

time, the designed multi-pinhole SPECT system can provide molecular and functional information about the target region as patients are in position for radiation therapy. This work is supported by NIH grant R21-CA156390-01A1.

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Incorporating PET/CT Images Into 3D Ultrasound-Guided Biopsy of the Prostate

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Purpose: Prostate cancer is the second leading cause of cancer mortality in American men. Systematic transrectal ultrasound (TRUS)-guided prostate biopsy is considered as the standard method for prostate cancer detection. The current biopsy technique has a significant sampling error and can miss up to 30% of cancers. As a **Result**, a patient may be informed of a negative biopsy **Result** but may in fact be harboring an occult early-stage cancer because the current ultrasound imaging technology has difficulty to differentiate carcinoma from benign prostate tissue and because the current TRUS-guided biopsy is blind and random. We are developing methods to combine PET/CT with three-dimensional (3D) ultrasound images for targeted biopsy of the prostate with the aim of improving cancer detection rate. **Methods:** The 3D ultrasound-guided biopsy system consists of a 3D mechanical localization system and software workstation for image segmentation, registration, and biopsy planning. For PET imaging, we use a new molecular imaging tracer called anti-1-amino-3-18F-fluorocyclobutane-1-carboxylic acid ([F18]FACBC) that has shown promising results for detecting and localizing prostate cancer in our human clinical trials. In order to plan biopsy, we developed a 3D, automatic segmentation method for the prostate ultrasound images. In order to incorporate PET/CT images into ultrasound-guided biopsy, we developed image registration methods to fuse TRUS and PET/CT images. **Results:** The segmentation method was tested in ten patients with a DICE overlap ratio of $92.4\% \pm 1.1\%$. The registration method has been tested in phantoms. The biopsy system was tested in prostate phantoms. Three-dimensional ultrasound images were acquired from four human patients. We are integrating the system for PET/CT directed, 3D ultrasound-guided, targeted biopsy in human patients. **Conclusions:** A PET/CT image-directed, 3D ultrasound-guided biopsy system has been developed for the prostate. This research is supported in part by NIH grant R01CA156775 (PI: Fei), Georgia Cancer Coalition Distinguished Clinicians and Scientists Award (PI: Fei), and the Emory Molecular and Translational Imaging Center (NIH P50CA128301).

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Obtaining Elemental Tissue Composition of Proton Therapy Patients Using Positron Emission Tomography: A Pilot Study

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Purpose: Determination of patient tissue elemental composition is vital to improve proton dose, range calculation and verification; however, currently no method of obtaining elemental composition currently exists. Our aim was to investigate the feasibility of obtaining tissue elemental composition after proton therapy by measuring several positron-emitting radioisotopes. **Methods:** Six 2-mm thick samples each containing carbon[C], oxygen[O], carbon/oxygen composite[C+O], carbon/nitrogen composite[C+N], O+N, or C+O+N were irradiated parallel using a monoenergetic proton beam with a median energy of 50-MeV delivering 2.5 Gy. Irradiated samples were moved to a gamma counter and 511-keV annihilation photons were counted for 60 min. Next, three 12-cm long phantoms each composed of C, O, or C+O were irradiated simultaneously first using a monoenergetic proton beam and then using a 6-cm SOBp proton beam of a range of 10-cm with ~2 Gy. After each irradiation, phantoms were PET scanned for 30-min in dynamic mode. Distinct radioisotope fractions from irradiated C-only and O-only phantoms/samples were used to calculate the relative fraction of C and O in composite phantom/samples. In addition, two patients were PET scanned after proton treatments of the head region. Three ROIs - bone&fat, eye, soft-tissue were analyzed. Time-activity signals from all measurements were separated into the constituting radioisotopes' decay curves (O15, N13, C11, etc). The methods above were compared with Monte Carlo and analytical methods using published proton nuclear cross-section data. **Results:** The fractions of each element in the C+O and C+O+N samples

were estimated with errors of 8 and 15% respectively. The composition of O+C phantom was estimated within 5% error. Elemental compositions of three ROIs were compared with ICRU elemental compositions and showed consistent C/O ratios with uncertainties of 20 to 30%. **Conclusions:** Elemental compositions of phantoms, samples and patients were estimated with relatively small errors. PET imaging may potentially be used to improve proton treatment planning and verification. Part of the data presented here are kindly provided by Massachusetts General Hospital

