Errata
2015 AAPM Annual Meeting
Electronic Campus Posters

CALENDAR OF EVENTS

*** = Presenting Author**

Monday, July 13, 2015

Therapy: Electronic Campus Posters

4:30 pm - 5:00 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-T Process Control

Provost: Eric Klein, Washington University, Saint Louis, MO

MO-FG-CAMPUS-T-01 A Comparison of Two Risk Analysis Techniques for Surface Image Guided Radiosurgery - G. Kim *, R. Manger, T. Pawlicki

MO-FG-CAMPUS-T-02 An Electronic Whiteboard Platform to Manage Treatment Planning Process - D. DiCostanzo *, S. Thompson, J. Woollard, N. Gupta, A. Ayan

MO-FG-CAMPUS-T-03 Data Driven Approaches for Determination of Treatment Table Tolerance Values for Record and Verification Systems - N. Gupta *, D. DiCostanzo, M. Fullenkamp

MO-FG-CAMPUS-T-04 Implementation of a Standardized Monthly Quality Check for Linac Output Management in a Large Multi-Site Clinic - H. Xu *, B. Yi, K. Prado

MO-FG-CAMPUS-T-05 SQL Database Queries to Determine Treatment Planning Resource Usage - C. Fox *, D. Gladstone

Joint Imaging – Therapy: Electronic Campus Posters

4:30 pm - 5:00 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-J MRI for RT Simulation

Provost: Robert Cormack, Harvard Medical School, Boston, MA

MO-FG-CAMPUS-J-01 Effect of Iodine Contrast Agent Concentration On Cerebrovascular Dose for Synchrotron Radiation Microangiography Based On a Simple Mouse Head Model and a Voxel Mouse Head Phantom - H. Lin *, J. Jing, Y. Lu, C. Xie

MO-FG-CAMPUS-J-02 Human Implanted Micro Bio Chip for Real-Time Atrial Fibrillation Monitoring with Wireless Power Transmission - J. Lee *

MO-FG-CAMPUS-J-03 Sorting 2D Dynamic MR Images Using Internal Respiratory Signal for 4D MRI - Z. Wen *, C. Hui, B. Stemkens, R. Tijssen, C. van den Berg, S. Beddar

MO-FG-CAMPUS-J-04 Tissue Segmentation-Based MR Electron Density Mapping Method for MR-Only Radiation Treatment Planning of Brain - H. Yu *, Y. Lee, M. Ruschin, I. Karam, A. Sahgal

MO-FG-CAMPUS-J-05 Toward MRI-Only Radiotherapy: Novel Tissue Segmentation and Pseudo-CT Generation Techniques Based On T1 MRI Sequences - S. Aouadi, M. McGarry, R. Hammoud, T. Torfeh *, G. Perkins, N. Al-Hammadi

Imaging: Electronic Campus Posters

4:30 pm - 5:00 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-I Breast Imaging

Provost: James Dobbins, Duke University Medical Center, Durham, NC

MO-FG-CAMPUS-I-01 Accuracy of Radiologists Interpretation of Mammographic Breast Density - S. Vedantham, L. Shi, A. Karellas *, A. O'Connell

MO-FG-CAMPUS-I-02 Accuracy in Converting the Average Breast Dose Into the Mean Glandular Dose (MGD) Using the F-Factor in Cone Beam Breast CT- a Monte Carlo Study Using Homogeneous and Quasi-Homogeneous Phantoms - C. Lai *, Y. Zhong, T. Wang, C. Shaw

Monday, July 13, 2015

MO-FG-CAMPUS-I-03 Tissue Equivalent Material Phantom to Test and Optimize Coherent Scatter Imaging for Tumor Classification - K. Albanese *, R. Morris, M. Lakshmanan, J. Greenberg, A. Kapadia

MO-FG-CAMPUS-I-04 Characterization of Fan Beam Coded Aperture Coherent Scatter Spectral Imaging Methods for Differentiation of Normal and Neoplastic Breast Structures - R. Morris *, K. Albanese, M. Lakshmanan, J. Greenberg, A. Kapadia

MO-FG-CAMPUS-I-05 The Total Internal Reflection Based Elastography Method for Tissue Elasticity Quantification and Characterization - J. Lee *

Therapy: Electronic Campus Posters

5:00 pm - 5:30 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-T SRS/SBRT Treatment Planning

Provost: Eric Klein, Washington University, Saint Louis, MO

MO-FG-CAMPUS-T-06 Radiosurgery of Multiple Brain Metastases with Single-Isocenter VMAT: Optimizing Treatment Geometry to Reduce Normal Brain Dose - Q. Wu *, K. Snyder, C. Liu, Y. Huang, H. Li, I. Chetty, N. Wen

MO-FG-CAMPUS-T-07 Optimizing Orientations of Hundreds of Intensity-Modulated Beams to Treat Multiple Brain Targets - L. Ma *, P. Dong, V. Keeling, S. Hossain, S. Ahmad, D. Larson, A. Sahgal

MO-FG-CAMPUS-T-08 Continuous Dose Delivery with Gamma Knife Perfexion - K. Ghobadi *, D. Aleman, W. Li, C. Chung, D. Jaffray

MO-FG-CAMPUS-T-09 Development and Evaluation of a Knowledge-Based Model for Treatment Planning of Lung Cancer Patients Using Stereotactic Body Radiotherapy (SBRT) - K. Snyder *, J. Kim, A. Reding, C. Fraser, S. Lu, J. Gordon, M. Ajlouni, B. Movsas, I. Chetty

MO-FG-CAMPUS-T-10 Correct Or Not to Correct for Rotational Patient Set-Up Errors in Stereotactic Radiosurgery - M. Briscoe *, N. Ploquin, J. Voroney

Joint Imaging – Therapy: Electronic Campus Posters

5:00 pm - 5:30 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-J Re-invigorating Quality Assurance

Provost: Robert Cormack, Harvard Medical School, Boston, MA

MO-FG-CAMPUS-J-06 A Novel and Efficient Daily QA Program for Both Modern Linear Accelerator and Optical Surface Motion Systems - J. Peng *, D. McDonald, M. Ashenafi, N. Koch, M. Fugal, K. Vanek

MO-FG-CAMPUS-J-07 Automatic Recognition of Patient Treatment Site in Portal Images Using Machine Learning - X. Chang *, D. Yang

MO-FG-CAMPUS-J-08 Evaluation and Use of Cubic Phantoms for Daily IGRT QA Process with TrueBeam 6DoF Couch - S. Ito *, L. Fong de los Santos, S. McCauley Cutsinger

MO-FG-CAMPUS-J-09 One-Year Analysis of Elekta CBCT Image Quality Using NPS and MTF - S. Nakahara *, M. Tachibana, Y. Watanabe

MO-FG-CAMPUS-J-10 Using 2D Relative Gamma Analysis From EPID Image as a Predictor of Plan Deterioration Due to Anatomical Changes - O. Piron *, N. Varfalvy, L. Archambault

Imaging: Electronic Campus Posters

5:00 pm - 5:30 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-I Clinical Applications, Phantoms

Provost: James Dobbins, Duke University Medical Center, Durham, NC

MO-FG-CAMPUS-I-06 EIT Imaging to Monitor Human Salivary Gland Functionality: A Feasibility Study - K. Kohli *, A. Karvat, J. Liu, K. Krishnan

MO-FG-CAMPUS-I-07 Stability Investigation of a Gamma Fitting Algorithm for Angiographic Parametric Imaging at Low X-Ray Exposures Using a Patient Specific Neurovascular Phantom - A. Balasubramoniam *, D. Bednarek, S. Rudin, C. Ionita

MO-FG-CAMPUS-I-08 CT and MR Characteristics of Some Specialty 3D Printing Filaments - K. Lam *

MO-FG-CAMPUS-I-09 Magnetic Resonance Imaging of An in Vitro 3D Tumor Model - C. Veiga *, T. Long, B. Siow, M. Loizidou, G. Royle, K. Ricketts

MO-FG-CAMPUS-I-10 Quantitative ADC Measurement of Esophageal Cancer Before and After Chemoradiation - L. Yang *, J. Son, J. Ma, S. Cheng, J. Hazle, B. Carter, S. Lin

Therapy: Electronic Campus Posters

5:30 pm - 6:00 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-T Proton Therapy Beam Measurement and QA

Provost: Eric Klein, Washington University, Saint Louis, MO

MO-FG-CAMPUS-T-11 IROC Houston QA Center's Anthropomorphic Proton Phantom Program - C. Lujano *, N. Hernandez, T. Keith, T. Nguyen, P. Taylor, A. Molineu, D. Followill

MO-FG-CAMPUS-T-12 Dosimetric Accuracy of the CrystalBallâ„¢: New Reusable Radiochromic Polymer Gel Dosimeter for Patient QA in Proton Therapy - S. Avery *, J. Kraus, L. Lin, A. Kassaee, M. Maryanski

MO-FG-CAMPUS-T-13 Verification of Range, SOBP Width, and Output for Passive-Scattering Proton Beams Using a Liquid Scintillator Detector - T. Henry *, D. Robertson, F. Therriault-Proulx, S. Beddar

MO-FG-CAMPUS-T-14 Utilization of Optical Dosimeter for Modulated Spot-Scanning Particle Beam - W. Hsi *, Y. Li, Z. Huang, Y. Sheng, Y. Deng, J. Zhao, F. Zhao, L. Sun, M. Moyers

MO-FG-CAMPUS-T-15 Design of An Innovative Beam Monitor for Particle Therapy for the Simultaneous Measurement of Beam Fluence and Energy - R. Sacchi *, N. Cartiglia, F. Cenna, L. Fanola Guarachi, M. Ferrero, S. Giordanengo, F. Marchetto, V. Monaco, A. Vignati, M. Varasteh Anvar, R. Cirio

Joint Imaging – Therapy: Electronic Campus Posters

5:30 pm - 6:00 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-J Novel In-Treatment Imaging

Provost: Robert Cormack, Harvard Medical School, Boston, MA

MO-FG-CAMPUS-J-11 Acoustic Range Verification of Proton Beams: Simulation of Heterogeneity and Clinical Proton Pulses - K. Jones, C. Sehgal, S. Avery *

MO-FG-CAMPUS-J-12 Commissioning of Radiofrequency Tracking for Gated SBRT of the Liver Using Novel Motion System - J. James *, A. Cetnar, V. Nguyen, B. Wang

MO-FG-CAMPUS-J-13 Development of a Human Brain PET for On-Line Proton Beam-Range Verification - Y. Shao *, X. Sun, K. Lou, J. Meier, Z. Wang

MO-FG-CAMPUS-J-14 Radiation Heat Load On the MR System of the Elekta Atlantic System - S. Towe *, D. Roberts, J. Overweg, E. Van Lanen

MO-FG-CAMPUS-J-15 Verification for Prompt Gamma Ray Imaging During Proton Boron Fusion Therapy - H. Shin *, D. Yoon, J. Jung, M. Kim, H. Jang, T. Suh

