagina opening). We analyzed the thickness of the vaginal wall and the mean voxel intensity of the surrounding tissue. Results: The ultrasound scans were successfully performed on all patients. The time required to perform the physical exam and obtain images did not exceed 10 minutes in all cases. In this cohort, the mean vaginal length was 9.2 cm (range: 6 to 12 cm). The mean vaginal wall thickness was 5.66 mm (range 2.50 to 8.98 mm) at the apex, 6.13 mm (range 2.11 to 10.94 mm) 2 cm from apex, and 5.95 mm (range 3.75 to 9.22 mm) 4 cm from apex. Vaginal thickening was observed in all patients as compared to the published reports (2.6 to 2.9 mm) of non-irradiated women. In addition, we found a 21% average increase in vaginal wall thickness and 24% average increase in voxel intensity in the three patients with radiation toxicity (complaints of sexual dysfunction and Grade 2 fibrosis) as compared to the two patients without toxicity. Conclusions: In this cohort of women previously treated with radiotherapy for GYN malignancy, transvaginal ultrasound is feasible. The vaginal wall of these patients appeared thicker than historical reports of non-irradiated women and the surrounding tissue had enhanced voxel intensity; both findings are suggestive of vaginal fibrosis. We plan to continue patient accrual, further develop this imaging tool in the clinic settings, and work towards better understanding of this difficult toxicity.


Significance of the Use of FDG-PET Combined with CT for Tumour Delineation in Primary Radiotherapy for Head&Neck Cancer.
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Purpose/Objective(s): Primary (chemo) radiotherapy is the main treatment option for patients with head and neck cancer. Besides organ sparing, good functional outcome is important. IMRT is the cornerstone for treatment, but requires a precise determination of the Gross target volume (GTV). In some studies, the combination of FDG-PET with CT have shown to be superior to CT alone. We investigated in a large cohort of patients the significance of this combined FDG-PET-CT approach for tumor delineation in head and neck cancer. Materials/Methods: Since 2003 269 patients were treated with IMRT for head and neck cancer with primary (chemo)radiotherapy (94%) or for recurrent disease (6%). A planning CT and a FDG-CT was performed in the same mould. Images were matched using a mutual information matching method. Analysis of the FDG-PET scans was performed by experienced radiation oncologists and a nuclear medicine physician. Pet images were visually analyzed. We analyzed the adjustments of the delineation of the GTV of the primary tumor and neck nodes, and the potential shift to another treatment option, based on the comparison of the FDG-PET-CT combined data with CT alone. Tumors were located in the pharynx, larynx, and oral cavity in 78%, 10%, and 11% respectively. Distribution of T-stage was 49%, 21%, 25%, and 6% for T1-2, T3, T4, and recurrent disease,
respectively. Positive neck nodes were seen in 65%. **Results:** Based on the combined approach the GTV delineation of the primary tumor was changed in 1 out of three patients. In 17% the primary tumor was not visible on CT-alone, mostly due to dental inlays. An increase of the GTV was performed in 9%, and a decrease in 6%. Most significant changes of the GTV were seen in the neck. A decrease in the delineated GTV with the combined approach was noted in 10%, an increase in 27%, in three patients FDG-PET was false negative. Increased Uptake of FDG outside the Head and Neck area occurred in 25%, mainly in the lung, in 10% related to distant metastases (n=15) or second tumors (n=10). Based on the FDG-PET analysis in these patients the treatment was modified. In the other 15% of the patients initially no tumor focus outside the head and neck was found, however, during follow-up in 7/24 patients a tumor focus was detected. **Conclusions:** Combination of FDG-PET and CT, performed in the same mould, results in a change in the GTV delineation in a significant number of patients. Most advantage was shown in delineation of the possible positive neck nodes. Besides, the finding of distant metastases or second tumors in 10% will change the choice of treatment. A disadvantage is the need for additional investigations to sort out the cause of the increased FDG-uptake outside the head and neck, initially negative in 15%.


178  **The Predictive Value Of 18 F]-fdg Pet In Predicting Outcome In Unfavorable Risk Hodgkin Lymphoma Treated With The Stanford V Regimen**

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**Purpose/Objective(s):** Several studies have substantiated the significant prognostic value of interim \(^{(18)}\text{F}\)-FDG PET in HL (Hodgkin Lymphoma). The majority of these studies included patients treated with ABVD, MOPP COPP or BEACOPP. Very few studies have explored the role of PET in predicting outcomes of patients treated with an abbreviated, dose intense regimen such as Stanford V. Herein, we report the role of \(^{(18)}\text{F}\)-FDG PET in predicting outcomes in patients with unfavorable risk early stage and advanced stage HL treated with the Stanford V protocol. **Patients and Methods:** Sixty -two (62) patients with unfavorable risk HL were treated with the Stanford V protocol from between 2000-2007. All 62 patients underwent PET scans at week 8 of chemotherapy (PET-8) and at the end of chemotherapy (PET-12). Eighteen patients had an interim scan only, 19 underwent a post-therapy scan only, and 25 patients had both. The association between PET positivity and recurrence-free survival was investigated. **Results:** With a median follow up of 61 months, 10 relapses occurred with a 5- year relapse free survival of 84 %. Positive PET scan was significantly associated with worse prognosis. The probability of 5-year recurrence-free survival (RFS) was 62% with a positive interim PET (PET- 8) compared to 93% (p < 0.015) for negative interim PET (PET-8). Similarly, for patients with post-chemotherapy PET positive scans (PET-12), the probability of recurrence-free survival at 5-years was 50% versus 93% (p < 0.0001) for patients who had a negative PET-12 scan. International prognostic score (IPS) 4 and the presence of B symptoms was significantly associated with inferior RFS. **Conclusion:** Positive interim and post-chemotherapy \(^{(18)}\text{F}\)-FDG PET scans are both significantly associated with inferior relapse free survival in unfavorable risk HL patients treated with the Stanford V regimen.

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179  **Sensitivity of PET Imaging in Detecting Hilar Lymph Node Involvement in Non-Small Cell Lung Cancer: Implications for Radiation Treatment Planning**

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**Purpose/Objective(s):** 18-fluorine florodeoxyglucose positron emission tomography (PET) is superior to computed tomography (CT) for staging non-small cell lung cancer (NSCLC). While multiple investigations have evaluated the sensitivity of PET to detect mediastinal lymph node involvement, few studies have specifically studied its ability to stage the hilum. This has significant implications for radiation treatment planning when considering elective nodal irradiation (ENI) for locally-advanced disease and stereotactic body radiation therapy (SBRT) in patients with clinical stage I NSCLC. We evaluated this further using our large surgical database. **Materials and Methods:** All patients who underwent surgery for NSCLC between 1995 and 2008 were evaluated. Those with pathologically involved N1 lymph nodes were identified. Patients who underwent preoperative chemotherapy or chemoradiotherapy were excluded. Patients who did not undergo pre-operative PET imaging at Duke or those who had primary tumors that extended to the hilum were also excluded. All PET studies were interpreted by an attending nuclear medicine radiologist and were scored as positive or negative in the hilum/peribronchial area based on visual analysis alone. As lymph nodes within a lobectomy/pneumonectomy specimen can be either hilar or peribronchial, we performed a subgroup analysis of patients with involved levels 10-12 lymph nodes which were dissected separately from the lobectomy/pneumonectomy specimen. A two-sided Fisher’s exact test compared patient subgroups. **Results:** 214 patients undergoing surgery for NSCLC with pathologially involved N1 nodes were identified. Of these, 78 had pre-operative PET imaging at Duke. After excluding those with primary disease extending to the hilum (n=9), 69 patients were available for analysis. Hypermetabolic lymph nodes in the ipsilateral hilum were noted in 31/69 patients, resulting in a sensitivity of 45%. The sensitivity was the same when comparing patients with one involved N1 lymph node (20/44, 45%) versus more than one N1 lymph node (11/25, 44%). Sensitivity was not different between right-sided and left-sided tumors (56% vs 34%, p=0.09) nor upper/middle lobe versus lower lobe tumors (48% vs 32%, p=0.28). When the analysis was restricted to patients who had separately dissected levels 10-12 lymph nodes, the sensitivity was 52% (15/29). **Conclusion:** The sensitivity of PET for staging the hilum was 45% in our series. When considering ENI for locally-advanced NSCLC, coverage of the ipsilateral hilum should be considered.

180  Kinetic Modelling Application To [(18f)]-fluoroethylcholine PET In Patients With Primary And Recurrent Prostate Cancer Using Two-tissue Compartmental Model.

Purpose/Objective(s): Influence of differentiation of primary and recurrent prostate cancer (PCA) vs. normal prostatic tissue was assessed. Quantitative and dynamic parameters of FECH-uptake and kinetic in PCA of patients with local recurrence and/or regional lymph node metastases were evaluated to detect differences caused by tumour location. Materials/Methods: 42 patients with PCA were enrolled (lymph node metastases [n=9], local recurrence [n=14], primary tumour [n=15], and no tumour [n=4]). PET was acquired, first with a dynamic study followed by static imaging. A two-tissue compartment model was applied [PMOD software, Adliswil, Switzerland], and parameters k1-k4 were obtained. FECH influx was calculated from the compartment data. SUV was also included Results: Analyzing patients with primary tumour (ROIs in tumour and in adjacent normal tissue) revealed significant differences in k1, influx, SUV (p<0.05). Comparison of lymph node metastasis and local recurrence revealed a significant difference in the k3 and influx. Conclusions: Dynamic studies provide useful data to distinguish primary tumour from normal tissue. Quantitative evaluation of dynamic FECH demonstrated heterogeneity of tracer-distribution in the different tumour-sites (lymph nodes metastases / local recurrence). However, dynamic parameters vary characteristically according to the tumour location. Possible reasons might be differences in angiogenesis and other factors requiring further investigation.


181  During-Treatment PET May Allow Deliver Hi gh Dose Radiation in 6 weeks with Concurrent Chemotherapy in Stage III Non-Small Cell Lung Cancer.

Purpose/Objective(s): With concurrent chemoradiation, RTOG0117 concluded 74 Gy in 7-8 weeks as the maximum tolerated radiation (RT) dose for stage III Non-Small Cell Lung Cancer (NSCLC). We hypothesized that RT dose can be further escalated with a shortened treatment duration by individualized and adaptive RT planning. Materials/Methods: Two consecutive prospective dose escalation trials have been conducted to test the hypothesis. The prescription dose of the first trial was set individually to correspond to a 15% risk of RT-induced lung toxicity (RILT) according to a normal tissue complication model. RT dose was further escalated in the second trial by adapting dose individually to the residual metabolic volume on PET obtained during-RT so that the residual metabolic volume would receive the maximal dose that would maintain a tolerable risk of RILT while the pre-RT clinical target volume by CT would receive at least 60 Gy. The treatment was to be completed in 30 daily fractions, with 5 fractions a week for both trials. Fraction size, total equivalent dose at 2 Gy fraction size (ED2), and biologic equivalent dose (BED) ranged from 2 to 3.8 Gy, 66 to 100 Gy, and 79.2 to 120 Gy, respectively. Carboplatin and paclitaxel were given concurrently and adjuvantly. Mature data from the first and the preliminary data from the second trial are reported. Results: The median ED2 were 66 Gy (range 66-100) and 100 Gy (range 80-100) (P<0.01), respectively. Of 18 patients treated on trial #1, with a minimum follow-up of 50 months, the median and 5-year overall survivals were 30 months and 33%, respectively. 12 patients died: 5 from local failure, 3 distant metastasis, 3 heart diseases, and 1 radiation pneumonitis. 6 patients were alive: 1 with local progression and 5 with no evidence of disease at the last follow-up. Patients treated to higher dose had significantly better survival (P=0.02). For toxicity, 5 (22%) patients had grade ≥ 2 RILT and 10 (55%) grade ≥ 2 radiation esophagitis. Thirty-eight patients have been treated on trial #2. All received at least 74 Gy ED2 within 6 weeks; 10 received the maximum trial dose of 100 Gy ED2. Overall, 1 had grade 3 RILT and 7 had grade ≥2 esophagitis. There were 2 deaths, one from bleeding esophageal and gastric ulcers, the other with unknown etiology without evidence of disease progression. None of the patients had local regional failure or other failure. Conclusions: Local failure remained the major cause of death in trial #1 with most patients not receiving high dose RT due to estimated RILT limitations. An adaptive RT plan, using during-RT PET, allowed high dose delivery safely in 6 weeks with concurrent chemotherapy in many patients with stage III NSCLC. RTOG 1106 will compare this adaptive regimen with conventionally fractionated 74 Gy RT.