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Real-Time Metabolic Image-Guidance to Aid Intraoperative Radiation Therapy: Pilot Results in a Small-Animal Model

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Purpose: Real-time biological imaging is being investigated to delineate positive tumor margins which may provide feedback during intraoperative radiation therapy. We investigated the feasibility of identifying prostate cancer invasion through the capsule of the prostate intra-operatively in a mouse model using Cerenkov optical emission from Fluorodeoxyglucose (FDG). The potential benefit of using Cerenkov emission is that it provides real-time images of glucose uptake while avoiding signal from the bladder and surrounding structures beyond the surgical margin. We investigated the performance of a Cerenkov imaging system during surgical prostatectomy in vivo in a tumor mouse model. **Methods:** All Cerenkov images were collected with a commercial optical imaging system. A transgenic adenocarcinoma of the mouse prostate (TRAMP) mouse model was used to investigate the feasibility of imaging local invasion of the cancer beyond the prostate capsule. A mouse with a ~1cm prostate tumor with questionable invasion as determined by T2-W MRI was injected with 1.2mCi of FDG. The injection was followed by PET/CT after 75 minutes, and subsequent sacrifice; surgery commenced 3:45 later. After prostatectomy, Cerenkov images were acquired during an attempt to clear the surgical margin. **Results:** In all, 8 tissue resections were performed in the surrounding tissues including the seminal vesicles, rectum, and other nearby organs. Cerenkov imaging identified tissues both before surgical resection in vivo, and confirmed their successful excision after surgical intervention ex vivo. The Cerenkov imaging confirmed uptake in the seminal vesicles, as is expected in this tumor model. In addition, several hyperintense regions that were not identified in PET/CT were visible with the interventional system. **Conclusions:** This proof-of-concept study explored the feasibility of using Cerenkov based imaging for the interventional identification of tumor tissue that had spread beyond the prostate. A more in-depth analysis is currently underway to determine the potential benefit to intraoperative radiation therapy. DOD Breast Cancer Fellowship W81XWH-10-1-0506, Center for Biomedical Imaging at Stanford (CBIS), NCI R01 CA128908, NIH ICMIC P50CA114747.

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Lung Cancer Patient Feasibility Study for Emission Guided Radiation Therapy

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Purpose: Emission guided radiation therapy (EGRT) is a new concept that allows for online biological targeting with radioactive tracers. The concept was previously demonstrated in phantom experiments involving free breathing trajectories. This study involves the first patient imaging data to assess feasibility and estimate performance in a more realistic context. **Methods:** A proposed EGRT geometry involves rotating two PET detector arcs with a linear accelerator and binary multi-leaf collimator on a CT gantry to deliver beamlets of radiation dynamically along detected PET emission paths. A lung cancer patient underwent PET-CT as part of radiotherapy planning. PET list-mode data were retrospectively used as an input to simulate the EGRT system's response and Monte Carlo simulations were used to calculate the dose to the patient. The gross target volume (GTV) was contoured based on the PET-CT images and the planning volume (PTV) was defined as a 10 mm extension of the GTV in all directions. The EGRT method was compared to uniformly irradiating the same PTV (IMRT), with both methods normalized for the same integral dose to the chest wall. Physiologic motion was ignored during the dose calculations as the tumor exhibited < 2 mm motion. **Results:** The dose peaks towards the center of the GTV with the EGRT method. However, even in the presence of this inhomogeneity, the EGRT method resulted in 18%