Monday, July 13, 2015

Imaging: Electronic Campus Posters

5:30 pm - 6:00 pm

-Electronic Poster Theater / Exhibit Hall C

MO-FG-CAMPUS-I Radiation Dose

Provost: James Dobbins, Duke University Medical Center, Durham, NC

MO-FG-CAMPUS-I-11 A System for Automatically Calculating Organ and Effective Dose for Fluoroscopically-Guided Procedures - Z. Xiong *, S. Vijayan, V. Rana, S. Rudin, D. Bednarek

MO-FG-CAMPUS-I-12 Occupational Conceptus Doses From Fluoroscopically-Guided Interventional Procedures - J. Damilakis *, K. Perisinakis, G. Solomou, J. Stratakis

MO-FG-CAMPUS-I-13 GPU Accelerated Monte Carlo Technique for Fast Concurrent Image and Dose Simulation - M. Becchetti *, X. Tian, P. Segars, E. Samei

MO-FG-CAMPUS-I-14 Patient Eye-Lens Dose Reduction in Routine Brain CT Examinations Using Organ-Based Tube Current Modulation and In-Plane Bismuth Shielding - H. Tsai *, Y. Liao, N. Lai, J. Chen, T. Chen

MO-FG-CAMPUS-I-15 Radiation Dosimetry of 99mTc-IDA-D-[c(RGDfK)]2, a SPECT Agent for Angiogenesis Imaging - J. Kim *

Therapy: Electronic Campus Posters

4:30 pm - 5:00 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-T Out-of-field Dose, Risk Assessment and Shielding

Provost: Sonja Dieterich, UC Davis Medical Center, Sacramento, CA

TU-G-CAMPUS-T-01 Dose and Energy Spectra From Neutron Induced Radioactivity in Medical Linear Accelerators Following High Energy Total Body Irradiation - S. Keehan *, M. Taylor, R. Smith, L. Dunn, T. Kron, R. Franich

TU-G-CAMPUS-T-02 Risk Assessment of Scattered Neutrons for a Fetus From Proton Therapy of a Brain Tumor During Pregnancy - C. Geng *, M. Moteabbed, X. Xu, H. Paganetti

TU-G-CAMPUS-T-03 Commissioning of a Custom Fetal Lead Shield for Radiotherapy - A. Owrangi *, D. Roberts, E. Covington, J. Hayman, K. Masi, C. Lee, J. Moran, J. Prisciandaro

TU-G-CAMPUS-T-04 An Evaluation of Out-Of-Field Doses for Electron Beams From Modern Varian and Elekta Linear Accelerators - C. Cardenas *, P. Nitsch, R. Kudchadker, R. Howell, S. Kry

TU-G-CAMPUS-T-05 Replacement Computational Phantoms to Estimate Dose in Out-Of-Field Organs and Tissues - K. Gallagher *, J. Tannous, R. Nabha, J. Feghali, Z. Ayoub, W. Jalbout, B. Youssef, P. Taddei

Joint Imaging – Therapy: Electronic Campus Posters

4:30 pm - 5:00 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-J The Dynamic Patient

Provost: George Starkschall, UT MD Anderson Cancer Center, Houston, TX

TU-G-CAMPUS-J-01 Inference of Prostate PTV Margins in VMAT Delivery From Intra-Fraction Prostate Motion During SBRT Delivery - K. Thind *, R. Wong, D. Wong, C. Gerdes, T. Chow

TU-G-CAMPUS-J-02 Mooney-Rivlin Biomechanical Modeling of Lung with Inhomogeneous Material Property - J. Nasehi Tehrani *, X. Guo, J. Wang

TU-G-CAMPUS-J-03 Prediction of Respiratory Motion Using State Space Models - J. Kotoku *, S. Kumagai, A. Haga, S. Nakabayashi, N. Arai, T. Kobayashi

TU-G-CAMPUS-J-04 Setup Uncertainties in the Mediastinum Area for IMRT Treatment of Lymphoma Patients - M. Aristophanous *, L. Court

TU-G-CAMPUS-J-05 Fast Volumetric MRI On An MRI-Linac Enables On-Line QA On Dose Deposition in the Patient - S. Crijns *, M. Glitzner, B. Denis de Senneville, C. Kontaxis, M. Maenhout, G. Bol, J. Lagendijk, B. Raaymakers

Imaging: Electronic Campus Posters

4:30 pm - 5:00 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-I MDCT, CBCT

Provost: Mahadevappa Mahesh, Johns Hopkins Univ, Baltimore, MD

TU-G-CAMPUS-I-01 Statistical Iterative Reconstruction for Perfusion CT with a Prior-Image Induced Hybrid Nonlocal Means Regularization - B. Li *, Q. Lyu, J. Ma, J. Wang

TU-G-CAMPUS-I-02 Contrast Enhanced Cone Beam CT Imaging with Dual-Gantry Image Acquisition and Constrained Iterative Reconstruction- a Simulation Study for Liver Imaging Application - Y. Zhong *, S. Gupta, C. Lai, T. Wang, C. Shaw

TU-G-CAMPUS-I-03 Enhancement of 4D CBCT Image Quality Using An Adaptive Prior Image Constrained Compressed Sensing - H. Lee *, J. Yoon, E. Lee, S. Cho, K. Park, W. Choi, K. Keum

TU-G-CAMPUS-I-04 Fully Automated Evaluation of CT AEC Performance Using a Novel Automated Noise Level Measurement Technique - M. Chun *, J. Kim

Tuesday, July 14, 2015

TU-G-CAMPUS-I-05 Investigation of An EMCCD Detector with Variable Gain in a Micro-CT System - S. Bysani Krishnakumar *, S. Setlur Nagesh, S. Rudin, D. Bednarek, C. Ionita

Therapy: Electronic Campus Posters

5:00 pm - 5:30 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-T QA Methods and Devices

Provost: Sonja Dieterich, UC Davis Medical Center, Sacramento, CA

TU-G-CAMPUS-T-06 Calculation of KQ for a Variety of Commercially Available Ionization Chambers in the Presence of An External Magnetic Field for MR-Linac Dosimetry - D. O'Brien *, M. Mathis, D. Roberts, G. Ibbott, G. Sawakuchi

TU-G-CAMPUS-T-07 Vernier Picket Fence Test: A Non-Imaging Method to Localize the Radiation Isocenter with Submillimeter Accuracy - J. Wong *, K. Gallagher, J. Zhang

TU-G-CAMPUS-T-08 A Novel Iris Quality Assurance Phantom for the CyberKnife Radiosurgery System - M. Descovich *, D. Pinnaduwage, A. Sudhyadhom, B. Nelson

TU-G-CAMPUS-T-09 Variations in Nominally Identical Small Fields From Photon Jaw Reproducibility and Associated Effects On Small Field Dosimetric Parameters - B. Muir *, M. McEwen

TU-G-CAMPUS-T-10 A Cloud-Based Monte Carlo Dose Calculation for Electron Cutout Factors - T. Mitchell *, K. Bush

Joint Imaging – Therapy: Electronic Campus Posters

5:00 pm - 5:30 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-J Image Features for Therapy Applications

Provost: George Starkschall, UT MD Anderson Cancer Center, Houston, TX

TU-G-CAMPUS-J-06 Dosimetric Effects of HU Changes During the Course of Proton Therapy for Lung Cancer - C. Teng *, L. Yin, C. Ainsley, C. Simone, B. Teo, A. Kassaee

TU-G-CAMPUS-J-07 Evaluation of Textural Feature Extraction for Radiotherapy Response Assessment of Early Stage Breast Cancer Patients Using Diffusion Weighted MRI and Dynamic Contrast Enhanced MRI - Y. Xie *, C. Wang, J. Horton, Z. Chang

TU-G-CAMPUS-J-08 Elasticity Functions Based On 4DCT Images to Predict Tumor and Normal Tissue Response to Radiation for Patients with Lung Cancers - H. Zhong *, H. Li, J. Gordon, I. Chetty

TU-G-CAMPUS-J-09 Impact of Voxel Anisotropy On Statistic Texture Features of Oncologic PET: A Simulation Study - F. Yang *, D. Byrd, S. Bowen, P. Kinahan, G. Sandison

TU-G-CAMPUS-J-10 Effect of Uncorrelated Noise Texture On Computed Tomography Quantitative Image Features - J. Oliver *, M. Budzevich, D. Hunt, E. Moros, G. Zhang

Imaging: Electronic Campus Posters

5:00 pm - 5:30 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-I Multi-detector CT

Provost: Mahadevappa Mahesh, Johns Hopkins Univ, Baltimore, MD

TU-G-CAMPUS-I-06 Investigation of the Effective Dose From Bolus Tracking Acquisitions at Different Anatomical Locations in the Chest for CT - P. Nowik *, R. Bujila, D. Merzan

TU-G-CAMPUS-I-07 Validation of a CT X-Ray Source Characterization Technique for Dose Computation Using An Anthropomorphic Thorax Phantom - M. Sommerville *, Y. Poirier, M. Tambasco

TU-G-CAMPUS-I-08 Preliminary Study of Size-Specific Dose Estimates in Adult Abdomenal CT Examinations in Taiwan - H. Tsai *, Y. Hwang, Y. Hu

TU-G-CAMPUS-I-09 A Novel Phantom to Evaluate Longitudinal and Angular Automatic Tube Current Modulation (ATCM) in CT - D. Merzan *, R. Bujila, P. Nowik
TU-G-CAMPUS-I-10 Parameterization of the Noise Power Spectrum in X-Ray Computed Tomography - R. Bujila *, G. Poludniowski, A. Fransson

Therapy: Electronic Campus Posters

5:30 pm - 6:00 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-T Nanoparticles in Radiotherapy

Provost: Sonja Dieterich, UC Davis Medical Center, Sacramento, CA

TU-G-CAMPUS-T-11 Potential of Using Cerium Oxide Nanoparticles (CONP) for Protecting Healthy Tissue During Accelerated Partial Breast Irradiation (APBI) - M. Mainali *, W. Ngwa, G. Cifter, J. Celli
TU-G-CAMPUS-T-12 Monte Carlo Evaluation of Kilovoltage Radiosurgery with AuNPs for Age Related Macular Degeneration (AMD) - D. Brivio *, P. Zygmanski, E. Sajo, G. Makrigiorgos, W. Ngwa
TU-G-CAMPUS-T-13 Enhancing the Tumor Specific Radiosensitization Using Molecular Targeted Gold Nanorods - P. Diagaradjane *, A. Deorukhkar, M. Sankaranarayanapillai, N. Manohar, P. Singh, G. Goodrich, R. Tailor, S. Cho, S. Krishnan
TU-G-CAMPUS-T-14 Using Gold Nanoparticles to Target Mitochondria in Radiation Therapy - A. McNamara *, S. McMahon, Y. Lin, H. Paganetti, Z. Kuncic, J. Schuemann
TU-G-CAMPUS-T-15 Dose Escalation to Biological Tumor Volumes of Prostate Cancer Patients Using Gold Nanoparticles - M. Jermoumi *, E. Sajo, K. Houari, W. Ngwa