182  Treatment Response Assessment through Advanced Integration of Radiation Therapy (RT) Data with Metabolic Imaging
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Purpose/Objective(s): Metabolic assessment of tumor response to therapy is often heterogeneous, and subject to inaccuracies which may be minimized through the use of deformable registration and a quantitative approach. This study proposes a novel solution that uses deformable registration to combine pre- and post- treatment PET scans with RT plan information for monitoring patient response to drug and radiation therapy in head and neck carcinomas. Materials/Methods: Data integration is performed through deformable registration that corrects for posture and internal anatomy changes, creating a voxel-by-voxel correspondence between pre- and post-treatment PET scans, simulation CT, and delivered dose. In the integrated system, the dose is displayed in relation to metabolic imaging and changes in FDG deposition are easily tracked and correlated with the delivered dose in order to differentiate among normal tissue uptake, inflammation, and tumor activity. Dose-response information can be obtained through dose volume histograms (DVH) of the dose delivered at the site of recurrence. Results: In order to better characterize dosimetric and metabolic features of tumors that failed locally, we applied this integrated approach to 15 patients with locally advanced head and neck cancer who were treated in our institution with definitive chemotheraphy and radiation. For the four patients with local failures, the most common site of recurrence was in the dose gradient at the borders of the treatment field in small regions far away from midline, where the isocenter was located. The median distance from the isocenter to failure sites was 5.4 cm. The areas of failure had a median pre-
treatment SUV of 11.8 and had the following median dose statistics: minimum 41.7Gy, mean 71.7Gy, and maximum 74.9Gy. By analyzing the site of recurrence in relationship with the dose matrix and treatment records, we hypothesized that tumors distant from the isocenter may have poorer local control due to under dosing caused by their physical susceptibility to set-ups errors such as chin deformations and rotations.

**Conclusions:** Using a mixture of advanced imaging analysis algorithms, we are able to correlate local biological changes with delivered dose for a comprehensive analysis of radiation therapy response. Based on our clinical cases, this technique is a valuable tool that increases the accuracy of early response assessment. Furthermore, by providing detailed dosimetric and metabolic information about local failures, and this approach has the potential to guide delivery of salvage therapy.

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### 183 FDG-PET in Carcinoma Nasopharynx- Role in Response Evaluation


**Purpose/Objective:** PET CT is an emerging modality for staging and response evaluation in Carcinoma Nasopharynx. This study was conducted to evaluate the impact of PET CT in assessing response in Carcinoma Nasopharynx. **Materials / Methods:** 45 patients with non-metastatic Carcinoma Nasopharynx who underwent PET-CT for response evaluation at 8-12 weeks post therapy between 2003 and 2009 were evaluated. Patients were classified as Responders (Group A) if there was complete response on PET CT or as Non-Responders (Group B) if there was any uptake above the background activity. Data regarding demographics, treatment and outcomes were collected from their records and compared across the Groups A and B. **Results:** The median age of the study population was 41 years. Forty-two out of forty five (93.3%) patients had WHO grade 2B disease (undifferentiated squamous carcinoma). 24.4%, 31.1%, 15.6 and 28.8% patients were in AJCC Stage Iib,III,IVa and Ivb. All patients were treated with a uniform protocol of NACT followed by concomitant chemoradiotherapy. Of these 45 patients, 28 (62.2%) were classified as Responders while 17 (37.8%) were classified as Non Responders. There was no significant difference in the age, sex, WHO grade and stage distribution between the groups. The median follow up of the group was 25.3 months (759 days). The disease free survival (DFS) of the group was 53.7% at 3 years. The DFS at 3 years was 87.3% and 19.7% for Group A and B, respectively (log-rank test <.001). Univariate and multivariate analysis revealed Groups to be the only significant factor predicting Disease Free Survival (p-value 0.002 and <0.001 respectively). In Group B the commonest site of disease failure was distant [8+1 (53%)]. **Conclusion:** From the above analysis PET-CT can be used as a method to evaluate response and , prognosticate in patients with Carcinoma Nasopharynx. Further to this it may also be used as a tool to select patients for adjuvant therapy. This needs to be studied prospectively.


### 184 FDG PET Response and Normal Tissue Regeneration After Stereotactic Body Radiation Therapy to Liver Metastases

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**Purpose/Objectives:** To characterize the change in standardized uptake value (SUV) in positron emission tomography (PET) scans and to determine the pace of normal tissue regeneration after stereotactic body radiation therapy (SBRT) for solid tumor liver metastases. **Materials/Methods:** We reviewed the records of patients with liver metastases treated with SBRT to ≥ 40 Gy in 3 - 5 fractions. Evaluable patients had a baseline pre-treatment PET and at least 1 post-treatment PET. Each follow-up PET/CT scan was fused to a pre-treatment PET/CT using dedicated medical image analysis software (MIMvista®, MIM Software, Inc., Cleveland, OH). The maximum SUV (SUV,max) for each treated lesion and the total liver volume was measured on each PET/CT scan. SUV,max levels pre- and post-SBRT were recorded and an exponential decay curve was fit to the data to describe the rate of decline and post-SBRT plateau. **Results:** Twenty six patients with 36 treated liver lesions were studied. The median number of PET scans per patient was 4 (range, 2-12). The SBRT regimen was 40 - 60 Gy in 5 fractions in 16 lesions and 45 - 60 Gy in 3 fractions for 20 lesions. The median follow-up for post-SBRT PET was 10.2 mos (range 1.5 - 33.7 mo). Failure was defined as post-SBRT SUV,max ≥ 6. Thirty one lesions were controlled, while there were 5 local failures, with a 1 yr local control rate of 87%. Median time to failure was 19.3 mo. The median baseline SUV,max was 7.16 for controlled lesions and 8.45 for failed lesions (p = ns). Exponential decay fitting (R = 0.97) showed that SUV,max declined to a plateau of 3.0 for controlled lesions at approximately 5 months post-SBRT. The estimated decay time to decrease the SUV,max by half its initial value was 2.0 months. The SUV,max in controlled lesions sometimes increased up to 4.1 during the follow-up period and later declined; this level is within 2 standard deviations of mean normal liver SUV. The failure cutoff of SUV,max = 6 is twice the calculated plateau SUV,max of controlled lesions. Parenchymal liver volume decreased by 14.7% at 3-6 months and then regenerated to pre-treatment volume levels at 30 months. **Conclusions:** SUV,max decreases over the first few months after SBRT to a plateau of 3.0, which is similar to the median SUV,max of normal healthy livers. Transient moderate SUV increases, with SUV,max up to 4.0, may be observed and do not correspond to subsequent local failure. We propose a cutoff SUV,max ≥ 6, twice the baseline FDG activity, to score local failure by PET criteria. Values from 4-6 would be suspicious for local recurrence. Lastly, the volume of normal liver nadired approximately 6 months post-SBRT and then regenerated to pretreatment volume at 30 months.

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Impact of Integrated High-Resolution FDG18-PET/CT into Radiotherapy Planning and Post-Treatment Assessment for Locoregional Advanced Squamous Cell Carcinoma of the Head and Neck

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Purpose/Objective(s): To evaluate the impact of integrated high-resolution head and neck FDG18-PET/CT and contrast-enhancing CT (CECT) in RT planning and to assess treatment response in locoregional advanced head neck cancer. Materials/Methods: From 7/2005 to 11/2009, 69 consecutive patients with locoregional advanced head neck SCC were treated with definitive RT or CRT. All patients underwent high-resolution dedicated head neck FDG18-PET/CT including contrast-enhancing CT (CECT) images. Patients were scanned inRT position with thermoplastic mask placed. FDG18-PET/CT images were transferred and integrated into the Eclipse planning system for both PET and CECT tumor target delineations. High dose PTVs encompassed all suspicious primary and nodal volumes shown on FDG18-PET/CT and CECT images. Patients repeated PET/CT and CECT 3 months after completion of RT or CRT for assessment of tumor response. Results: The mean primary tumor volume was 29.5 cm3 (range, 3.9-165.2) delineated on CECT, compared 29.4 cm3 (range, 1.1-151.5) on PET (p=0.92); the mean nodal disease volume was 25.7 cm3 (range, 0.0-216.3) on CECT, and 23.1 cm3 (range, 0.0-198.4) on PET (p=0.026). With median follow up 22.0 months (range, 2.2-57.6), Kaplan-Meier OS, DFS, local control, and nodal control at 1-, 2-, and 4-year were 70.6%, 68.7%, and 65.6%; 75.3%, 71.2%, and 67.0%; 83.3%, 83.3%, and 83.3%; 91.6%, 91.6%, and 91.6%, respectively. Among 25 patients with post-treatment measurable SUVmax in the primary tumor sites, 7/11 patients with SUVmax >6.0 had persistent disease, compared to 2/14 with SUVmax <= 6.0 (4.9 and 5.6) (p=0.05); 6/9 of patients with persistent primary disease had post-treatment SUVmax reduction <60%. Seventeen patients had post-treatment residual enhancement in the primary site, 6/7 (85.7%) with tumor size reduction <40% had persistent or progressive disease, compared to 3/10 patients (30%) reduction >40% (p=0.05). Twenty-four patients had post-treatment PET/CT measurable residual LNs, 3 pts relapsed in the regional node had nodal size reduction <40%, compared to 0/1 failure if nodal reduction >40% (p=0.001). There was no significant difference of post-treatment SUVmax reduction in regional failure. No patients developed local or regional recurrence by time of 3 months or more after since completion of definitive RT or CRT. All late disease relapses were distant metastases. Conclusions: High-resolution dedicated head and neck FDG18-PET/CT CECT is helpful in accurate tumor target delineations. Post-treatment residual tumor volume and corresponding SUVmax reductions predicted disease local and regional control. Distant metastases are still the challenge affecting long-term disease free survival. Author Disclosure Block: Y. J. Hitchcock: None. K. A. Morton: None. B. G. Bentz: None. J. Hunt: None. J. M. Hoffman: None. B. Salter: None. D. C. Shrieve: None.

Using 18f-fluorodeoxyglucose Pet / Ct Imaging To Access Treatment Response For Lung Radiosurgery

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Purpose/Objective(s): Stereotactic radiosurgery has been adopted as a treatment modality for patients with solitary lung cancer who medically do not meet the indications for surgery. The response of the tumor to treatment was conventionally measured by CT imaging. However, distinguishing viable persistent tumor fibrotic changes from radiotherapy is always difficult. This study describes how PET/ CT is used for follow-up at our institution after lung stereotactic radiosurgery. Materials/Methods: Patients with biopsy proven Non-small cell lung cancer were all staged initially with PET / CT. We reviewed 10 patients with medically unresectable stage I cancer. All were treated with radiosurgery, 6000 cGy in 3 fractions using the Accuray Cyberknife radiosurgery system. PET / CT imaging was preformed prior to treatment and at 3 month intervals post-treatment. The tumor size and SUV (standard uptake value was recorded prior to treatment and post-treatment, tumor size, tumor SUV, volume of radiation fibrotic changes and SUV with the areas of fibrosis were recorded. Results: A cohort of ten patients with an average tumor diameter of 2.3 cm were treated over a one year period. The mean SUV was 6.8. Each patient received 6000 cGy in 3 fractions to the tumor volume plus a 5 mm margin. At a minimum follow-up of 2 years, 9 of 10 were locally controlled. No late complications or symptomatic pneumonitis was observed. Imaging, 3 months post treatment tended to show a decrease in tumor volume - averaging 60% of its original diameter. The SUV also decreased on average 38% of its original value. Finding of radiation fibrosis was minimal at the 3 month interval. At 6 months the tumor volume continued to decline ~ now 67% of its pre-treatment diameter. Therefore, only minimally changed from the 3 month diameter. The SUV however declined to 57% of its original value. Radiation fibrosis began to develop, extending on average 1.4 cm beyond the residual tumor volume. The SUV within the fibrosis had a mean of 2.1. At 9-12 months, the radiation fibrosis became better defined. The volume tended to correlate to the portion of lung that received 14 Gy or greater. There was no clinical symptoms of pneumonitis. SUV however remained below 3 in the area of fibrosis. The single failure detected at 18 month had a SUV of 9.1; confirmed via biopsy. Two patients with progressive fibrosis, but SUV less than 3 were biopsied; both, negative for disease. Conclusion: To justify local control, the tumor volume must decrease and the SUV must be below 3 and not exhibit increase values. Radiation fibrosis is expected. The volume of fibrosis corresponded to the lung volume which received 14 Gy. Even though fibrosis can be extensive, symptomatic pneumonitis was not seen. Author Disclosure Block: M. P. McLaughlin: None. B. Gordon: None. T. Whitaker: None. K. Haile: None.

Optimized Timing Of PET/CT Scans In Pediatric Bone And Soft Tissue Tumors

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Purpose/Objective(s): To review our experience using PET/CT in the staging and surveillance of children with suspected bone and soft tissue sarcomas and to determine the optimum scan timing. Material/Methods: 104 children with presumed diagnosis of bone or soft tissue sarcoma were imaged with low dose FDG-PET/CT and compared to other standard imaging to detect malignancy at diagnosis, evaluate tumor response and detect relapse. To assess impact, in children who had pathologically confirmed sarcoma, 90 scans were retrospectively grouped into the following clinical time intervals. T1: pre biopsy, T2: pre local therapy; T3: end of therapy; T4: surveillance. Results: Unsuspected metastases or disease progression was detected in 23/90 scans. At T1, 24 scans were done and 21 scans were of pathologically confirmed sarcomas. At T2, a
positive response to neo-adjuvant therapy was identified in 12/21 scans. In 7/21 surgery was altered on the basis of scan findings. At T3, 19 scans were done. Recurrence or progression of disease was seen in 5/19 scans which impacted management. At T4, 26 scans were completed. 10 scans were performed in patients without clinical signs or relapse detected on other radiologic studies and were classified as non indicated. 10/10 non indicated scans had no impact. The other 16 scans were indicated and treatment was impacted in 15/16 scans. Conclusions: FDG PET/CT shows promise in the management of pediatric bone and soft tissue tumors. The chosen four scan time intervals appear most useful. Surveillance scans are indicated only when there are clinical symptoms or management decisions required.


188 Automated PET-CT Therapy Response Assessment of Head and Neck Cancer Patients
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Purpose/Objectives: Consecutive imaging with positron emission tomography (PET) is a powerful tool to assess treatment response as it visualizes metabolic changes induced by therapy. Currently, treatment response is measured by simple global measures that do not capture the tumor’s heterogeneous response. For example, the standard approach to response assessment observes changes in tracer deposition by comparing pre and post treatment datasets through single-voxel metrics on segmented tumor regions. We present an advanced in vivo imaging analysis algorithm (level-set clustering analysis) to quantify local biological changes for an in-depth classification of radiation therapy response applied to a cohort of head and neck cancer patients. Materials/Methods: The algorithm employs level-set mathematics to extract changing features to classify voxels into response patterns using pre-treatment, treatment and post-treatment imaging. First, pre and post-treatment images are rigorously aligned using a deformable registration to correct for posture and soft tissue changes. The detailed mapping is modeled by free form deformations B-spline optimized using the limited memory L-BFGS algorithm. Once images are aligned, a clustering algorithm combining the concepts of voxel and distance-based techniques classifies voxels into patterns of signal reduction or enhancement. While signal reduction is evidence of successful treatment, signal-enhancing regions are an indication of treatment failure. For an in-depth analysis of potential treatment errors, patterns of signal enhancement are correlated with the dose and structures from the treatment plan. Results: The response assessment algorithm was implemented on 80 clinical cases representing PET/CT and radiotherapy (RT) oncology data for combined drug and radiation therapy in head and neck cancer patients. The technique was instrumental in detecting geometrical and segmentation misses on the actual clinical cases by providing accurate voxel-by-voxel analysis of metabolic changes. Results of the level-set based clustering algorithm are saved as a detailed report of enhancing /non-enhancing regions and their location, and can be further displayed as a colorwash overlaid over the original anatomy for in-depth analysis. Conclusions: The imaging response assessment algorithm was instrumental in analyzing treatment response on a large pool of clinical cases, and should enable faster and more accurate decision making for imaging and image-guided interventions applied to cancer patients.


189 Application of 18F-FDG PET-CT in Pretreatment Staging of Head and Neck Squamous Cell Carcinoma
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Purpose/Objectives: Currently, Computed Tomography (CT) is the modality of choice for the staging of Head and Neck Squamous Cell Carcinoma (HNSCC). However, factors such as normal-size metastatic lymph nodes can limit the sensitivity and specificity of the CT. Recent studies have suggested that Positron Emission Tomography (PET) has the ability to overcome these limitations by providing relevant metabolic information. The aim of this study is to assess the impact of PET-CT on HNSCC staging when compared to conventional CT. Patients and Methods: Through retrospective chart review, 37 patients with biopsy proven HNSCC who had not received any treatment prior to the PET-CT were identified. All of the patients had undergone modified radical unilateral or bilateral neck dissection following PET-CT. Postoperative histopathological results were used as the reference to compare the CT and PET-CT results. Results: Conventional and PET-CT staging were discordant in 14 (37.8%) patients. In these patients, PET-CT accurately increased the staging in 11 cases whilst decreasing the staging in 2 patients (29.7% and 5.4%, respectively). The PET incorrectly upstaged 1 patient (2.7%). TNM staging in 23 patients (62.6%) remained unchanged. The results indicate that compared to conventional CT, PET-CT has a significantly higher accuracy in staging HNSCC (p< 0.001). Conclusion: PET-CT can significantly enhance the accuracy of HNSCC staging and should be considered in the initial workup of these patients.

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190 Variability of Acquisition Protocols Among Institutions and Over Time Makes PET/CT Interpretation Difficult
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Purpose/Objective(s): The use of PET/CT scans for routine staging of cancer patients has increased dramatically over the past several years. These scans are also frequently used to determine the GTV in radiation treatment planning. A number of PET/CT acquisition protocols exist, however, which can cause potential variance in the results. We analyzed variability of a random selection of PET/CT scans performed outside our institution. Materials/Methods: We analyzed a random subset of PET/CT scans performed at outside institutions that were subsequently brought to the Moffitt Cancer Center for import into our radiology PACS. To assess the scans, SUV mean and max were determined for the normal liver and the aortic arch blood pool (to determine “background”) and mean/max for the left ventricular wall (LV). Results: We analyzed a random subset of outside PET/CT scans imported into the Moffitt Radiology PACS on 5 different days; 26 scans were reviewed from 20 patients. Three scans were either incomplete or calculated in raw counts only (SUV not available); these were removed from further analysis. For the remainder, the liver SUV mean/max were relatively stable (2.2 ± 0.6 and 3.2 ± 1.0, respectively). Likewise the mean/max of the aortic blood
pool varied little (1.8 ± 0.5 and 2.1 ± 0.7, respectively). However, the LV mean/max varied greatly across the scans (4.6 ± 3.0 and 7.1 ± 4.0, respectively). Of note, one patient had 5 PET/CT scans performed at 2 different institutions. The 2 scans from Institution A were quite similar in LV mean/max (4.5 ± 0.2 and 7.1 ± 0.2, respectively), while the 3 scans from Institution B varied markedly (2.6 ± 2.0 and 3.1 ± 2.5, respectively). PET/CT scans from a 2nd patient at Institution B also varied dramatically: LV SUV mean 6.9 and 2.1, and LV SUV max 7.9 and 2.4, respectively. We are expanding our analysis to include a larger sampling of scans. Discussion: It is remarkable that the analysis of even a small random sample of PET/CT scans demonstrated such variability in results. PET/CT acquisition protocols at some institutions appear standardized/reproducible, but this is not uniformly true. Furthermore, PET/CT results varied markedly over time. While most insurance plans raise questions if PET/CT scans are repeated, they do not consider the fact that scans might vary markedly in quality. It is important for radiologists and radiation oncologists to consider these facts when basing treatment decisions on outside PET/CT scans or utilizing them to generate a GTV for treatment planning.


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Purpose/Objective(s): PET provides physician with a non-invasive tool to detect and stage cancers, as well as monitor tumor response to anticancer treatment. During the past 10 years, FLT and FDG PET radiotracer comparison studies have attracted attention from the biomarker imaging community. In this analysis, we investigated the clinical value of serial quantitative FLT positron imaging for early assessment of tumor response to radiotherapy or chemo-radiotherapy regimens in comparison to serial quantitative FDG images. Materials/Methods: FDG PET was the active comparator. The patients included in the trial were those with confirmed NSCLC or head and neck cancer. All patients were treated with curative intent. Each consented patient underwent two investigational FLT scans in addition to FDG scans to monitor the treatment between cycles. The first investigational FLT scan was performed prior to the start of a treatment, and within ± 2 days of the FDG scan. The second investigational FLT scan was performed at 4 weeks after the start of treatment. PET images for both FLT scans were evaluated on-site by the investigators. In addition to collecting and evaluating basic safety data for this trial, efficacy was also assessed during treatment. The evaluation included tumor size, SUV, and tumor-to-background ratio changes between the pre treatment FLT images and mid treatment FLT image sets. Qualitative parameters were evaluated in both pre treatment and post treatment PET scans, and evaluated in a paired assessment. Results: 6 patients were enrolled at our institution. 3 patients had laryngeal squamous cell carcinoma, and 3 had non-small cell lung adenocarcinoma. Patients were enrolled between Sept 2009 and December 2009. The pre-treatment and mid treatment SUV levels were obtained for all patients for both the FLT and FDG PET scans. These were reported as a percent change between the pre-treatment SUV and mid treatment SUV. For laryngeal cancer patients, the mean percentage change in FDG SUV was 77%, and was 72% for FLT SUV. For lung cancer patients, the mean percentage change in FDG SUV was 35%, and was 47% for FLT SUV. In one of the laryngeal cancer patients, the mid-treatment FDG SUV went up while the mid-treatment FLT-SUV went down. This patient had a complete response to treatment at 3 months follow up. Conclusion: In this data set, there was concordance between the FDG PET and FLT PET for all patients except one laryngeal cancer patient which showed an elevated SUV on FDG with a concurrent decrease in FLT while the patient had a good clinical response suggesting that for discordant response assessments FLT may be superior to FDG. This warrants further investigation with a larger scale clinical study.