Joint Imaging – Therapy: Electronic Campus Posters

5:30 pm - 6:00 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-J Imaging for RT Treatment Planning

Provost: George Starkschall, UT MD Anderson Cancer Center, Houston, TX

TU-G-CAMPUS-J-11 A Formulation of 4D Treatment Planning for Tumour Tracking Volumetric Modulated Arc Therapy for Lung Cancer - M. Cheung *, K. Lee, A. Chan
TU-G-CAMPUS-J-12 Developing a Phenomenological Model of the Proton Trajectory Within a Heterogeneous Medium Required for Proton Imaging - C. Collins-Fekete *, P. Doolan, M. Dias, L. Beaulieu, J. Seco
TU-G-CAMPUS-J-13 Evaluation of a New GE Device-Less Cine 4D-CT - R. Martin *, A. Chandler, D. Doan, C. Rowland, T. Pan
TU-G-CAMPUS-J-14 Evaluation of Metal Artifact Reduction Technique for the Radiation Therapy Planning - K. Jeong *, H. Kuo, J. Ritter, J. Shen, A. Basavatia, R. Yaparpalvi, S. Kalnicki, W. Tome
TU-G-CAMPUS-J-15 Quantitative Evaluation of the Relationship Between Tissue Velocity and Motion-Artifacts of Free-Breathing Low-Dose Fast-Helical CT Scans - L. Yang *, T. Dou, D. O'Connell, D. Thomas, D. Ruan, J. Lamb, D. Low

Imaging: Electronic Campus Posters

5:30 pm - 6:00 pm

-Electronic Poster Theater / Exhibit Hall C

TU-G-CAMPUS-I MRI

Provost: Mahadevappa Mahesh, Johns Hopkins Univ, Baltimore, MD

TU-G-CAMPUS-I-11 Head and Neck Squamous Cell Carcinoma: Short-Term Repeatability of Apparent Diffusion Coefficient and Intravoxel Incoherent Motion Parameters at 3.0T - Y. Ding *, C. Fuller, A. Mohamed, J. Wang, J. Hazle
TU-G-CAMPUS-I-12 Phosphorus Metabolite Differences Between Type 2 Diabetic and Normal Skeletal Muscle - E. Ripley *, G. Clarke
TU-G-CAMPUS-I-13 Quantitative Cardiac MRI Reveals Functional Abnormalities in Intrauterine Growth Restricted (IUGR) Baboons - G. Clarke *, J. Li, A. Kuo, P. Nathanielsz

Tuesday, July 14, 2015

TU-G-CAMPUS-I-14 Head-Only Asymmetric Gradient System Evaluation: ACR Image Quality and Acoustic Noise - P. Weavers *, Y. Shu, S. Tao, S. Lee, J. Piel, J. Mathieu, T. Foo, M. Bernstein
TU-G-CAMPUS-I-15 Semi-Automated, Open Source MRI Quality Assurance and Quality Control Program for Multi-Unit Institution - J. Yung *, S. Wolfgang, D. Reeve, R. Stafford

Therapy Electronic Campus — Exhibit Hall
Process Control

MO-FG-CAMPUS-T-01

A Comparison of Two Risk Analysis Techniques for Surface Image Guided Radiosurgery

G Kim*, R Manger, T Pawlicki, University of California, San Diego, La Jolla, CA

Purpose: Failure Modes and Effects Analysis (FMEA) techniques have been used to analyze surface image guided radiosurgery (SIG-RS). Hazard model, a modified FMEA approach developed by the Dutch, is applied to SIG-RS risk assessment and evaluated against the AAPM's FMEA approach**. Methods:** The SAFER approach uses a risk inventory matrix to categorize hazards (rather than probabilities). A multidisciplinary team was assembled to create the process map of SIG-RS and 91 steps and 167 failure modes were determined. Each failure mode was categorized for frequency (weekly, monthly, quarterly, yearly and less than once a year) and severity (negligible, minor, moderate, major and catastrophic) according to the SAFER procedures. All failure modes are placed in the matrix of arbitrary risk score matrix: very high, high, low, and very low. The top 14 high risk failure modes from the **Result** of FMEA and SAFER analysis were compared**. Results:** 167 failure modes categorized in the risk inventory matrix with 1 very high, 13 high, 66 low and 87 very low. Comparison of top 14 high risk failure modes between two techniques shows 9 common failure modes and 5 isolated failure modes. Two failure modes (FM: 58, 145) with the highest risk priority number (both RPN=288) in FMEA are also ranked as high risk in SAFER analysis. However one failure mode (FM: 154) with very high risk score in SAFER is not recognized by FMEA analysis due to its low "lack of detectability" score**. Conclusion:** FMEA is a well-established technique for prospective risk analysis. SAFER is a practical alternative that is easy to implement with a reliable category structure. Also the risk inventory matrix is conceptually straightforward to obtain agreement among multidisciplinary team members but still demonstrates a full scale of criticality.

MO-FG-CAMPUS-T-02

An Electronic Whiteboard Platform to Manage Treatment Planning Process

D DiCostanzo[1]*, S Thompson[2], J Woollard[1], N Gupta[1], A Ayan[1], (1) Ohio State University, Columbus, OH, (2) Santa Cruz Radiation Oncology, Santa Cruz, CA

Purpose: In an effort to improve patient safety and streamline the radiotherapy treatment planning (TP) process, a software based whiteboard had been developed and put in use in our facility**Methods:** The electronic whiteboard developed using SQL database (DB) and PHP/JavaScript based web interface, is published via department intranet and login credentials. The DB stores data for each TP process such as patient information, plan type, simulation/start dates, physician, dosimetrist, QA and the current status in planning process. Users interact with the DB per plan and perform status updates in real time as the planning process progresses. All user interactions with the DB are recorded with timestamps so as to calculate statistical information for TP process management such as contouring times, planning and review times, dosimetry, physics and therapist QA times. External beam and brachytherapy plans are categorized according to complexity (ex: IMRT, 3D, HDR, LDR etc) and treatment types and applicators. Each plan category is assigned specific timelines for each planning process. When a plan approaches or passes the predetermined timeline, users are alerted via color coded graphical cues. When certain process items are not completed in time, pre-determined actions are triggered such as a delay in treatment start date**. Results:** Our institution has been using the electronic whiteboard for two years. Implementation of pre-determined actions based on the statistical information collected by the whiteboard improved our TP process. For example, the average time for normal tissue contouring decreased from 0.73±1.37 to 0.24±0.33 days. The average time for target volume contouring decreased from 3.2±2.84 to 2.37±2.54 days. This increase in efficiency allows more time for quality assurance processes, improving patient safety**. Conclusion:** The electronic whiteboard has been an invaluable tool for streamlining our TP processes. It facilitates timely and accurate communication between all parties involved in the TP process increasing patient safety.

MO-FG-CAMPUS-T-03

Data Driven Approaches for Determination of Treatment Table Tolerance Values for Record and Verification Systems

N Gupta*, D DiCostanzo, M Fullenkamp, Ohio State University, Columbus, OH

Purpose: To determine appropriate couch tolerance values for modern radiotherapy linac R&V systems with indexed patient setup**. Methods:** Treatment table tolerance values have been the most difficult to lower, due to many factors including variations in patient positioning and differences in table tops between machines. We recently installed nine linacs with similar tables and started indexing every patient in our clinic. In this study we queried our R&V database and analyzed the deviation of couch position values from the acquired values at verification simulation for all patients treated with indexed positioning. Mean and standard deviations of daily setup deviations were computed in the longitudinal, lateral and vertical direction for 343 patient plans. The mean, median and standard error of the standard deviations across the whole patient population and for some disease sites were computed to determine tolerance values**. Results:** The plot of our couch deviation values showed a gaussian distribution, with some small deviations, corresponding to setup uncertainties on non-imaging days, and SRS/SRT/SBRT patients, as well as some large deviations which were spot checked and found to be corresponding to indexing errors that were overriden. Setting our tolerance values based on the median + 1 standard error resulted in tolerance values of 1cm lateral and longitudinal, and 0.5 cm vertical for all non-SRS/SRT/SBRT cases. Re-analizing the data, we found that about 92% of the treated fractions would be within these tolerance values (ignoring the mis-indexed patients). We also analyzed data for disease site based subpopulations and found no difference in the tolerance values that needed to be used**. Conclusion:** With the use of automation, auto-setup and other workflow efficiency tools being introduced into radiotherapy workflow, it is very essential to set table tolerances that allow safe treatments, but flag setup errors that need to be reassessed before treatments.

MO-FG-CAMPUS-T-04

Implementation of a Standardized Monthly Quality Check for Linac Output Management in a Large Multi-Site Clinic

H Xu*, B Yi, K Prado, Univ. of Maryland School Of Medicine, Baltimore, MD

Purpose: This work is to investigate the feasibility of a standardized monthly quality check (QC) of LINAC output determination in a multi-site, multi-LINAC institution. The QC was developed to determine individual LINAC output using the same optimized measurement setup and a constant calibration factor for all machines across the institution. **Methods:** The QA data over 4 years of 7 Varian machines over four sites, were analyzed. The monthly output constancy checks were performed using a fixed source-to-chamber-distance (SCD), with no couch position adjustment throughout the measurement cycle for all the photon energies: 6 and 18MV, and electron energies: 6, 9, 12, 16 and 20 MeV. The constant monthly output calibration factor (Nconst) was determined by averaging the machines' output data, acquired with the same monthly ion chamber. If a different monthly ion chamber was used, Nconst was then re-normalized to consider its different NDW,Co-60. Here, the possible changes of Nconst over 4 years have been tracked, and the precision of output results based on this standardized monthly QA program relative to the TG-51 calibration for each machine was calculated. Any outlier of the group was investigated. **Results:** The possible changes of Nconst varied between 0-0.9% over 4 years. The normalization of absorbed-dose-to-water calibration factors corrects for up to 3.3% variations of different monthly QA chambers. The LINAC output precision based on this standardized monthly QC relative to the TG-51 output calibration is within 1% for 6MV photon energy and 2% for 18MV and all the electron energies. A human error in one TG-51 report was found through a close scrutiny of outlier data. **Conclusion:** This standardized QC allows for a reasonably simplified, precise and robust monthly LINAC output constancy check, with the increased sensitivity needed to detect possible human errors and machine problems.

MO-FG-CAMPUS-T-05

SQL Database Queries to Determine Treatment Planning Resource Usage

C Fox*, D Gladstone, Dartmouth Hitchcock-Medical Center, Hanover, NH

Purpose: A radiation oncology clinic's treatment capacity is traditionally thought to be limited by the number of machines in the clinic. As the number of fractions per course decrease and the number of adaptive plans increase, the question of how many treatment plans a clinic can plan becomes increasingly important. This work seeks to lay the ground work for assessing treatment planning resource usage**. Methods:** Care path templates were created using the Aria 11 care path interface. Care path tasks included key steps in the treatment planning process from the completion of CT simulation through the first radiation treatment. SQL Server Management Studio was used to run SQL queries to extract task completion time stamps along with care path template information and diagnosis codes from the Aria database. 6 months of planning cycles were evaluated. Elapsed time was evaluated in terms of work hours within Monday – Friday, 7am to 5pm**. Results:** For the 195 validated treatment planning cycles, the average time for planning and MD review was 22.8 hours. Of those cases 33 were categorized as urgent. The average planning time for urgent plans was 5 hours. A strong correlation between diagnosis code and range of elapsed planning time was as well as between elapsed time and select diagnosis codes was observed. It was also observed that tasks were more likely to be completed on the date due than the time that they were due. Follow-up confirmed that most users did not look at the due time**. Conclusion:** Evaluation of elapsed planning time and other tasks suggest that care paths should be adjusted to allow for different contouring and planning times for certain diagnosis codes and urgent cases. Additional clinic training around task due times vs dates or a structuring of care paths around due dates is also needed.

Joint Imaging - Therapy Exhibit Hall
Electronic Campus
MRI for RT Simulation

MO-FG-CAMPUS-J-01

Effect of Iodine Contrast Agent Concentration On Cerebrovascular Dose for Synchrotron Radiation Microangiography Based On a Simple Mouse Head Model and a Voxel Mouse Head Phantom

H LIN1*, J JING1, Y Lu2, C Xie1, (1)Hefei University of Technology, Hefei, China;(2)Shanghai Jiao Tong University, Shanghai, China

Purpose: To find effective setting methods to mitigate the irradiation injure in synchrotron radiation microangiography(SRA) by Monte Carlo simulation**. Methods:** A mouse 1-D head model and a segmented voxel mouse head phantom were simulated by EGSnrc/Dosxyznrc code to investigate the dose enhancement effect of the iodine contrast agent irradiated by a monochromatic synchrotron radiation(SR) source. The influence of, like iodine concentration (IC), vessel width and depth, with and without skull layer protection and the various incident X ray energies, were simulated. The dose enhancement effect and the absolute dose based on the segmented voxel mouse head phantom were evaluated**. Results:** The dose enhancement ratio depends little on the irradiation depth, but strongly on the IC, which is linearly increases with IC. The skull layer protection cannot be ignored in SRA, the 700μm thick skull could decrease 10% of the dose. The incident X-ray energy can significantly affact the dose. E.g. compared to the dose of 33.2keV for 50mgI/ml, the 32.7keV dose decreases 38%, whereas the dose of 33.7 keV increases 69.2%, and the variation will strengthen more with enhanced IC. The segmented voxel mouse head phantom also showed that the average dose enhancement effect and the maximal voxel dose per photon depends little on the iodine voxel volume ratio, but strongly on IC**. Conclusion:** To decrease dose damage in SRA, the high-Z contrast agent should be used as little as possible, and try to avoid radiating locally the injected position immediately after the contrast agent injection. The fragile vessel containing iodine should avoid closely irradiating. Avoiding irradiating through the no or thin skull region, or appending thin equivalent material from outside to protect is also a better method. As long as SRA image quality is ensured, using incident X-ray energy as low as possible.

MO-FG-CAMPUS-J-02

Human Implanted Micro Bio Chip for Real-Time Atrial Fibrillation Monitoring with Wireless Power Transmission

j lee[1]*, (1) Keimyung University, School of Medicine, Department of Biomedical Engineering

Purpose: There are numerous medical problems whose treatment requires the constant monitoring of vital signs from several body organs. In this study, a micro-sized implantable electrocardiogram (ECG) sensor for personal heart disease monitoring was developed, as such devices generally provide a high diagnostic yield. **Methods:** An op-amp amplifies an input electrical potential to the level desired by the user and produces an output potential augmented to this intended level. For this study an instrumentation amplifier was fabricated using op-amps and configured to amplify micro-fine ECG signals by a factor of about 100 using a band-pass filter (BPF). The proposed ECG sensor has a current consumption of about 11 mA and a noise generation inversely proportional to the length of the wireless communication antenna inside the sensor. The packaging materials selected must be biocompatible to avoid causing inflammation or necrosis of human tissues. In addition, a near-field wireless power transmission system and the medical Implant Communication Service (MICS) was used as a communications and power protocol. MICS operates in the frequency range of 402–405 MHz and is normally used for communication between body-worn monitoring systems and implants**. Results:** A pig was used as a sensor-implanted animal model because the animal's physiological characteristics are similar to those of humans. An incision was made between the left 5th–7th ribs and separated using blunt dissection to a depth of 4 mm under the skin. From the experiments, we successfully monitor the ECG with wireless communication and wireless power transmission**. Conclusion:** This study demonstrated that the use of a quasi-permanent ECG employing a double loop coil-shaped magnetic resonance-type wireless power transmission system sensor eliminates the need for surgical replacement.

MO-FG-CAMPUS-J-03

Sorting 2D Dynamic MR Images Using Internal Respiratory Signal for 4D MRI

Z Wen[1]*, C Hui[2], B Stemkens[3], R Tijssen[4], C van den Berg[5], S Beddar[6], (1) MD Anderson Cancer Center, Houston, TX, (2) UT MD Anderson Cancer Center, Houston, TX, (3) UMC Utrecht, Utrecht, Utrecht, (4) University Medical Center Utrecht, Utrecht, Utrecht, (5) University Medical Center Utrecht, Utrecht, Nederland, (6) UT MD Anderson Cancer Center, Houston, TX

Purpose: To develop a novel algorithm to extract internal respiratory signal (IRS) for sorting dynamic magnetic resonance (MR) images in order to achieve four-dimensional (4D) MR imaging**. Methods:** Dynamic MR images were obtained with the balanced steady state free precession by acquiring each two-dimensional sagittal slice repeatedly for more than one breathing cycle. To generate a robust IRS, we used 5 different representative internal respiratory surrogates in both the image space (body area) and the Fourier space (the first two low-frequency phase components in the anterior-posterior direction, and the first two low-frequency phase components in the superior-inferior direction). A clustering algorithm was then used to search for a group of similar individual internal signals, which was then used to formulate the final IRS. A phantom study and a volunteer study were performed to demonstrate the effectiveness of this algorithm. The IRS was compared to the signal from the respiratory bellows**. Results:** The IRS computed by our algorithm matched well with the bellows signal in both the phantom and the volunteer studies. On average, the normalized cross correlation between the IRS and the bellows signal was 0.97 in the phantom study and 0.87 in the volunteer study, respectively. The average difference between the end inspiration times in the IRS and bellows signal was 0.18 s in the phantom study and 0.14 s in the volunteer study, respectively. 4D images sorted based on the IRS showed minimal mismatched artifacts, and the motion of the anatomy was coherent with the respiratory phases**. Conclusion:** A novel algorithm was developed to generate IRS from dynamic MR images to achieve 4D MR imaging. The performance of the IRS was comparable to that of the bellows signal. It can be easily implemented into the clinic and potentially could replace the use of external respiratory surrogates.

This research was partially funded by the the Center for Radiation Oncology Research from UT MD Anderson Cancer Center.

MO-FG-CAMPUS-J-04

Tissue Segmentation-Based MR Electron Density Mapping Method for MR-Only Radiation Treatment Planning of Brain

H Yu[1]*, Y Lee[2], M Ruschin[3], I Karam[4], A Sahgal[5], (1) Sunnybrook Health Sciences Centre, Toronto, Ontario, (2) Sunnybrook Odette Cancer Centre, Toronto, Ontario, (3) Odette Cancer Centre, Toronto, ON, (4) Sunnybrook Odette Cancer Center, Toronto, Ontario, (5) University of Toronto, Toronto, ON

Purpose: Automatically derive electron density of tissues using MR images and generate a pseudo-CT for MR-only treatment planning of brain tumours**. Methods:** 20 stereotactic radiosurgery (SRS) patients' T1-weighted MR images and CT images were retrospectively acquired. First, a semi-automated tissue segmentation algorithm was developed to differentiate tissues with similar MR intensities and large differences in electron densities. The method started with approximately 12 slices of manually contoured spatial regions containing sinuses and airways, then air, bone, brain, cerebrospinal fluid (CSF) and eyes were automatically segmented using edge detection and anatomical information including location, shape, tissue uniformity and relative intensity distribution. Next, soft tissues - muscle and fat were segmented based on their relative intensity histogram. Finally, intensities of voxels in each segmented tissue were mapped into their electron density range to generate pseudo-CT by linearly fitting their relative intensity histograms. Co-registered CT was used as a ground truth. The bone segmentations of pseudo-CT were compared with those of co-registered CT obtained by using a 300HU threshold. The average distances between voxels on external edges of the skull of pseudo-CT and CT in three axial, coronal and sagittal slices with the largest width of skull were calculated. The mean absolute electron density (in Hounsfield unit) difference of voxels in each segmented tissues was calculated. **Results:** The average of distances between voxels on external skull from pseudo-CT and CT were 0.6±1.1mm (mean±1SD). The mean absolute electron density differences for bone, brain, CSF, muscle and fat are 78±114 HU, and 21±8 HU, 14±29 HU, 57±37 HU, and 31±63 HU, respectively. **Conclusion:** The semi-automated MR electron density mapping technique was developed using T1-weighted MR images. The generated pseudo-CT is comparable to that of CT in terms of anatomical position of tissues and similarity of electron density assignment. This method can allow MR-only treatment planning.

MO-FG-CAMPUS-J-05

Toward MRI-Only Radiotherapy: Novel Tissue Segmentation and Pseudo-CT Generation Techniques Based On T1 MRI Sequences

S Aouadi, M McGarry, R Hammoud, T Torfeh*, G Perkins, N Al-Hammadi, Hamad Medical Corporation, NCCCR, Doha, Qatar

Purpose: To develop and validate a 4 class tissue segmentation approach (air cavities, background, bone and soft-tissue) on T1-weighted brain MRI and to create a pseudo-CT for MRI-only radiation therapy verification**. Methods:** Contrast-enhanced T1-weighted fast-spin-echo sequences (TR = 756ms, TE= 7.152ms), acquired on a 1.5T GE MRI-Simulator, are used.MRIs are firstly pre-processed to correct for non uniformity using the non parametric, non uniformity intensity normalization algorithm. Subsequently, a logarithmic inverse scaling log(1/image) is applied, prior to segmentation, to better differentiate bone and air from soft-tissues. Finally, the following method is enrolled to classify intensities into air cavities, background, bone and soft-tissue:Thresholded region growing with seed points in image corners is applied to get a mask of Air+Bone+Background. The background is, afterward, separated by the scan-line filling algorithm. The air mask is extracted by morphological opening followed by a post-processing based on knowledge about air regions geometry. The remaining rough bone pre-segmentation is refined by applying 3D geodesic active contours; bone segmentation evolves by the sum of internal forces from contour geometry and external force derived from image gradient magnitude.Pseudo-CT is obtained by assigning -1000HU to air and background voxels, performing linear mapping of soft-tissue MR intensities in [-400HU, 200HU] and inverse linear mapping of bone MR intensities in [200HU, 1000HU]**. Results:** Three brain patients having registered MRI and CT are used for validation. CT intensities classification into 4 classes is performed by thresholding. Dice and misclassification errors are quantified. Correct classifications for soft-tissue, bone, and air are respectively 89.67%, 77.8%, and 64.5%. Dice indices are acceptable for bone (0.74) and soft-tissue (0.91) but low for air regions (0.48). Pseudo-CT produces DRRs with acceptable clinical visual agreement to CT-based DRR. **Conclusion:** The proposed approach makes it possible to use T1-weighted MRI to generate accurate pseudo-CT from 4-class segmentation.