192 Incidental Findings on Pediatric Oncology PET/CT Patients

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Purpose/Objective(s): Determine the incidence and significance of incidental findings on pediatric oncologic PET-CT. Materials/Methods: Retrospective analysis of consecutive PET-CT scans obtained at Helen DeVos Children’s hospital between 2004 - 2008 in pediatric oncology patients. The specific data points for the study are the following; DOB, primary diagnosis, secondary diagnosis, treatment status (chemotherapy and radiation), PET-CT findings. The studies will be reviewed and the findings confirmed with a board certified Nuclear Medicine and Pediatric Radiologist. All recorded findings will be classified as being of major, moderate, or minor significance, corresponding to definitions previously used in similar studies. Results: A total of 104 pediatric patients with various malignancies underwent 323 integrated PET/CT for staging or monitoring during the study period. 46 were female and 58 were male. Of these patients, 71 (68.2%) had at least one finding present on the CT component of the studies that did not exhibit correlative F-FDG activity. Of the 323, 116 (35.9%) studies had incidental findings on CT. Of the 128 incidental findings, 45 were located in the thorax, 44 in the abdomen or pelvis, 29 in the head and neck, and 10 in the bony skeleton. Of the 123 findings, 17 (13.3%) were of major significance, 73 (57%) were of moderate significance, and 38 (29.6%) were of minor significance. Conclusions: The CT component of PET/CT, even if performed for purely anatomic localization, must be comprehensively interpreted to accurately identify all potentially important findings. Our classification of abnormalities as being of major, moderate, or minor clinical importance, although somewhat subjective to the pediatric population, was used in an attempt to quantify the significance of abnormalities present on the PET/CT studies. Evidence in our study shows that careful evaluation of the CT component of integrated PET/CT scans provides clinically important information that may necessitate additional workup or treatment.

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Purpose/Objective(s): Determination of metabolic loco-regional extent of tumor is important in the evaluation of patients for surgical resection and radiation therapy. Optimizing technical factors that affect the quantification of disease involvement with tumors that move with respiration is ongoing at our institution. This retrospective study analyzes our initial experience with integration of (4D) PET/CT into clinical practice.

Materials/Methods: Utilization of a GE Discovery DVCT PET/CT scanner fitted by the manufacturer with optical tracking of respiratory motion started at Moffitt Cancer Center in 2008. With this system, an external gating marker is generally placed on the lower right abdomen, away from the heart. Data is then recorded throughout the respiratory cycle and reframed into 3-10 bins upon image post processing. Gated bed positions are set to target the clinical region of interest. Those patients receiving radiotherapy are scanned in the treatment position with the custom immobilization device and with radio-opaque markers on the iso-center tattoos for treatment planning. To date, we have performed 160 respiratory gated PET scans that were eligible for this analysis. Results: Prior to clinical implementation, our team worked on moving phantom simulated acquisitions to develop technical proficiency. Shifting to patient integration, the full challenge of translating 4-D PET/CT into busy clinical practice became apparent. We organized a monthly coordinating conference with staff from radiology as well as radiation oncology. As problems arose, ongoing root-cause analyses and process revisions were addressed first at the operational level and then discussed by the multidisciplinary team. Issues such as the selection of the bed position(s) to reflect the region of interest by calling the patient’s radiation oncologist to the scanner as well as coordination of therapy immobilization with respect to height of device, arm position, body habitus, and physical limitations have all been addressed. Processing, including archiving, staff allocation, execution of processing software, and integration with therapy planning software has been achieved. Clinical patients are now routinely examined within 60 minutes table time. After initial failure rates of 50%, 14 failures with data not suitable for analysis were recorded in our subsequent sample of 160 examinations. Conclusions: A multispecialty team approach enabled clinical implementation of 4-D PET/CT into practice at our cancer center. This integration has allowed gated PET acquisition in the radiation treatment position. A 4D CT is still acquired both at the time of simulation in radiation oncology and at the time of the PET scan. Work is ongoing to develop full integration and eliminate the separate therapy planning 4D CT.


PET-CT in the Periprocedural Radiofrequency Ablation of Lung Tumors: A Radiological Atlas

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Purpose/Objective(s): Radiofrequency ablation (RFA) of lung tumors is an increasingly accepted treatment modality for the loco-regional control of both primary and metastatic lung malignancies. Although diagnostic CT scans play a vital role in the pre-RFA evaluation of patients with suspected lung malignancy, they are limited in their ability to distinguish residual malignant tissue from superimposed inflammatory treatment-related changes. Imaging with PET-CT can differentiate between these entities, but is highly dependent on the selection of an optimal time period to minimize this superimposed inflammation. Prior authors have utilized PET-CT to map out viable and residual lung tumor in the pre- and late postprocedural phases, but little data exists on the immediate periprocedural (within 12-24 hours postprocedure) period in human models. Recent experience with animal models and in patients undergoing hepatic tumor ablation suggest that periprocedural PET-CT in the immediate post-RFA period may be preferred to late postprocedural PET-CT, providing a nearly immediate assessment of residual viable lung tumor post RFA ablation. Material/Methods: A total of 5 patients with primary or metastatic lung tumors underwent RFA according to standard equipment manufacturer protocols (generally 15 minutes per session, with some tumors requiring the multiple overlapping technique). The pre- and, if available, immediate periprocedural (within 24 hours post-RFA) PET-CTs were reviewed. All patients were scanned on a PET-CT scanner 45-60 minutes following the intravenous administration of 10-15 mCi FDG (370-555 MBq). Results: A radiological atlas was created to illustrate the evolution of the pre-, peri- and postprocedural PET-CT changes in these patients with RFA ablations (some multiple). In many cases the correlative periprocedural diagnostic CT findings would have been insufficient to definitively evaluate for residual malignancy. PET-CT imaging in the periprocedural period (12-24 hours post-RFA) was able to establish the presence of residual malignancy before the manifestation of superimposed inflammation from treatment. Conclusions: The periprocedural PET-CT findings in our small series suggest a promising role for this modern imaging modality in the immediate postprocedure evaluation for the extent or adequacy of ablation. The potential for more timely assessment of tumor response may be extrapolated to other treatment modalities in addition to RFA, allowing for earlier re-treatment once recurrence is detected.


Pears and Pitfalls of PET CT in Radiation Therapy Treatment Planning

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Purpose/Objective(s): To demonstrate the application of PET CT in radiation therapy treatment planning including potential pitfalls based on our experience with over 300 cases treated in a single institution. Materials/Methods: In the last two and a half years, we have used FDG PET CT as an additional tool for treatment planning for conventional radiation therapy or SBRT in a variety of cancers including lung, breast, liver, GYN, GU, CNS, and other miscellaneous indications. In a significant number of cases, PET CT was instrumental in the target volume delineation, identification of tumor spread, and verification of localization of the tumor. In some patients PET CT demonstrated previously unidentified malignant sites including tumors outside the typical limited whole body field of view as well as incidentally discovered secondary tumors such as unsuspected breast and colon cancers. Potential pitfalls we encountered include benign causes of FDG uptake such as: physiological causes,
inflammatory processes, radiation pneumonitis, pleural effusions, infections, pneumonia, granulomatous disease like sarcoidosis, rib fractures, postoperative changes including wound infections, and typical and atypical locations of brown fat. **Results:** In most patients PET CT provided additional information, which either improved or even changed the treatment approach. **Conclusions:** PET CT represents an extremely helpful addition to the imaging methods available for radiation oncology treatment planning. Knowledge of normal variants and potential pitfalls is necessary to obtain the maximum benefits from this technique.

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**196** FLT PET Imaging for Weekly Evaluation of Bone Marrow Compensatory Response to Chemoradiation Therapy in Cervical Cancer Patients

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**Purpose:** The purpose of this study was to identify and evaluate the response of bone marrow activity outside the radiation treatment field using FLT PET imaging at multiple time points during chemoradiation therapy. **Method and 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. 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. Bone marrow compensatory response was measured outside the radiation treatment field within the CT defined boney volume of the L1-L4 vertebral bodies. **Results and Discussion:** FLT PET imaging demonstrated measurable FLT uptake changes in lumbar vertebrae with mean SUVs ranging from 3 to 5.5 before treatment and from 3 to 7 during treatment. A stronger compensatory response was observed in the vertebral marrow just outside the radiation field for subject 1 than subject 2. FLT uptake in the L1 vertebral body bone marrow increased nearly 50% in week 1 for subject 1. Subject 1 L1 mean SUVs were 3.8, 5.6, 7.0, and 5.8 for weeks 1, 2, 3, and 4 respectively. L1 was the furthest outside the radiation field and received a mean weekly dose of 6.0 cGy. L4, the vertebral body nearest the radiation field, received 102.9 cGy/week and did not show an increase in FLT uptake. Subject 2 L1 and L4 vertebral bodies received similar weekly doses (6.6 and 113.1 cGy, respectively), but the L4 mean SUV only increased ~17% in week 1 and the L4 mean SUV decreased nearly 50% in week 3. 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. It may be that a WBC nadir must be reached before a significant bone marrow activity compensatory response is observed with FLT PET. **Conclusions:** Two subjects enrolled in a clinical trial using FLT PET to measure bone marrow response to chemoradiation therapy showed markedly different compensatory responses. Subject 1 showed an obvious increase in FLT uptake outside the radiation field, while subject 2 did not. This may be due to the initial WBC count differences between the two patients. Subject 2 WBCs were over two times greater than Subject 1 WBCs before initiation of chemoradiation therapy and only dropped below 5 K/mm³ after week 3. FLT PET was useful in demonstrating measurable differences in bone marrow compensatory response that may correlate to systemic changes during chemoradiation therapy.