Imaging Electronic Campus Exhibit Hall

Breast Imaging

MO-FG-CAMPUS-I-01

Accuracy of Radiologists Interpretation of Mammographic Breast Density

S Vedantham[1], L Shi[1], A Karellas[1]*, A O'Connell[2], (1) University of Massachusetts Medical School, Worcester, MA, (2) University of Rochester Medical Center, Rochester, NY

Purpose: Several commercial and non-commercial software and techniques are available for determining breast density from mammograms. However, where mandated by law the breast density information communicated to the subject/patient is based on radiologist's interpretation of breast density from mammograms. Several studies have reported on the concordance among radiologists in interpreting mammographic breast density. In this work, we investigated the accuracy of radiologist's interpretation of breast density**. Methods:** Volumetric breast density (VBD) determined from 134 unilateral dedicated breast CT scans from 134 subjects was considered the truth. An MQSA-qualified study radiologist with more than 20 years of breast imaging experience reviewed the DICOM "for presentation" standard 2-view mammograms of the corresponding breasts and assigned BIRADS breast density categories. For statistical analysis, the breast density categories were dichotomized in two ways; fatty vs. dense breasts where "fatty" corresponds to BIRADS breast density categories A/B, and "dense" corresponds to BIRADS breast density categories C/D, and extremely dense vs. fatty to heterogeneously dense breasts, where extremely dense corresponds to BIRADS breast density category D and BIRADS breast density categories A through C were grouped as fatty to heterogeneously dense breasts. Logistic regression models (SAS 9.3) were used to determine the association between radiologist's interpretation of breast density and VBD from breast CT, from which the area under the ROC (AUC) was determined**. Results:** Both logistic regression models were statistically significant (Likelihood Ratio test, $p<0.0001$). The accuracy (AUC) of the study radiologist for classification of fatty vs. dense breasts was 88.4% (95% CI: 83-94%) and for classification of extremely dense breast was 94.3% (95% CI: 90-98%)**. Conclusion:** The accuracy of the radiologist in classifying dense and extremely dense breasts is high. Considering the variability in VBD estimates from commercial software, the breast density information communicated to the patient should be based on radiologist's interpretation.

This work was supported in part by NIH R21 CA176470 and R21 CA134128. The contents are solely the responsibility of the authors and do not reflect the official views of the NIH or NCI.

MO-FG-CAMPUS-I-02

Accuracy in Converting the Average Breast Dose Into the Mean Glandular Dose (MGD) Using the F-Factor in Cone Beam Breast CT- a Monte Carlo Study Using Homogeneous and Quasi-Homogeneous Phantoms

C Lai*, Y Zhong, T Wang, C Shaw, UT MD Anderson Cancer Center, Houston, TX

Purpose: To investigate the accuracy in estimating the mean glandular dose (MGD) for homogeneous breast phantoms by converting from the average breast dose using the F-factor in cone beam breast CT. **Methods:** EGSnrc-based Monte Carlo codes were used to estimate the MGDs. 13-cm in diameter, 10-cm high hemi-ellipsoids were used to simulate pendant-geometry breasts. Two different types of hemi-ellipsoidal models were employed: voxels in quasi-homogeneous phantoms were designed as either adipose or glandular tissue while voxels in homogeneous phantoms were designed as the mixture of adipose and glandular tissues. Breast compositions of 25% and 50% volume glandular fractions (VGFs), defined as the ratio of glandular tissue voxels to entire breast voxels in the quasi-homogeneous phantoms, were studied. These VGFs were converted into glandular fractions by weight and used to construct the corresponding homogeneous phantoms. 80 kVp x-rays with a mean energy of 47 keV was used in the simulation. A total of 109 photons were used to image the phantoms and the energies deposited in the phantom voxels were tallied.

Breast doses in homogeneous phantoms were averaged over all voxels and then used to calculate the MGDs using the F-factors evaluated at the mean energy of the x-rays. The MGDs for quasi-homogeneous phantoms were computed directly by averaging the doses over all glandular tissue voxels. The MGDs estimated for the two types of phantoms were normalized to the free-in-air dose at the iso-center and compared. **Results:** The normalized MGDs were 0.756 and 0.732 mGy/mGy for the 25% and 50% VGF homogeneous breasts and 0.761 and 0.733 mGy/mGy for the corresponding quasi-homogeneous breasts, respectively. The MGDs estimated for the two types of phantoms were similar within 1% in this study. **Conclusion:** MGDs for homogeneous breast models may be adequately estimated by converting from the average breast dose using the F-factor.

MO-FG-CAMPUS-I-03

Tissue Equivalent Material Phantom to Test and Optimize Coherent Scatter Imaging for Tumor Classification

K Albanese*, R Morris, M Lakshmanan, J Greenberg, A Kapadia, Duke University, Durham, NC

Purpose: To accurately model different breast geometries using a tissue equivalent phantom, and to classify these tissues in a coherent x-ray scatter imaging system**. Methods:** A breast phantom has been designed to assess the capability of coded aperture coherent x-ray scatter imaging system to classify different types of breast tissue (adipose, fibroglandular, tumor). The tissue-equivalent phantom was modeled as a hollow plastic cylinder containing multiple cylindrical and spherical inserts that can be positioned, rearranged, or removed to model different breast geometries. Each enclosure can be filled with a tissue-equivalent material and excised human tumors. In this study, beef and lard, placed inside 2-mm diameter plastic Nalgene containers, were used as surrogates for fibroglandular and adipose tissue, respectively. The phantom was imaged at 125 kVp, 40 mA for 10 seconds each with a 1-mm pencil beam. The raw data were reconstructed using a model-based reconstruction algorithm and yielded the location and form factor, or momentum transfer (q) spectrum of the materials that were imaged. The measured material form factors were then compared to the ground truth measurements acquired by x-ray diffraction (XRD) imaging. **Results:** The tissue equivalent phantom was found to accurately model different types of breast tissue by qualitatively comparing our measured form factors to those of adipose and fibroglandular tissue from literature. Our imaging system has been able to define the location and composition of the various materials in the phantom. **Conclusion:** This work introduces a new tissue equivalent phantom for testing and optimization of our coherent scatter imaging system for material classification. In future studies, the phantom will enable the use of a variety of materials including excised human tissue specimens in evaluating and optimizing our imaging system using pencil- and fan-beam geometries.

United States Department of Homeland Security Duke University Medical Center - Department of Radiology Carl E Ravin Advanced Imaging Laboratories Duke University Medical Physics Graduate Program

MO-FG-CAMPUS-I-04

Characterization of Fan Beam Coded Aperture Coherent Scatter Spectral Imaging Methods for Differentiation of Normal and Neoplastic Breast Structures

R Morris*, K Albanese, M Lakshmanan, J Greenberg, A Kapadia, Duke University Medical Center, Durham, NC, Carl E Ravin Advanced Imaging Laboratories, Durham, NC

Purpose: This study intends to characterize the spectral and spatial resolution limits of various fan beam geometries for differentiation of normal and neoplastic breast structures via coded aperture coherent scatter spectral imaging techniques. In previous studies, pencil beam raster scanning methods using coherent scatter computed tomography and selected volume tomography have yielded excellent results for tumor discrimination. However, these methods don't readily conform to clinical constraints; primarily prolonged scan times and excessive dose to the patient. Here, we refine a fan beam coded aperture coherent scatter imaging system to characterize the tradeoffs between dose, scan time and image quality for breast tumor discrimination. **Methods:** An X-ray tube (125kVp, 400mAs) illuminated the sample with collimated fan beams of varying widths (3mm to 25mm). Scatter data was collected via two linear-array energy-sensitive detectors oriented parallel and perpendicular to the beam plane. An iterative reconstruction algorithm yields images of the sample's spatial distribution and respective spectral data for each location. To model in-vivo tumor analysis, surgically resected breast tumor samples were used in conjunction with lard, which has a form factor comparable to adipose (fat)**. Results:** Quantitative analysis with current setup geometry indicated optimal performance for beams up to 10mm wide, with wider beams producing poorer spatial resolution. Scan time for a fixed volume was reduced by a factor of 6 when scanned with a 10mm fan beam compared to a 1.5mm pencil beam. **Conclusion:** The study demonstrates the utility of fan beam coherent scatter spectral imaging for differentiation of normal and neoplastic breast tissues has successfully reduced dose and scan times whilst sufficiently preserving spectral and spatial resolution. Future work to alter the coded aperture and detector geometries could potentially allow the use of even wider fans, thereby making coded aperture coherent scatter imaging a clinically viable method for breast cancer detection.

United States Department of Homeland Security; Duke University Medical Center - Department of Radiology; Carl E Ravin Advanced Imaging Laboratories; Duke University Medical Physics Graduate Program

MO-FG-CAMPUS-I-05

The Total Internal Reflection Based Elastography Method for Tissue Elasticity Quantification and Characterization

J Lee[1]*, (1) Keimyung University, Daegu, Daegu

Purpose: Diagnosing early formation of tumors or lumps, particularly those caused by cancer, has been a problem. Our goal is to develop a simple and easy to use system that can document the properties of palpable lumps in soft tissue using noninvasive technique**. Methods:** The tactile sensor we propose comprises of an elastic optical waveguide unit, a high resolution CCD camera unit, a LED light source unit, and a laptop computer. The sensing element is formed on poly dimethylsiloxane (PDMS) and is illuminated along its four edges by LED light sources. The tactile sensor operates on the principle of total internal reflection (TIR) within an optical waveguide. The light directed into the waveguide remains within it due to the TIR generated, since the waveguide is surrounded by air having a lower refractive index than the waveguide. When an object adheres to the waveguide and compresses, the contact area of the waveguide deforms and causes the light to scatter. **Results:** To validate the proposed method, three patients presented with a lesion that was initially detected by another modality (mammography, ultrasound, or manual palpation). When performing the sensor scans, the doctor already knew where the lesions were located. For each lesion, 10 tactile images were obtained and the estimated parameters were averaged. Regarding the hardness estimation of the lesions, malignant breast lesion of the patient 1 had increased Young's modulus (146 kPa), compared to benign lesions (97 kPa and 103 kPa, patient 2 and 3). The elasticity information was correlated with the malignancy data from the pathology reports. The minimum and maximum relative errors are 1.1% and 11.72%. The mean error is 5.07% with 3.39% standard deviation**. Conclusion:** In this paper, a tactile elasticity imaging sensor using the total internal reflection principle is designed and experimentally evaluated.