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**197** Lung Tumor Motion and Deformation During the Respiratory Cycle: Potential Implications for Radiation Therapy

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**Purpose:** Primary lung tumors are susceptible to motion (deformation and translation) during the respiratory cycle. While conventional radiotherapy includes a consensus estimated margin to account for tumor motion, four-dimensional (4D) CT imaging reveals more detailed and accurate motion information. We analyzed lung tumor motion characteristics during the respiratory cycle of patients undergoing simulation for lung cancer radiation therapy. **Materials/Methods:** An IRB-approved retrospective review identified lung cancer patients treated in our department using 4D-CT simulation for treatment planning between 2005 and 2010. Parenchymal gross tumor volumes (GTV) were contoured by a single physician on the CT images of average (AVG) and maximum intensity pixels (MIP), in addition to the maximum inhalation (MAXI) and maximum exhalation (MAXE) phases of the respiratory cycle for each patient. Nodal volumes were excluded. Contours were reviewed by an independent physician observer. GTV volume and sup-inf, right-left, and ant-post diameters were recorded for each series. Tumor translation and deformation were analyzed based on these measured quantities. Their correlation with histology and tumor location was also evaluated. **Results:** The GTV contours of 41 patients were analyzed. The total tumor motion (R = VMIP/AVG) was significantly greater for smaller tumors (< 10cm³) than larger tumors. There was no significant difference in MAXI and MAXE volumes, although the variance of the volumes and diameter deformation (T = VINH/VEXH) were significantly larger for small than large tumors. Translation (Q = VEXH+VINH)/VMIP, was also significantly larger for small lesions compared to large lesions. Adenocarcinoma histology was associated with a significantly larger variance in tumor deformation. Both adenocarcinoma histology and tumor location within the lower/middle lobes were associated with a trend towards greater total tumor motion and larger tumor translation. **Conclusion:** Our data indicate that there may be patients that do not benefit from 4D-CT simulation, as there are identifiable characteristics that may predict for less tumor motion during the respiratory cycle.

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A comparison of Contrast Enhanced CT with FDG-PET Image-based Target Volume Delineation in Locally Advanced Pancreatic Cancer For Radiotherapy
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Purpose/Objective(s): To compare radiotherapy (RT) target delineation and therapeutic response using anatomic and functional imaging for patients undergoing chemoradiation plus the Akt-inhibitor nelfinavir for locally advanced pancreatic cancers (PDAC). PDAC is difficult to delineate for radiotherapy due to its important desmoplastic component contributing to the tumour mass and poor contrast from surrounding organs such as the duodenum. Metabolic imaging (e.g., FDG-PET) could help to better identify vital tumour tissue. Material/Methods: For the first six patients accrued to an ethics approved combined modality protocol the gross tumour volume (GTV) at the time of treatment planning and regions of persistent disease six weeks following RT were compared on contrast enhanced CT (CECT) and 18FDG-PET (PET) imaging. Treatment was prescribed to two volumes: 1) PTV50 (the GTV and elective nodal volumes plus a margin) and 2) PTV59 (the gross tumour volume only plus a margin). All CECT based treatment plans were re-calculated using the same beam arrangements and dose constraints to determine the potential gains of using PET-based imaging. The differences in GTV and resultant PTV59 between the two imaging modalities were compared, and the spatial relationship of residual disease at follow-up to the volumes of high dose radiotherapy evaluated. Results: Six patients had baseline imaging and four had imaging at six weeks post RT. The mean baseline GTVs (range) were 49.2 cc (14.5, 73.4), and 43.9 cc (8.1-63.1) on CECT and PET respectively. At follow-up the mean (range) residual GTVs were 21.3cc (11.1, 37.8) and 20.2 cc (6.7, 27.7) on CECT and PET respectively. Repeat plans based on the baseline PET PTV59 for all patients were compared to the clinical plans. The mean (range) PET PTV59 was 274cc (118, 365) which was 11% smaller than the mean (range) CECT based PTV59 which was 306cc (169, 397). Treatment plans based on the PET GTV59 volumes, resulted in a reduced volume of normal tissue treated in the high dose volume in five of six patients. Over all patients the dose to 30% of the right kidney was reduced by 3% (range 1 - 6 %). In one patient a 20% reduction in the volume of stomach treated to 50Gy was observed. The reduction in tumour volume from baseline to six-weeks post treatment was 52% (CECT) and 43% (PET). For all patients, there was no persistent disease that extended spatially beyond the PET based PTV volume on either PET or CT imaging. Conclusion: 18FDG PET tumour volumes were consistently smaller than CECT based volumes and resulted in treatment plans with reduced high-dose treatment volumes. Using these volumes for planning , has the potential to further minimise doses to organs at risk. Further validation and spatial quantification of the dose response is on-going.

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Use of Deformable Image Registration Software for the Dosimetric Evaluation of Local Recurrence of Head and Neck Squamous Cell Carcinoma
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Purpose/Objective(s): To evaluate the dosimetry of local tumor recurrences in patients with head and neck squamous cell carcinoma (HNSCC) using deformable registration software. Materials/Methods: Data from 101 patients with HNSCC who received definitive concurrent chemoradiation therapy (CRT) from January 2006-June 2009 were analyzed for recurrence. Patients were included in our analysis if they had local recurrence as first site of failure after a complete or partial response to CRT. Patients had locoregionally advanced HNSCC (cT1 and cN1 or ≥cT3). Nodal recurrences were not evaluated. Using deformable registration software (Velocity AI, Velocity Medical Systems, Atlanta, GA), the CT at the time of recurrence was registered to the planning CT and its associated dose distribution. Volumes delineated as a recurrence were identified. These volumes in the high dose field (70 Gy) were classified as (1) in-field (D95≥95%), (2) marginal (D95<95% with overlap of the original PTV), and (3) out-of-field (no overlap of the recurrence and the original PTV). The percentage of recurrence volume outside the PTV was calculated using registration software. Finally, the D95 (Gy) and minimum dose to 0.1cc (Gy) was calculated for each recurrence volume. Results: A total of 12 patients had local failures during the study period. The primary tumor sites were the following: retromolar trigone (1), base of tongue (1), supraglottic (3), pyriform sinus (1), tonsil (2), glottic (3), and soft palate (1). Eight patients had in-field recurrences, with a median tumor recurrence volume outside the original PTV of 4.29% (0-25%). The median D95 for patients with in-field recurrences was 68.75 Gy (66.58-69.67 Gy) and the median minimum dose to 0.1cc was 68.02 Gy (2.71-69.67 Gy). Four patients had marginal recurrences with a median tumor recurrence volume outside the original PTV of 26.78% (4.67-59.46%). The median D95 for patients with a marginal recurrence was 60.86 Gy (44.3-65.84 Gy) with a median minimum dose to 0.1cc of 50.86 Gy (4.62-63.57 Gy). No patients in our study had out-of-field recurrences. Conclusion: We used deformable registration with imaging at the time of recurrence to evaluate the local patterns of failure in HNSCC. To our knowledge, there is no consensus for categorizing and evaluating patterns of local failure. The majority of failures in our cohort were in-field failures. We have used this method to evaluate radiotherapy and treatment techniques for HNSCC in an attempt to improve outcomes. Similarly, deformable image registration software may also be used to evaluate local recurrences at other sites.

Purpose/Objective(s): To evaluate the role of FDG-PET/CT in the staging and target volume definition in cervical cancer. Materials and Methods: From June to October 2010, 18 patients (pts) affected by cervical cancer were treated with RapidArc simultaneous integrated boost (SIB)-RA-IMRT at the European Institute of Oncology, Milan, Italy. After standard staging with CT and MRI, all pts underwent FDG-PET/CT in order to exclude distant metastases and to define gross tumour volume (GTV). Seven and 11 pts received exclusive and adjuvant radiotherapy, respectively. In all cases concomitant chemotherapy was administered during radiotherapy. The CT and MRI TNM and FIGO stage of disease of pts was: T1bN0=3, T1bN1=6, T2bN0=3, T2aN1 = 2, T2bN1=3, T3bN1=1 ; Ib=3, IIb=3, IIb=12. All pts underwent a 3 mm simulation CT scan then integrated the volumes definition with a FDG-PET/CT. Clinical target volume (CTV-T) and CTV-N were created by manual clinical margin and adding 7 mm margin to GTV-T and GTV-N respectively. Margins of 15 mm and 5 mm were then added to create PTV-T (planning target volume) and PTV-N from CTV-T and CTV-N, respectively. SIB-IMRT technique was employed: 50 Gy (2 Gy/fraction) was prescribed to the T, 46-50Gy (2 Gy/fraction) to surgical bed, 45 Gy (1.8 Gy/fraction) to N0 pelvic lymph nodes, 55 Gy (2.2 Gy/fraction) to the positive lymph nodes and 50 Gy (2 Gy/fraction) to the para-aortic lymph nodes. PTV was always covered by 95-107% of the prescribed dose. For all pts the radiation treatment schedule included also a boost of 15-30 Gy delivered with high or pulsed dose rate brachytherapy (HDR or PDR). Results: In 5 pts FDG-PET/CT changed the TNM and FIGO stage (N status) of disease compared to conventional MRI staging and CT scan: particularly in 4 and in 1 pts FDG-PET/CT imaging showed highlights metabolically active tumour in para-aortic lymph nodes and in external iliac nodes therefore the stage is changed from M0 to M1 (IIb vs IVb) and from N0 to N1 (IIb vs IIIb) respectively. At the mean follow-up of 2 months (range 0.5-4 months) all pts are alive and no evidence of disease, particularly the pts underwent to radical treatment are in complete remission confirmed by a conventional MRI imaging and FDG-PET/CT scan. Conclusions: Our preliminary results indicate that the FDG-PET/CT leads to a better staging of disease and to a better volume definition and has the potential of showing lymph-nodes metastasis not only within the pelvis but also in the para-aortic area. The impact of FDG-PET/CT findings on long-term survival will be a subject of our future studies.


1 Effect of Abdominal Compression on Respiratory Motion of Esophageal Cancers Measured with 4DCT after EUS-guided Fiducial Marker Placement

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Purpose/Objective(s): To evaluate the effect of abdominal compression (AC) on the respiratory motion of primary esophageal cancers using 4D Computer Tomography (4DCT) after endoscopic ultrasound guided fiducial marker placement. Materials/Methods: We retrospectively identified consecutive patients with cancer of the mid or distal esophagus who had EUS-guided insertion of esophageal gold fiducial markers at the proximal and/or distal margins of their tumors prior to 4DCT simulation between 2/2008 and 3/2010. Presence of fiducials at time of simulation and on follow-up imaging was recorded. Each fiducial marker was reproducibly contoured on all 10 phases of the 4DCT using a uniform Hounsfield unit threshold. The maximal (peak-to-peak) respiratory displacement of each fiducial in the lateral (LR), anteroposterior (AP), and craniocaudal (CC) directions as well as 3D net vector (3DV) displacement was measured by comparing the locations of the centers of mass of each contoured fiducial. A two-tailed, heteroscedastic Student’s t-test was used to compare the displacements in each direction between the two populations with and without AC. Results: A total of 21 patients underwent EUS-guided submucosal implantation of a total of 34 0.75mm x 1cm gold fiducials. 4DCT simulation was performed at a median of 1 day (range 0-87 days) after implantation. Abdominal compression (AC) was utilized in 13 patients. At the time of simulation, 31/34 (91%) fiducials were present. Two of the three fiducials no longer present in the esophagus were visualized distally in the GI tract at the time of simulation. 30 fiducials were contoured on all 10 phases of the 4DCT datasets. One fiducial was not evaluable due to significant imaging artifact. The mean (SD) peak respiratory displacements of the 18 fiducials in 13 patients simulated with AC were 0.18 (0.11) cm in the LR, 0.25 (0.14) cm in the AP, 0.39 (0.14) cm in the CC and 0.48 (0.19) in the 3DV directions. The mean (SD) peak respiratory displacements of the 12 fiducials in 8 patients simulated without AC were 0.15 (0.08) cm in the LR, 0.23 (0.14) cm in the AP, 0.61 (0.20) cm in the CC, and 0.67 (0.21) in the 3DV directions. Statistical analysis comparing motion between the AC and non-AC patients returned p-values of 0.429 (LR), 0.753 (AP), 0.004 (CC), and 0.022 (3DV). Follow-up imaging revealed that 1 additional fiducial was lost after simulation. Conclusions: EUS-guided fiducial placement is a promising technique to aid radiotherapy target delineation for esophageal cancers. Abdominal compression was associated statistically with a significant decrease in mean peak respiratory motion in the craniocaudal and 3D net vector directions allowing for decreased target volumes.