Therapy Electronic Campus Exhibit Hall

SRS/SBRT Treatment Planning

MO-FG-CAMPUS-T-06

Radiosurgery of Multiple Brain Metastases with Single-Isocenter VMAT: Optimizing Treatment Geometry to Reduce Normal Brain Dose

Q Wu[1]*, K Snyder[2], C Liu[2], Y Huang[2], H Li[2], I Chetty[2], N Wen[2], (1) Wayne State University, Detroit, MI, (2) Henry Ford Health System, Detroit, MI

Purpose: To develop an optimization algorithm to reduce normal brain dose by optimizing couch and collimator angles for single isocenter multiple targets treatment of stereotactic radiosurgery**. Methods:** Three metastatic brain lesions were retrospectively planned using single-isocenter volumetric modulated arc therapy (VMAT). Three matrices were developed to calculate the projection of each lesion on Beam's Eye View (BEV) by the rotating couch, collimator and gantry respectively. The island blocking problem was addressed by computing the total area of open space between any two lesions with shared MLC leaf pairs. The couch and collimator angles resulting in the smallest open areas were the optimized angles for each treatment arc. Two treatment plans with and without couch and collimator angle optimization were developed using the same objective functions and

to achieve 99% of each target volume receiving full prescription dose of 18Gy. Plan quality was evaluated by calculating each target's Conformity Index (CI), Gradient Index (GI), and Homogeneity index (HI), and absolute volume of normal brain V8Gy, V10Gy, V12Gy, and V14Gy**. Results:** Using the new couch/collimator optimization strategy, dose to normal brain tissue was reduced substantially. V8, V10, V12, and V14 decreased by 2.3%, 3.6%, 3.5%, and 6%, respectively. There were no significant differences in the conformity index, gradient index, and homogeneity index between two treatment plans with and without the new optimization algorithm**. Conclusion:** We have developed a solution to the island blocking problem in delivering radiation to multiple brain metastases with shared isocenter. Significant reduction in dose to normal brain was achieved by using optimal couch and collimator angles that minimize total area of open space between any of the two lesions with shared MLC leaf pairs. This technique has been integrated into Eclipse treatment system using scripting API.

MO-FG-CAMPUS-T-07

Optimizing Orientations of Hundreds of Intensity-Modulated Beams to Treat Multiple Brain Targets

L Ma[1]*, P Dong[1], V Keeling[2], S Hossain[2], S Ahmad[2], D Larson[1], A Sahgal[3], (1) University of California San Francisco, San Francisco, CA, (2) University of Oklahoma Health Science Center, Oklahoma City, OK, (3) University of Toronto, Toronto, ON

Purpose: To investigate a new modulated beam orientation optimization (MBOO) approach maximizing treatment planning quality for the state-of-the-art flattening filter free (FFF) beam that has enabled rapid treatments of multiple brain targets**. Methods:** MBOO selects and optimizes a large number of intensity-modulated beams (400 or more) from all accessible beam angles surrounding a patient's skull. The optimization algorithm was implemented on a standalone system that interfaced with the 3D Dicom images and structure sets. A standard published data set that consisted of 1 to 12 metastatic brain tumor combinations was selected for MBOO planning. The planning results from various coplanar and non-coplanar configurations via MBOO were then compared with the results obtained from a clinical volume modulated arc therapy (VMAT) delivery system (Truebeam RapidArc, Varian Oncology)**. Results:** When planning a few number of targets (n<4), MBOO produced results equivalent to non-coplanar multi-arc VMAT planning in terms of target volume coverage and normal tissue sparing. For example, the 12-Gy and 4-Gy normal brain volumes for the 3-target plans differed by less than 1 mL (3.0 mLvs 3.8 mL; and 35.2 mL vs 36.3 mL, respectively) for MBOO versus VMAT. However, when planning a larger number of targets (n≥4), MBOO significantly reduced the dose to the normal brain as compared to VMAT, though the target volume coverage was equivalent. For example, the 12-Gy and 4-Gy normal brain volumes for the 12-target plans were 10.8 mL vs. 18.0 mL and 217.9 mL vs. 390.0 mL, respectively for the non-coplanar MBOO versus the non-coplanar VMAT treatment plans, yielding a reduction in volume of more than 60% for the case. **Conclusion:** MBOO is a unique approach for maximizing normal tissue sparing when treating a large number (n≥4) of brain tumors with FFF linear accelerators.

Dr Ma and Dr Sahgal are currently on the board of international society of stereotactic radiosurgery. Dr Sahgal has received support for educational presentations from Elekta company

MO-FG-CAMPUS-T-08

Continuous Dose Delivery with Gamma Knife Perfexion

Ghobadi[1]*, D Aleman[2], W Li[1], C Chung[1], D Jaffray[1], (1) Princess Margaret Cancer Centre and University Health Network, Toronto, Ontario (2) University of Toronto, Toronto, Ontario

Purpose: We propose continuous dose delivery techniques for stereotactic treatments delivered by Gamma Knife Perfexion using inverse treatment planning system that can be applied to various tumour sites in the brain. We test the accuracy of the plans on Perfexion's planning system (GammaPlan) to ensure the obtained plans are viable. This approach introduces continuous dose delivery for Perefxion, as opposed to the currently employed step-and-shoot approaches, for different tumour sites. Additionally, this is the first realization of automated inverse planning on GammaPlan. **Methods:** The inverse planning approach is divided into two steps of identifying a quality path inside the target, and finding the best collimator composition for the path. To find a path, we select strategic regions inside the target volume and find a path that visits each region exactly once. This path is then passed to a mathematical model which finds the best combination of collimators and their durations. The mathematical model minimizes the dose spillage to the surrounding tissues while ensuring the prescribed dose is delivered to the target(s). Organs-at-risk and their corresponding allowable doses can also be added to the model to protect adjacent organs. **Results:** We test this approach on various tumour sizes and sites. The quality of the obtained treatment plans are comparable or better than forward plans and inverse plans that use step-and-shoot technique. The conformity indices in the obtained continuous dose delivery plans are similar to those of forward plans while the beam-on time is improved on average (see Table 1 in supporting document). **Conclusion:** We employ inverse planning for continuous dose delivery in Perfexion for brain tumours. The quality of the obtained plans is similar to forward and inverse plans that use conventional step-and-shoot technique. We tested the inverse plans on GammaPlan to verify clinical relevance.

This research was partially supported by Elekta, Sweden (vendor of Gamma Knife Perfexion).

MO-FG-CAMPUS-T-09

Development and Evaluation of a Knowledge-Based Model for Treatment Planning of Lung Cancer Patients Using Stereotactic Body Radiotherapy (SBRT)

K Snyder*, J Kim, A Reding, C Fraser, S Lu, J Gordon, M Ajlouni, B Movsas, I Chetty, Henry Ford Health System, Detroit, MI

Purpose: To describe the development of a knowledge-based treatment planning model for lung cancer patients treated with SBRT, and to evaluate the model performance and applicability to different planning techniques and tumor locations**. Methods:** 105 lung SBRT plans previously treated at our institution were included in the development of the model using Varian's RapidPlan DVH estimation algorithm. The model was trained with a combination of IMRT, VMAT, and 3D–CRT techniques. Tumor locations encompassed lesions located centrally vs peripherally (43:62), upper vs lower (62:43), and anterior vs posterior lobes (60:45). The model performance was validated with 25 cases independent of the training set, for both IMRT and VMAT. Model generated plans were created with only one optimization and no planner intervention. The original, general model was also divided into four separate models according to tumor location. The model was also applied using different beam templates to further improve workflow. Dose differences to targets and organs-at-risk were evaluated. **Results:** IMRT and VMAT RapidPlan generated plans were comparable to clinical plans with respect to target coverage and several OARs. Spinal cord dose was lowered in the model-based plans by 1Gy compared to the clinical plans, p=0.008. Splitting the model according to tumor location resulted in insignificant differences in DVH estimation. The peripheral model decreased esophagus dose to the central lesions by 0.5Gy compared to the original model, p=0.025, and the posterior model increased dose to the spinal cord by 1Gy compared to the anterior model, p=0.001. All template beam plans met OAR criteria, with 1Gy increases noted in maximum heart dose for the 9-field plans, p=0.04**. Conclusion:** A RapidPlan knowledge-based model for lung SBRT produces comparable results to clinical plans, with increased consistency and greater efficiency. The model encompasses both IMRT and VMAT techniques, differing tumor locations, and beam arrangements.

Research supported in part by a grant from Varian Medical Systems, Palo Alto CA.

MO-FG-CAMPUS-T-10

Correct Or Not to Correct for Rotational Patient Set-Up Errors in Stereotactic Radiosurgery

M Briscoe*, N Ploquin, JP Voroney, University of Calgary, Tom Baker Cancer Centre, Calgary, AB

Purpose: To quantify the effect of patient rotation in stereotactic radiation therapy and establish a threshold where rotational patient set-up errors have a significant impact on target coverage**. Methods:** To simulate rotational patient set-up errors, a Matlab code was created to rotate the patient dose distribution around the treatment isocentre, located centrally in the lesion, while keeping the structure contours in the original locations on the CT and MRI. Rotations of 1°, 3°, and 5° for each of the pitch, roll, and yaw, as well as simultaneous rotations of 1°, 3°, and 5° around all three axes were applied to two types of brain lesions: brain metastasis and acoustic neuroma. In order to analyze multiple tumour shapes, these plans included small

spherical (metastasis), elliptical (acoustic neuroma), and large irregular (metastasis) tumour structures. Dose-volume histograms and planning target volumes were compared between the planned patient positions and those with simulated rotational set-up errors. The RTOG conformity index for patient rotation was also investigated**. Results:** Examining the tumour volumes that received 80% of the prescription dose in the planned and rotated patient positions showed decreases in prescription dose coverage of up to 2.3%. Conformity indices for treatments with simulated rotational errors showed decreases of up to 3% compared to the original plan. For irregular lesions, degradation of 1% of the target coverage can be seen for rotations as low as 3°. **Conclusions:** This data shows that for elliptical or spherical targets, rotational patient set-up errors less than 3° around any or all axes do not have a significant impact on the dose delivered to the target volume or the conformity index of the plan. However the same rotational errors would have an impact on plans for irregular tumours.