2  An Education And Reference Tool For The Delineation Of Target Lymph Nodes In The Head And Neck

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Purpose/Objective(s): Contouring lymph node chains in the head and neck for the purpose of intensity modulated radiotherapy planning is a time consuming, yet critical process. The purpose of this work is to develop, implement and evaluate a software module that works with our treatment planning system to automatically contour these regions. Materials/Methods: The module first selects the most similar contour set from an atlas of 10 patient CT scans that have been expertly contoured in accordance with the published Radiation Therapy Oncology Group
(RTOG) lymphatic nodal atlas. The image scan and associated contour set are then deformed and registered to the patient being planned using a previously published algorithm. The software was evaluated by a group of 3 radiation oncology residents asked to contour each of four test patients. Each resident contoured two patients with the tool and two patients without the tool. The order of patients was changed for each resident to eliminate learning bias. The time needed to contour; the accuracy of contours drawn and opinions were recorded for each plan.

**Results:** Use of the tool reduced the time needed to contour by 10.8 minutes (averaged over residents and patients). The reduction did not depend on patient. The conformity index (ratio of the sum of all combinations of total intersecting volume to the sum of all combinations of total encompassing volume) was significantly closer to unity for those patients contoured using the tool (0.65±0.02) compared to without the tool (0.46±0.02). When the tool was used, no significant difference was observed in the contouring time between the first and second patient, however when no tool was used, the second patient was contoured at least six minutes faster.

**Conclusions:** Automatically generated contours can increase both the efficiency and consistency of contouring head and neck lymph node chains by clinicians with fewer than three years experience.

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**203** Quantification Of Radiation Induced Liver Damage Using Dynamic Contrast Enhanced Computed Tomography Perfusion In Hepatic Tumors: Preliminary Study

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**Purpose:** The low tolerance of the liver to radiation and the frequent development of radiation-induced liver disease (RILD) limit the use of radiation as an alternative treatment of advanced liver tumor not resectable or suitable for transplantation. The purpose of this study is to demonstrate that dynamic contrast enhanced computed tomography (DCE-CT) perfusion can noninvasively detect RILD following Intensity-Modulated Radiation Therapy (IMRT). **Materials and Methods:** Our institutional ethics board approved this study. The livers of rabbits implanted with VX2 carcinoma were scanned weekly with helical CT and DCE-CT to measure tumor size and perfusion parameters. At a size of 1 cm diameter, the tumor was treated with IMRT to minimize radiation dose to critical structures including the stomach, gallbladder, and blood vessels and surrounding normal tissue. A Varian On-Board cone-beam CT Imaging system was used to align animals to the planning helical CT scans and treatments were performed within 24 hrs of the planning helical scan. The radiation dose delivery was gated using the Varian RPM system and a ventilation system. Tumor dose was 20 Gy in one fraction and the treatment margin around the tumor was 0.5 cm. Following treatment, weekly helical CT and DCE-CT were continued to measure tumor size and detect RILD as a decrease in hepatic blood flow (HTBF) and portal vein blood flow (PVBF).

**Results:** Our preliminary experiments showed that DCE-CT perfusion could detect RILD by the decrease in HTBF and PVBF. Eight days following therapy, the normal liver region that received more than 90% of the planned dose appeared normal in CT and HTBF and PVBF maps. However, by day 15, damage to irradiated normal liver manifested as a significant reduction from before treatment of 47% and 68% in HTBF and PVBF respectively, whereas the damage area appeared normal in the CT images. The dose delivered directly to the tumor was sufficient to achieved local control of the tumor, with no meaningful increase in tumor volume by day 15 after the radiation treatment.

**Conclusions:** DCE-CT perfusion can monitor the effectiveness of radiotherapy and the onset of RILD. In addition, the data suggest that a single radiation fraction of 20 Gy was sufficient to cause RILD of normal liver, but also achieved good tumor control.

**Clinical relevance:** This study suggests that DCE-CT perfusion can be used to optimize and monitor the delivery of focal radiotherapy with/out adjuvant anti-angiogenesis therapy while avoiding RILD.

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**204** Integrated FDG18 PET/CT Imaging for Simultaneous In-Field Boost (SIB) IMRT in Locoregionally Advanced Head Neck Cancer

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**Purpose/Objectives:** To evaluate the efficacy of integrated FDG18-PET/CT images into RT planning for patients with locoregionally advanced head neck cancer and treated with simultaneous in-field boost (SIB) IMRT technique. **Materials/Methods:** From October, 2005 through October, 2010, 54 consecutive patients(49 male, 5 female) with newly diagnosed locoregionally advanced head neck cancer were treated with definitive radiotherapy (RT) or CRT using IMRT-SIB technique. All patients underwent high-resolution dedicated head neck FDG18-PET/CT imaging including contrast-enhanced CT (CECT) images, in which, patients were scanned in radiation treatment position with thermoplastic mask placement. High dose PTVs encompassed all suspicious primary and nodal tumor volumes shown on high-resolution dedicated head neck FDG18-PET/CT and CECT images. IMRT-SIB doses were 67.5, 60.0, and 54 Gy of 30 daily fractions at 2.25, 2.0, and 1.8 Gy to the PTVs for gross disease, intermediate and elective nodal sites, respectively. Patients repeated PET/CT and CECT 3 months after completion of RT or CRT for assessment of tumor response. **Results:** The mean primary tumor volume was 34.1 cm³ (range, 29.2-165.2) delineated on CECT, compared 33.2 cm³ (range, 1.1-151.5) on PET (p=0.564); the mean nodal disease volume was 30.2 cm³ (range, 0.0-216.3) on CECT, and 26.6 cm³ (range, 0.0-198.4) on PET (p=0.018). With mean follow-up of 30.9 months (range, 6.5-54.9) for all alive patients, Kaplan-Meier estimated 1-, 2-, and 4-year overall survival, disease-free survival, locoregional control and distant metastatic free survival were 71.0%, 63.8%, and 59.8%; 76.8%, 66.5%, and 61.0%; 83.3%, 80.3% and 80.3%; 89.9%, 77.9%, and 62.5%, respectively. On follow-up FDG18-PET/CT, 5 patients with persistent primary tumor had minimal maxSUV of 4.8 (4.8-12.2); while two patients with persistent nodal disease had maxSUVs of 4.9 and 8.7. In addition, percentages of post-treatment maxSUV in the primary sites or tumor size reduction in the nodal sites predicted a better disease local or regional control. **Conclusions:** It is very helpful with integrated high-resolution dedicated head and neck FDG18-PET/CT for accurate tumor target...
delineations in IMRT-SIB therapy. Post-treatment residual tumor volume and corresponding maxSUV reductions may predict disease local and regional control. 

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**205 Magnetic Resonance And Computed Tomography Functional Imaging For Delineations Of Dominant Intra-prostatic Lesions For Radiation Boosts: Histologic Correlations And Modeling Dosimetric Feasibility**

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**Purpose/Objective(s):** Dose escalation to dominant intraprostatic lesions (DILs) may provide improvement of tumor control with lower risks of complications compared to dose escalation to the entire prostate in external beam radiotherapy of localized prostate cancers. In this study, we addressed two challenges: accurate definition of the DILs and precise delivery of an escalated dose to the DILs. **Material/Methods:** MR and CT structural and functional imaging were obtained from patients prior to their prostatectomies in a prospective clinical trial. An endorectal coil was employed in 3T MR imaging (Discovery MR750, GE Healthcare) which included T1-weighted gadolinium contrast-enhanced acquisitions. After CT anatomical imaging (Discovery CT750 HD, GE Healthcare), dynamic CT imaging was performed with iodine contrast injection to derive CT perfusion maps. Whole-mount digital histology images were also obtained for registration with the preoperative imaging using fiducial markers applied to the specimen. In this study, we identified patients with dominant intra-prostatic lesions (DILs). Deformable registration was performed based on control points derived from prostate contours segmented manually on the MR, CT and histology. The deformed MR and histology images were fused with a planning CT in Pinnacle v9.0 beta (Philips Medical Systems) for delineation of the boost-target. Planning target volumes (PTV) for the prostate and the DIL were created with a margin of 7 mm. 5-field intensity-modulated radiotherapy (IMRT) and volumetric-modulated arc therapy (VMAT) were generated on Pinnacle for a simultaneous and a sequential boost plan, each aimed to deliver 76 Gy to the entire prostate and an additional 10 Gy to the PTV of the DIL. A reference plan delivering 86 Gy to the entire prostate was generated. All plans were delivered for dosimetric accuracy checks, with and without added modeled intra-fraction motion. **Results:** In our preliminary analysis, post-contrast T1 MR and CT permeability surface maps showed correspondence to the histology-defined DIL. The DIL was less than approximately 1/8 of the volume of the prostate. The treatment plan delivering 86 Gy to the entire prostate exceeded recommended dose volume constraints to the bladder and rectum, while the IMRT and VMAT simultaneous and sequential plans with boosts to the DIL satisfied both prescription doses and normal tissue constraints. Including effects of motion, the sequential plans were more sensitive to motion than the simultaneous boost plan. **Conclusions:** We demonstrated the feasibility of using IMRT/VMAT simultaneous integrated boost plans for dose escalations to the DIL identified by MR and CT functional images. 

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**206 ITV definition using PET Images in Radiation Therapy for NSCLC: Determination of a Multi-dimensional Non-linear Parametric Model to Predict the Optimum PET SUV Threshold Values**


**Purpose/Objective(s):** Using FDG-PET in addition to CT to define the tumor volume has been shown to reduce the inter-observer variability and to effectively discriminate malignant from normal tissue. However, PET SUV threshold values used to define the internal tumor volume (ITV) has a large variation. Further more, PET images, taken over multiple respiratory cycles are prone to respiratory motion effects. We developed a functional form to predict the SUV threshold by tumor motion amplitude, 4DCT ITV volume, and maximum PET SUV. **Material/Methods:** Pre-treatment FDG-PET/CTs and 4DCTs from 30 lung cancer patients were co-registered. Tumor volume, V ranged from 0.5 cc to 440 cc while the motion amplitude, A, determined from 4DCT range from 0 to 1.5 cm. The, PET SUV_max ranged from 3.8 to 18.95 corresponding to a fractional SUV threshold range, [SUV_threshold / SUV_max] of 0.2 to 0.86. The ITV was contoured in the 4DCT, and used as the tumor volume. Using the 4DCT ITV as the gold standard, PET image was contoured and PET SUV threshold value was changed until the PET ITV agreed to within 1 cc of 4DCT ITV. Data for 20 patients were input into a multi variable non-linear chi squared minimization routine (MINUIT from CERN) to optimize a 5 parameter function that fit the optimum SUV threshold. We assumed that the SUV threshold depends on the following parameter combinations: constant coefficient, SUV_max up to its second order, (SUV_max)^2, and A(SUV_max)^2. Data from the remaining 10 patients was used to independently validate the predictive accuracy of the parameterization. **Results:** The parameterization shows that the first order SUV_max term is the most significant contributor to the SUV threshold while the (SUV_max)^2 term is the secondmost significant contributor. The convergence of the minimization showed that motion amplitude is more important for tumors with higher SUV_max values. The mean difference of tumor radii between the measured ITV and the parameterization predicted ITV for the 20 patients used for the fit was 0.1 mm (SD, 1.1mm, maximum, 1.7mm). The mean difference of radii between the measured ITV and the parameterization predicted ITV for 5 verification patients were 0.7 mm (SD, 0.9 mm, maximum, 1.4 mm). **Conclusion:** We have defined a model with 5 parameters which accurately predicts the SUV threshold of a PET scan for NSCLC, given the motion amplitude, SUV_max, and 4DCT ITV volume. This model will allow clinicians to “normalize” SUV thresholds across different patient populations by using our parametrically derived SUV threshold. 