Joint Imaging - Therapy Exhibit Hall Electronic Campus

Re-invigorating Quality Assurance

MO-FG-CAMPUS-J-06

A Novel and Efficient Daily QA Program for Both Modern Linear Accelerator and Optical Surface Motion Systems

J Peng*, D McDonald, M Ashenafi, N Koch, M Fugal, K Vanek, Medical University of South Carolina, Charleston, SC

Purpose: The camera-based optical surface monitoring system(OSMS) is a standard motion-tracking system for TrueBeam™ machine. Daily quality assurance(DQA) procedures for the TrueBeam and OSMS systems currently require multiple phantoms and test sequences. Machine Performance Check(MPC) uses the IsoCal™ phantom to test geometric and dosimetric aspects, and has been validated for routine TrueBeam DQA. This work examines the novel use of MPC to simultaneously conduct DQA of OSMS,utilizing one phantom and test sequence for QA of both the TrueBeam and OSMS systems**. Methods:** TrueBeam with 6 degree-of-freedom(6DOF) couch, MPC and OSMS were installed. The therapists routinely use MPC with the IsoCal phantom to verify geometric and dosimetric parameters with an automated sequence of varying gantry and collimator angles, MLC positions, and couch translations and rotations as the DQA for TrueBeam. A surface outline of the IsoCal phantom, generated from a CT dataset, was imported to OSMS and used to monitor the position of the phantom at isocenter and to track its movement up to 5cm/10°(yaw) and rotation in pitch and roll up to 3° in real time during the automated MPC sequence. Motion of the phantom throughout the MPC routine was compared to the couch position shown by the digital readout**. Results:** The coincidence of isocenter, as determined by OSMS, and TrueBeam radiation isocenter was within ±0.8mm/±0.8° in three axes. Between OSMS and TrueBeam 6DOF couch, the mean couch relative shifts/angles were within ±0.7mm/±0.8° for each axis. Reported pitch and roll values were within ±0.4mm/±0.4°. The total measurement time for each DQA session took approximately 5 minutes**. Conclusion:** Use of the IsoCal phantom and MPC for simultaneous DQA of TrueBeam and OSMS increases QA efficiency and reduces complexity. OSMS isocenter position and motion-tracking capability in 6DOF were verified in real-time and were found to be within 1mm of the expected value.

MO-FG-CAMPUS-J-07

Automatic Recognition of Patient Treatment Site in Portal Images Using Machine Learning

X Chang*, D Yang, Washington University in St Louis, St Louis, MO

Purpose: To investigate the method to automatically recognize the treatment site in the X-Ray portal images. It could be useful to detect potential treatment errors, and to provide guidance to sequential tasks, e.g. automatically verify the patient daily setup**. Methods:** The portal images were exported from MOSAIQ as DICOM files, and were 1) processed with a threshold based intensity transformation algorithm to enhance contrast, and 2) where then down-sampled (from 1024x768 to 128x96) by using bi-cubic interpolation algorithm. An appearance-based vector space model (VSM) was used to rearrange the images into vectors. A principal component analysis (PCA) method was used to reduce the vector dimensions. A multi-class support vector machine (SVM), with radial basis function kernel, was used to build the treatment site recognition models. These models were then used to recognize the treatment sites in the portal image. Portal images of 120 patients were included in the study. The images were selected to cover six treatment sites: brain, head and neck, breast, lung, abdomen and pelvis. Each site had images of the twenty patients. Cross-validation experiments were performed to evaluate the performance**. Results:** MATLAB image processing Toolbox and scikit-learn (a machine learning library in python) were used to implement the proposed method. The average accuracies using the AP and RT images separately were 95% and 94% respectively. The average accuracy using AP and RT images together was 98%. Computation time was ~0.16 seconds per patient with AP or RT image, ~0.33 seconds per patient with both of AP and RT images**. Conclusion:** The proposed method of treatment site recognition is efficient and accurate. It is not sensitive to the differences of image intensity, size and positions of patients in the portal images. It could be useful for the patient safety assurance.

The work was partially supported by a research grant from Varian Medical System.

MO-FG-CAMPUS-J-08

Evaluation and Use of Cubic Phantoms for Daily IGRT QA Process with TrueBeam 6DoF Couch

S Ito*, L Fong de los Santos, S McCauley Cutsinger, Mayo Clinic, Rochester, MN

Purpose: To improve efficiency and efficacy of Daily IGRT QA process and to prepare for Varian TrueBeam 6DoF couch implementation**Methods:** MIMI phantom from Standard Imaging was compared to PentaGuide phantom from Modus Medical in order to replace and update our daily IGRT QA process. The following metrics were used as our evaluation criteria: contrast structures, predefined shift mark, TG-142 compliance, support for 6DoF and ease of use. To improve process compliance, daily IGRT QA set up and process, an acrylic in-house baseplates with known offsets were designed. New Daily IGRT QA protocol for 3DoF and 6DoF systems was developed and implemented into our practice. The selected phantom was used for the commissioning of Varian TrueBeam 6DoF couches and test the reproducibility and accuracy of 2D/2D and 3D/3D matching and localization processes. Baseline and tolerances for Daily IGRT QA for 6DoF couch were determined**. Results:** Based on our evaluation criteria, the MIMI phantom fit best our QA processes and matching goals. Comprehensive daily IGRT QA which includes CBCT 3D automatic registration, couch positioning, coincidence of kV/MV isocenters, image quality, and laser alignment were accurately and efficiently validated using the MIMI phantom and the setup baseplate with Varian TrueBeam and EX systems with 3DoF and 6DoF couches. Also, the use of MIMI phantom and setup baseplate was found to be a useful and effective tool for the commissioning of the Varian TrueBeam 6DoF couches**. Conclusion:** Implementation of MIMI phantom improved our Daily IGRT QA process by eliminating the use multiple phantoms which resulted in 40% Daily IGRT QA time reduction. Feedback from therapists has been positive and 100% compliance to new protocol has been achieved with minimal training. MIMI phantom was used to test the stability of the couch and to set baseline for Daily QA target and tolerance values.

MO-FG-CAMPUS-J-09

One-Year Analysis of Elekta CBCT Image Quality Using NPS and MTF

S Nakahara[1]*, M Tachibana[2], Y Watanabe[3], (1) Hiroshima International University, Hiroshma, Hiroshima, (2) Hiroshima International University, Hiroshma, Hiroshima, (3) University of Minnesota, Minneapolis, MN

Purpose: To compare quantitative image quality (IQ) evaluation methods using Noise Power Spectrum (NPS) and Modulation Transfer Function (MTF) with standard IQ analyses for minimizing the observer subjectivity of the standard methods and maximizing the information content. **Methods:** For our routine IQ tests of Elekta XVI Cone-Beam CT, image noise was quantified by the standard deviation of CT number (CT#) (Sigma) over a small area in an IQ test phantom (CatPhan), and the high spatial resolution (HSR) was evaluated by the number of line-pairs (LP#) visually recognizable on the image. We also measured the image uniformity, the low contrast resolution ratio, and the distances of two points for geometrical accuracy. For this study, we did additional evaluation of the XVI data for 12 monthly IQ tests by using NPS for noise, MTF for HSR, and the CT#-to-density relationship. NPS was obtained by applying Fourier analysis in a small area on the uniformity test section of CatPhan. The MTF analysis was performed by applying the Droege-Morin (D-M) method to the line pairs on

the phantom. The CT#-to-density was obtained for inserts in the low-contrast test section of the phantom**. Results:** All the quantities showed a noticeable change over the one-year period. Especially the noise level changed significantly after a repair of the imager. NPS was more sensitive to the IQ change than Sigma. MTF could provide more quantitative and objective evaluation of the HSR. The CT# was very different from the expected CT#; but, the CT#-to-density curves were constant within 5% except two months. **Conclusion:** Since the D-M method is easy to implement, we recommend using MTF instead of the LP# even for routine periodic QA. The month-to-month variation of IQ was not negligible; hence a routine IQ test must be performed, particularly after any modification of hardware including detector calibration.

MO-FG-CAMPUS-J-10

Using 2D Relative Gamma Analysis From EPID Image as a Predictor of Plan Deterioration Due to Anatomical Changes

O Piron[1, 2]*, N Varfalvy[1, 2], L Archambault[1, 2], (1) Departement de radio-oncologie et axe oncologie du centre de recherche du CHU de Quebec, CHU de Quebec, QC, Canada, (2) Departement de physique, genie physique et d'optique et Centre de recherche sur le cancer, Universite Laval, QC, Canada

Purpose: One of the side effects of radiotherapy for head and neck (H&N) cancer is the patient's anatomical changes. The changes can strongly affect the planned dose distribution. In this work, our goal is to demonstrate that relative analysis of EPID images is a fast and simple method to detect anatomical changes that can have a strong dosimetric impact on the treatment plan for H&N patients**. Methods:** EPID images were recorded at every beam and all fractions for 50 H&N patients. Of these, five patients that showed important anatomical changes were selected to evaluate dosimetric impacts of these changes and to correlate them with a 2D relative gamma analysis of EPID images. The planning CT and original contours were deformed onto CBCTs (one mid treatment and one at the end of treatment). By using deformable image registration, it was possible to map accurate CT numbers from the planning CT to the anatomy of the day obtained with CBCTs. Clinical treatment plan were then copied on the deformed dataset and dose was re-computed. In parallel, EPID images were analysed using the gamma index (3%3mm) relative to the first image**. Results:** It was possible to divide patients in two distinct, statistically different ($p<0.001$) categories using an average gamma index of 0.5 as a threshold. Below this threshold no significant dosimetric degradation of the plan are observed. Above this threshold two types of plan deterioration were seen: (1) target dose increases, but coverage remains adequate while dose to at least one OAR increases beyond tolerances; (2) the OAR doses remain low, but the target dose is reduced and coverage becomes inadequate. **Conclusion:** Relative analysis gamma of EPID images could indeed be a fast and simple method to detect anatomical changes that can potentially deteriorates treatment plan for H&N patients.

This work was supported in part by Varian Medical System

Imaging Electronic Campus Exhibit Hall

Clinical Applications, Phantoms

MO-FG-CAMPUS-I-06

EIT Imaging to Monitor Human Salivary Gland Functionality: A Feasibility Study

K Kohli*, A Karvat, J Liu, K Krishnan, BC Cancer Agency, Surrey, BC

Purpose: Clinically, there exists a need to develop a non-invasive technique for monitoring salivary activity. In this study, we investigate the feasibility of a using the electrical conductivity information from Electrical Impedance Tomography (EIT) to monitor salivary flow activity**. Methods:** To acquire EIT data, eight Ag/AgCl ECG electrodes were placed around the mandible of the subject. An EIT scan was obtained by injecting current at 50 KHz, 0.4 mA through each pair of electrodes and recording voltage across other electrode pairs. The functional conductivity image was obtained through reconstruction of the voltage data, using Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software (EIDORS) in Matlab. In using EIDORS, forward solution was obtained using a user-defined finite element model shape and inverse solution was obtained using one-step Gaussian solver. EIT scans of volunteer research team members were acquired for three different physiological states: pre-stimulation, stimulation and post-stimulation. For pre-stimulation phase, data were collected in intervals of 5 minutes for 15 minutes. The salivary glands were then stimulated in the subject using lemon and the data were collected immediately. Post-stimulation data were collected at 4 different timings after stimulation. **Results:** Variations were observed in the electrical conductivity patterns near parotid regions between the pre- and post- stimulation stages. The three images acquired during the 15 minute pre-stimulation phase showed no major changes in the conductivity. Immediately after stimulation, electrical conductivity increased near parotid regions and 15 minutes later slowly returned to pre-stimulation level**. Conclusion:** In the present study involving human subjects, the change in electrical conductivity pattern shown in the EIT images, acquired at different times with and without stimulation of salivary glands, appeared to be consistent with the change in salivary gland activity. The conductivity changes imaged through EIT are potentially useful for the purpose of salivary monitoring.