207 Delineation of Target Volumes on Maximum Intensity Projection Images for 4 Dimensional Computed Tomography based radiotherapy planning in Non Small Cell Lung Carcinoma: The Optimum CT thresholds

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Purpose/Objective(s): With advent of 4-D CT, the respiratory motion in NSCLC has been focussed but the accurate target delineation in Maximum Intensity Projection (MIP) images is essential. The target delineation including the Internal Gross Tumor Volume (IGTV) and the Clinical Target Volume (CTV) on CT images depends on CT thresholds which may be different for the MIP images from the standard 3D-CT. The aim of the study was to determine the optimum CT window/level thresholds for IGTV and CTV delineation in MIP images for 4-DCT based Radiotherapy planning in NSCLC.

Materials/Methods: The 4D-CT image datasets of 5 patients of NSCLC who underwent 4-D CT based RT planning was analysed. The IGTV were delineated by combining GTV contours from ten respiratory phases ofIGTVALLPHASES at standard CT window/level of 1600HU/-300HU and on corresponding MIP images for different CT window/levels at 1600HU/-300HU (IGTVMIP1) ;1600/-450HU (IGTVMIP2) ;1600/-600HU (IGTVMIP3) ;1600/-700HU (IGTVMIP4) and 1200/-700HU (IGTVMIP5). The CTV was auto-generated with 6-7mm margins and corrections done at each individual slices of IGTVMIP and IGTVALLPHASES. Volumes and maximal diameter (MD) of each IGTVMIP and CTVMIP was compared with IGTVALLPHASES and CTVALLPHASES taken as reference IGTV and CTV. Underestimation and overestimation of volumes also measured. Statistical analysis was done by SPSS Version 16. Results: The correlation coefficient of IGTVMIP volume with IGTVALLPHASES ranged from 0.73 to 0.90 with IGTVMIP(r=0.90) and IGTVALLPHASES(r=0.89) being better. The correlation coefficient of CTVMIP volume with CTVALLPHASES volume ranged from 0.85 to 0.95 with CTVMIP(r=0.948) and CTVALLPHASES(r=0.946) being better correlated. The correlation coefficient of the IGTVMIP MD with IGTVALLPHASES ranged from 0.82 to 0.99 IGTVMIP(r=0.988) and IGTVALLPHASES(r=0.98) being better. Overestimation of total volumes was seen consistently in IGTVMIP and CTVMIP. Conclusion: Qualitatively, MIP images generated from 4D-CT data set differs from individual 3D-CT images. Our study indicates that CT window/level thresholds of 1600/-450HU and 1600/-600HU are better than standard CT window/levels for accurate IGTV and CTV delineation in MIP images for radiotherapy planning in NSCLC.


208 Evaluation of Breast Tissue Marker Impact on Advanced MR Imaging

E. S. Paulson, R. W. Prost, M. Gono, X. Li, K. M. Schmainda, J. A. White, Medical College of Wisconsin, Milwaukee, WI

Purpose/Objective(s): Advanced MRI techniques, including diffusion-weighted (DW) and perfusion-weighted (PW) imaging, may aid in the diagnosis, targeted therapy definition, and treatment response evaluation of breast cancer. However, magnetic susceptibility effects arising from breast tissue markers placed during biopsy may hamper the efficacy of these advanced MRI techniques. The goal of this study was to evaluate several commercially available breast tissue markers in terms of impact on advanced MR image quality. Materials/Methods: A total of five breast tissue markers were evaluated. Three of the five markers were ultrasound-guided (Bard UltraClip, Bard UltraClip II, HydroMARK) and the remaining two were stereotactic-guided (Gel Mark UltraCor, ATEC). Imaging phantoms for each marker were constructed using 500 mL round bottom Florence flasks containing 1.25% weight by volume agarose gel doped with 0.3 mL/L gadobenate dimeglumine (MultiHance, Bracco), 2 mmol choline, and 10 mmol n-acetyl-aspartate. One of the phantoms was constructed without a marker to serve as a control. Imaging was performed on a Siemens 3T Verio scanner using a commercial phased-array coil. A multi-shot, variable-density spiral spin-echo pulse sequence of our own design was used to acquire DW images: FOV: 22 cm2; matrix: 1282; TE: 70ms; TR: 3000ms, BW: 200kHz, thickness: 5mm, b-values: 0, 1000 s/mm2. A single-shot, dual-echo, fid-spiral pulse sequence of our own design was used to acquire PW images: FOV: 20 cm2, matrix: 642, TE1: 3ms, TE2: 38ms, TR: 1600ms, BW: 200kHz, thickness: 5mm. Images were reconstructed offline using custom software developed at our institution. Results: The five markers displayed varying degrees of image artifact, consisting of localized magnetic susceptibility-induced signal dropout and signal intensity pile-up. Overall, the stereotactic-guided markers produced markedly less image artifacts compared with the ultrasound-guided markers. The Gel Mark UltraCor stereotactic-guided marker was found to have the least effect on advanced MR image quality of all five markers evaluated. The marker demonstrating the most severe artifacts was found to be the Bard UltraClip II ultrasound-guided marker. Of the ultrasound-guided markers, the HydroMARK marker had the least effect on advanced MR image quality. Conclusion: Advanced MR image quality can be affected by choice of breast tissue marker. The Gel Mark UltraCor stereotactic-guided marker and the HydroMARK ultrasound-guided marker resulted in the least image artifacts of the five markers studied. Selection of an optimal breast tissue marker is critical to maintain the fidelity of advanced MR images, particularly at higher fields, where magnetic susceptibility effects are exacerbated. Acknowledgements: Funding support provided by the MCW Cancer Center and the Komen Foundation.

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209 Integrating Diagnostic Imaging And Radiotherapy Objects Into A Single Case Management System For Clinical Research


Purpose/Objective(s): Imaging, a critical modality of clinical trials, validates eligibility, staging, response, outcome and defines radiation therapy (RT) targets. Study investigators need ability to view images to determine study compliance and treatment pathways. From a single case record images are retrieved/viewed with RT objects to evaluate target volume appropriateness in real time. Quality Assurance Review Center (QARC) has provided RT quality assurance (QA)/diagnostic data management services to National Cancer Institute’s Cancer Therapy Evaluation Program for >25 years. In the 2D era QARC acquired/reviewed RT dose/target volume information (planning/portal images). The advent of image based treatment planning generated need to collect diagnostic imaging. QARC became the imaging repository for studies with and without RT. Collaborating with Childrens Oncology Group diagnostic imaging committee and Advanced Imaging.

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Technology Consortium, QARC integrated and maintains a complete case management system on one informatics platform. As the Diagnostic Imaging and Radiation Oncology disciplines evolve, QARC’s system supports advanced imaging modalities for review/archiving.

Materials/Methods: Images/RT objects are acquired by multiple methods (CD, sFTP, DicomCommunicator, AG Mednet) and reviewed on site or remotely via secure VPN and SSL terminal server connections. The validated relational database has controls in place to assure 21 CFR Part 11 compliance for industry/cooperative group clinical trials. DICOM and Dicom RT files are imported into the Patient Electronic Image Archive (QARC PACS). File pathway is stored in the patient record and with one click image files are viewable. Reports/other patient information submitted in digital formats are also stored.linked to the patient record creating a complete electronic patient record for clinical research. Imaging modalities in the archive include CT, MR, Ultrasound, Mammogram, X-ray, Bone/Gallium/PET/Thallium/MIBG scans. Data management QA ensures files are readable/complete. Scans are organized in the patient record by protocol timepoints. Investigators evaluate cases with multiple tools including CERR, MIMVista, DicomCommunicator. Results: QARC PACS has >60,000 DICOM and Dicom RT files on 52,000 patients treated on >375 trials with >120 trials currently active for data acquisition. This year over 3400 cases have been assigned to remote reviewers and 1936 cases have been reviewed on site. Conclusions: Seamlessly integrating advancing imaging/RT technologies into RT QA and patient treatment management for study compliance is feasible. Providing these data to the clinical trials enterprise enables critical quality improvement in the short term and valuable research resources for the future.


210 Target Definition Via Deformable Image Registration And Its Effect On Normal Tissue Sparing
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Purpose/Objective(s): Application of 4D imaging in radiotherapy planning has enabled clinicians to define patient-specific motion margins by way of an internal target volume (ITV), which is the envelope of tumor motion. Although a major improvement from the use of uniform or population-based margins, this approach exposes an appreciable portion of surrounding normal tissue to high prescription doses. A more optimal plan can be generated by defining the target volume such that tumor coverage and normal tissue exclusion are simultaneously maximized. This can be achieved by the use of deformation vector fields (DVFs) derived from deformable image registration. The DVFs describe the trajectory of each voxel and therefore can be used in deriving such efficient targets. We hypothesize that this optimized method will have tumor coverage comparable to that of the ITV method but with better normal tissue sparing.

Materials/Methods: A 4DCT volume of a previously treated lung patient; tumor volume: 78cc, extent of motion: (1, 4, 9) mm in the (LR, AP and SI) axes was used for this preliminary study. Two 4D plans were developed (1) based on the ITV method and (2) utilizing a DVF-optimized target. Using the DVF, we partitioned the ITV into 2; a sub target (MinIP) that always intersected with the moving tumor and never intersected with a normal tissue in the ITV and the remainder (ITV-MinIP). We maintained the same beam geometry for the 2 plans; however the DVF plan involved 2 segments per beam with a weighting that resulted in an MU delivery of 2:1 to the MinIP and ITV remainder respectively. We compared the two 4D plans for target coverage and normal tissue sparing.

Results: Target coverage was comparable between the 2 modalities, with D95 (minimum dose irradiating 95% of GTV) > 95% of the prescribed dose in both modalities, however with a more homogenous dose in the ITV-4D plan. We observed better normal tissue sparing in the latter method where mean lung dose reduced from 13Gy to 10Gy, lung V20 reduced from 23% to 15% and mean dose to the GTV-ring (a 2cm concentric ring around the GTV) reduced from 50Gy to 39Gy. Conclusions: This preliminary work demonstrates that we can improve normal tissue sparing while still attaining acceptable target coverage if, at the level of treatment planning, both the tumor inclusion and the normal tissue exclusion from primary beams are taken into account. In reality, a large set of target configurations can be derived from the DVFs. Future work is aimed at learning the set of criteria that can enable us to generate the optimal target configuration in the clinical setting. Further work including many patient studies are also needed to investigate the relative benefits of this approach as a function of tumor characteristics such as size and motion extent.


211 What Is A More Accurate Method to Determine Internal Target Volume (ITV) for Stereotactic Body Radiation Therapy (SBRT) of Lung Cancer
H. Ge, J. Cai, C. Kelsey, F. Yin, Duke University Medical Center, Durham, NC

Purpose/Objective(s): SBRT has been shown an effective treatment for early stage lung cancer. One of the greatest challenges is the tumor motion induced uncertainty in target volume determination. Maximum intensity projection (MIP) of 4DCT has been widely used to generate tumor ITV, but can significantly underestimate it due to patient breathing irregularity. This study is to show that a new ITV (ITVCOMB) which combines ITV contoured from MIP images and GTV contoured from free-breathing CT (GTV3D) is more accurate than individual volume for lung SBRT.

Materials and Methods: 13 non-small cell lung cancer (NSCLC) patients who underwent SBRT treatment were included in this retrospective study. All patients were imaged with both free-breathing 3D helical CT (3DCT) scan and 4DCT scan (Lightspeed, GE Healthcare, Milwaukee, WI). Varian’s Real-time Position Management (RPM) system (Varian Medical Systems, Inc., Palo Alto, CA) was used to obtain patient breathing signal. The cine duration per slice and the cine time (image acquisition time per phase per slice) were set to the breathing period plus one second and one tenth of the breathing period, respectively. MIP was generated from the 10-phase 4DCT and was exported, along with 3DCT, to a treatment planning system (Eclipse, version 8.6, Varian Medical Systems, Palo Alto, CA) for contouring and planning. ITVCOMB was calculated for each patient. All CT images were set to the same lung window/level before contouring the target volumes. Comparison between ITVCOMB and ITV3D was performed using t-test. Results: The ITVCOMB for all patients except one were greater than ITV3D, indicating 4DCT MIP under-estimated tumor motion information. On average, ITVCOMB (mean: 13.53 ± 9.42 cm3) is significantly greater (13.8%) than ITV3D (11.89 ± 9.09 cm3) (p = 0.002).

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Conclusion: Preliminary results demonstrated that ITV determined from 4DCT MIP did not include all tumor motion information, and thus underestimated the true tumor ITV. Combining ITV_{max} and ITV_{10} to determine ITV can reduce this potential source of error. Whether ITV_{comb} is the optimal tumor ITV remains a question and further investigation on this matter is highly desired.

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212 The Role Of Histogram Equalization For Gross Tumor Volume Delineation In Contrast Enhanced Tomography Images For Radiotherapy Planning In Head and Neck Cancer: An Initial Clinical Experience

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Purpose/Objective(s): Histogram equalization is a nonlinear transformation scheme especially used in computed tomography of lung, in dentistry and in histopathological slides for better contrast view. In our study, we explore the possibilities of histogram equalization for Gross Tumor Volume delineation (GTV) in radiotherapy planning for head and neck cancers. Materials/ Methods: 10 patients of Oropharyngeal Cancers were included in this study protocol after informed consent. After clinical examination and baseline imaging, they were staged and either planned for radiation therapy alone or concurrent chemo radiation. Planning CECT was done in Philips Big Bore CT scanner and images were transferred to Pinnacle Treatment Planning system( Version 8).The GTV delineation was done in both linear and histogram intensity window settings at standard head and neck CT thresholds. The differences in contoured volumes were noted. Another radiation oncologist also contoured GTV on both intensity settings for all 10 patients. The Clinical target volume (CTV) and Planning Target Volume (PTV) and other organs were defined on the histogram equalization intensity settings and 3D Conformal Radiotherapy treatment plans were generated and patients were treated with radical radiotherapy (70Gy/35#/7weeks) or Chemoradiotherapy (70Gy/35#/7weeks with weekly cisplatin, 40mg/m2).A CECT was done to evaluate response at 1 month post treatment along with clinical examination. Results: The study included 6 patients of carcinoma base of tongue, 3 patients had carcinoma vallecula and one with tonsillar malignancy with T stage (T3=7, T2=2, T1=1). The mean GTV of 10 patients was 20.97(SD=±14.65) cm3 and 24.58(SD=±13.19) cm3 in the linear intensity window settings. The mean GTV in histogram intensity settings was 18.10(SD=±11.13) cm³ and 32.14(SD=±23.1) cm³. The differences between the linear intensity value and histogram values were not significant (p>0.05). There was no significant interobserver variability noted. The post treatment CECT and clinical examination at 1 month revealed complete response at the primary site in all the 10 patients. Conclusion: The use of histogram equalization for GTV delineation in Oropharyngeal Cancers in our study have shown good clinical results although the contouring benefit over linear intensity function was not proved in this study probably, due to less number of patients and observers involved. The head and neck tumors showed sharp enhancement with histogram equalization intensity function. Further studies are needed to find out whether using this function reduces the inter-observer and intra-observer variability in GTV delineation for head and neck cancers.


213 Volume, Shape and Position Changes Due to Motion During CT Image Acquisition

P. Besa, R. Yanez, D. Venencia, Pontificia Universidad Catolica/Chile, Santiago, Chile

Purpose/Objective(s): CT images are used for radiotherapy treatment planning and to evaluate tumor response. Changes in shape, volume and position due to motion during CT image acquisition can produce inaccuracy in tumor delineation and measurement. The purpose of the study was to evaluate the volume, shape and position changes on moving phantom when images were acquired with CT. Materials/Methods: A motorized oscillatory platform with radio opaque phantoms (GRILON 1.13 g/cm³) attached was build. Image acquisition was obtained with a CT GE Light Speed (8 slice scanner). A static reference volume was attached for comparison. Oscillatory movement was fixed to amplitude of 1cm and frequency of 1cycles/minute. Axial and helicoidal CT modes were employed and images were acquired with different X-ray tube rotation and couch speeds. No synchronization was used between CT image acquisition and phantom movement. Image reconstruction was contoured automatically using Varian Eclipse v.7.3 virtual simulation workstation. Volume changes and center of mass (CM) displacement were compared with the static reference image. Results: Comparison between static image and moving phantoms show a range of volume change from 3% to 37%. Volume differences varied with the phantom figure and image acquisition mode. With axial acquisition for a pyramid and sphere phantoms volume change were 26% and 14% respectively and for helicoidal scans 37% and 21%. Helicoidal scans produce a smoothing of the motion artifacts. Faster table speed produces less volume deformation. Displacement of the CM occurs along the direction of the phantom movement. For axial and helicoidal scans the largest CM displacement was 9mm. Conclusions: CT acquired images with a moving target produce phantom changes in volume, shape and relative position. The phantom modifications vary with phantom figure, tube rotation speed, CT table speed and acquisition mode. Error can occur in volume delineation for radiotherapy or for the tumor response measurements.

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214 Comparative Studies Of 153sm-edtmp, 166ho-edtmp And 177lu-edtmp As Novel Agents For Treatment Of Painful Skeletal Metastases

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Introduction: Ethylene diamine tetramethylene phosphonate (EDTMP) is one of the most widely used ligands which forms stable complexes with various radionuclides and all the complexes showed high bone uptake in biodistribution studies. The surface bone-seeking radiopharmaceuticals 153Sm-EDTMP, 166Ho-EDTMP and 177Lu-EDTMP were investigated among vital rat organs by scarification studies and imaging. Materials/Methods: 153Sm (T1/2 = 46.27 h, E3max= 810 keV), 166Ho (T1/2 = 26.8 d, E3max= 1.85 MeV) and 177Lu (T1/2 = 6.71 h)
d, $E_{\text{f}(\text{max})} = 497 \text{ keV}$) were used as the radioisotopes that produced by thermal neutron bombardment on $153\text{Sm}_2\text{O}_3$, $166\text{Ho}_2\text{O}_3$ and $176\text{Lu}_2\text{O}_3$ target in the 5MW Tehran Research Reactor (TRR). The radiochemical purity of complexes was checked by irradiation thin layer chromatography (ITLC). For comparative biodistribution studies, $153\text{Sm}$-EDTMP, $166\text{Ho}$-EDTMP and $177\text{Lu}$-EDTMP were injected into wild-type rats through tail vein, and then biodistribution data were obtained as percentages of injected dose per gram of tissue (% ID/g). Furthermore, whole-body images were acquired after injection of the radiopharmaceuticals to quantify the skeletal uptake. **Results:** The radiochemical purity results of were showed high purity of more than 98% for the radiopharmaceuticals under optimized reaction conditions. All the complexes were stable at the room temperature. High bone uptakes of the $153\text{Sm}$-EDTMP, $166\text{Ho}$-EDTMP and $177\text{Lu}$-EDTMP were: 1.77, 3.19 and 3.18 %ID/g at 4 hr, respectively; and 1.59, 2.1 and 2.33% ID/g at 24hr, respectively. **Conclusions:** $153\text{Sm}$-EDTMP, $166\text{Ho}$-EDTMP and $177\text{Lu}$-EDTMP were found to have high potential as bone pain palliation agents. $177\text{Lu}$-EDTMP showed higher bone uptake and slower bone clearance in rat than those of $153\text{Sm}$-EDTMP and $166\text{Ho}$-EDTMP, also the comparatively longer half-lives of $177\text{Lu}$ will provide much needed logistic advantages in countries with limited reactor facilities.

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**215 Shoulder Morbidity In Breast Cancer Patients Treated with Co-60 Photon Beam in a Low Resource Centre**

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Breast cancer is one of the most common female malignancies in the region. Presentation is commonly late with huge breast tumour and regional lymph nodes metastases. Post mastectomy radiotherapy (PMRT) is therefore an essential modality in the management of these patients. However, due to limited facilities, external beam radiotherapy treatment planning is carried out manually using surface anatomy. This presents a great challenge to the radiation oncologists practicing in low resource setting.

The objective of this study was to assess the prevalence and degree of shoulder morbidity in breast cancer patients who received PMRT.

**TECHNIQUE DEMONSTRATION IN POSTER PICS**

There were 61 females and 1 male. Patients age-range was 32years - 69years.

All the patients had modified radical mastectomy with axillary clearance.

Histology: Invasive Ductal Carcinoma. All the patients had postive axillary lymph nodes. Stages II-III.

Post mastectomy Radiotherapy was delivered with the aid of a tilt-board, on Co-60 teletherapy machine using a bi-tangential chestwall and a direct anterior supraclav/axillary portals. A total of 50Gy in conventional fractionation (2 Gy/fr) over 5 weeks, was given. The dose reference depth for the supraclav/axilla was 3cm. A Pb-block was applied to shield the head of humerus. None of the patients was simulated. All the patients had their shoulder function assessed before and after radiotherapy and at follow up visits.

Result: At a minimum follow up of 9 months, 23 patients (37%) reported mild pain in the shoulder. 7 patients (1.1%) had some restriction in the shoulder range of motion. None of the patients had any interference in daily activities as result. Age and body mass index had no impact on shoulder morbidity. No axillary lymph node recurrence was observed among the patients.

Discussion: The study showed that regional lymph node irradiation in breast cancer patients treated with post mastectomy irradiation using Co-60 in low resource setting was well tolerated with minimal shoulder morbidity. Long-term follow up of the patient is required.

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