MO-FG-CAMPUS-I-07

Stability Investigation of a Gamma Fitting Algorithm for Angiographic Parametric Imaging at Low X-Ray Exposures Using a Patient Specific Neurovascular Phantom

A Balasubramoniam[1, 2]*, D Bednarek[2], S Rudin[1, 2], C Ionita[1, 2], (1) Department of Biomedical Engineering, SUNY Buffalo, Buffalo, NY, (2) Toshiba Stroke and Vascular Research Center, SUNY Buffalo, Buffalo, NY

Purpose: To analyze the stability of a Gamma fitting algorithm based on digital subtraction angiography sequences, at different exposure, hence noise levels. **Methods:** Starting with a patient CT volume, we built a 3D printed neurovascular phantom which contained a complete Circle of Willis with major arteries and five aneurysms. We placed the phantom in a 15 cm water bath and connected it to a flow loop containing a peristaltic pump which simulated physiological relevant flow conditions. We injected 10 ml contrast boluses using an automatic contrast injector at a rate of 10 ml/sec. Digital Subtraction Angiography images were acquired at 30 frames/sec and processed with a gamma fitting based algorithm, to yield parametric maps of: Mean transit time (MTT), Time-to-Peak (TTP), Bolus Arrival Time (BAT). Starting with the optimal exposure parameters selected by the x-ray system automatic exposure control, while keeping the same kV, we lowered the mA and exposure per frame in four steps until we reached the minimum value allowed by the system. We analyzed the variation of the MTT, TTP and BAT for various artery signal to noise ratios using four ROIs**. Results:** The peak (maximum opacification) SNRs for full dose and minimum dose were: 35 and 13 for 4 mm arteries and 18 and 7 for 2 mm arteries. The parameters standard deviation expressed as a percent fraction of the value measured at the full dose value, were: MTT=2.4%, BAT=0.5% and TTP=1.9% for 4 mm vessels and MTT=3.7%, BAT=5.4% and TTP=6.3% for 2 mm vessels**. Conclusion:** Despite a significant decrease of the peak SNR the algorithm performed very well displaying variations less than 6.3% of the ideal conditions. Partial Support: NIH grant R01EB002873 and Toshiba Medical Systems Corp.

Partial Support: NIH grant R01EB002873 and Toshiba Medical Systems Corp.

MO-FG-CAMPUS-I-08

CT and MR Characteristics of Some Specialty 3D Printing Filaments

K Lam[1]*, (1) University of Michigan, Ann Arbor, MI

Purpose: To quantify the Hounsfield Unit and demonstrate MR signal of specialty 3D printer filaments that are recently made available to fused deposition modeling (FDM) 3D printers as raw materials to print 3D objects such as phantoms and patient specific boluses or shields**. Methods:** We acquired 2.85mm diameter batches of ColorFabb copperfill metal filament, Soft PLA filaments of different colors (Red, Blue, White, Beige, Black), BendLay filament, Taulman Bridge filament, NinjaFlex water semi-transparent thermoplastic elastomer filament, Light Cherry Wood LAYWOO-D3 filament, as well as the more commonly used polylactic acid (PLA) filament and acrylonitrile butadiene styrene (ABS) filament. We also included 2.5mm diameter silicone, polyurethane, neoprene, and nitrile rubber (soft Buna-N) o-ring cords for comparison. These filaments were arranged in a 4x4 array in a 5cm x 15cm x 15cm block of UHMW polyethylene. CT scan of 1mm slice thickness was performed with a cranial SRS protocol. MR scan was performed with an ultra-short echo time point-wise encoding time reduction with radial acquisition (UTE PETRA) protocol in a water bath. The CT and MR of these different materials were imported into Eclipse. In order to reduce the contribution of partial volume

effect, the maximum HU of each material were determined in 4 slices and averaged**. Results:** The copperfill filament HU was saturated at 2975. Soft PLA filaments had HU in the range of 400-500. PLA and NinjaFlex were 100-200 HU. Taulman Bridge filament was about 63 HU. LAYWOO-D3, ABS, and BendLay filaments were between -60 to -30 HU. Overall, the HU of these specialty filaments spanned the range from -60 to >3000. The materials were also visible in the UTE MR image**. Conclusion:** The wide range of materials available to FDM 3D printing made possible the fabrication of various objects for medical physics to emulate different tissues.

MO-FG-CAMPUS-I-09

Magnetic Resonance Imaging of An in Vitro 3D Tumor Model

C Veiga*, T Long, B Siow, M Loizidou, G Royle, K Ricketts, University College London, London, UK

Purpose: To investigate the use of an in vitro 3D tumor model (tumoroid) as a bio-phantom for repetitive and sequential magnetic resonance imaging (MRI) studies. **Methods:** The tissue engineered tumoroid comprised an artificial cancer mass (ACM) containing 30 million HT29 cancer cells seeded in a collagen type I matrix, whose density was increased by plastic compression (dry/wet weight=40%). The ACM was embedded in an uncompressed collagen gel that mimicked the tumor stroma, and the tumoroid was incubated for 24h before imaging. Images were acquired using the 1T ICON™ (Bruker Corporation, Billerica, MA) MRI scanner. T1 maps were calculated using an IR-RARE sequence (TE=12ms, TR=10000ms, 7 inversion times), while for T2 maps a MSME technique (TR=6000ms, 16 echoes) was used. T1 and T2 fittings were performed using a pixel-wise approach to produce relaxometric parametric maps**. Results:** The images acquired and corresponding T1 and T2 maps indicate contrast between the ACM and the stroma. T1 was 2500 and 2800ms, while T2 was 520 and 760ms, for the ACM and stroma respectively. The ACM construct was not homogenous and internal features were visible, which can be explained by local gradients of cell and/or collagen density. The viability of the cells was confirmed via confocal microscopy for several days after the imaging session, demonstrating the suitability of the tumoroid for sequential imaging studies. **Conclusions:** We have engineered a tumor model compatible with repetitive and sequential MRI. We found T1 and T2 contrast between the ACM and stroma using a pre-clinical MRI scanner. The model, which enables controllable cell and matrix densities, has potential for a wide range of applications in radiotherapy, such as to study tumor progression and to validate imaging biomarkers. Further work is necessary to understand the mechanisms behind the contrast achieved, and to correlate findings with biology and histology data.

MO-FG-CAMPUS-I-10

Quantitative ADC Measurement of Esophageal Cancer Before and After Chemoradiation

L Yang[1, 2]*, JB Son[2], J Ma[2], S Cheng[1], J Hazle[2], BW Carter[2], S Lin[2], (1) The University of Oklahoma, Tulsa, OK, (2) UT MD Anderson Cancer Center, Houston, TX

Purpose: We investigated whether quantitative diffusion imaging can be used as an imaging biomarker for early prediction of treatment response of esophageal cancer**. Methods:** Eight patients with esophageal cancer underwent a baseline and an interim MRI studies during chemoradiation on a 3T whole body MRI scanner with an 8-channel torso phased array coil. Each MRI study contained two axial diffusion-weighted imaging (DWI) series with a conventional DWI sequence and a reduced field-of-view DWI sequence (FOCUS) of varying b-values. ADC maps with two b-values were computed from conventional DWI images using a mono-exponential model. For each of DWI sequences, separate ADCall was computed by fitting the signal intensity of images with all the b-values to a single exponential model. For the FOCUS sequence, a bi-exponential model was used to extract perfusion and diffusion coefficients (ADCperf and ADCdiff) and their contributions to the signal decay. A board-certified radiologist contoured the tumor region and mean ADC values and standard deviations of tumor and muscle ROIs were recorded from different ADC maps**. Results:** Our results showed that (1) the magnitude of ADCs from the same ROIs by the different analysis methods can be substantially different. (2) For a given method, the change between the baseline and interim muscle ADCs was relatively small (≤10%). In contrast, the change between the baseline and interim tumor ADCs was substantially larger, with the change in ADCdiff by FOCUS DWI showing the largest percentage change of 73.2%. (3) The range of the relative change of a specific parameter for different patients was also different**. Conclusion:** Presently, we do not have the final pathological confirmation of the treatment response for all the patients. However, for a few patients whose surgical specimen is available, the quantitative ADC changes have been found to be useful as a potential predictor for treatment response.

Therapy Electronic Campus Exhibit Hall

Proton Therapy Beam Measurement and QA

MO-FG-CAMPUS-T-11

IROC Houston QA Center's Anthropomorphic Proton Phantom Program

C Lujano*, N Hernandez, T Keith, T Nguyen, P Taylor, A Molineu, D Followill, UT MD Anderson Cancer Center, Houston, TX

Purpose: To describe the proton phantoms that IROC Houston uses to approve and credential proton institutions to participate in NCI-sponsored clinical trials**. Methods:** Photon phantoms cannot necessarily be used for proton measurements because protons react differently than photons in some plastics. As such plastics that are tissue equivalent for protons were identified. Another required alteration is to ensure that the film dosimeters are housed in the phantom with no air gap to avoid proton streaming. Proton-equivalent plastics/materials used include RMI Solid Water, Techron HPV, blue water, RANDO soft tissue material, balsa wood, compressed cork and polyethylene. Institutions wishing to be approved or credentialed request a phantom and are prioritized for delivery. At the institution, the phantom is imaged, a treatment plan is developed, positioned on the treatment couch and the treatment is delivered. The phantom is returned and the measured dose distributions are compared to the institution's electronically submitted treatment plan dosimetry data**. Results:** IROC Houston has developed an extensive proton phantom approval/credentialing program consisting of five different phantoms designs: head, prostate, lung, liver and spine. The phantoms are made with proton equivalent plastics that have HU and relative stopping powers similar (within 5%) of human tissues. They also have imageable targets, avoidance structures, and heterogeneities. TLD and radiochromic film are contained in the target structures. There have been 13 head, 33 prostate, 18 lung, 2 liver and 16 spine irradiations with either passive scatter, or scanned proton beams. The pass rates have been: 100%, 69.7%, 72.2%, 50%, and 81.3%, respectively. **Conclusion:** IROC Houston has responded to the recent surge in proton facilities by developing a family of anthropomorphic phantoms that are able to be used for remote audits of proton beams.

Work supported by PHS grant CA10953 and CA081647

MO-FG-CAMPUS-T-12

Dosimetric Accuracy of the CrystalBallâ„¢: New Reusable Radiochromic Polymer Gel Dosimeter for Patient QA in Proton Therapy

S Avery[1]*, J Kraus[1], L Lin[1], A Kassaee[1], M Maryanski[2] (1) University of Pennsylvania, Philadelphia, PA (2) MGS Research, Inc., Madison, CT

Purpose: To evaluate the accuracy of monoexponential normalization in a new class of commercial, reusable, human-soft-tissue-equivalent, radiochromic polymer gel dosimeters for patient-specific QA in proton therapy**. Methods:** Eight formulations of the dosimeter (sealed in glass spheres of 166 mm OD), were exposed to a 150 MeV proton beam (5 cm x 5 cm square field, range 15 cm, modulation10 cm), with max dose ranging from 2.5 Gy to 20 Gy, depending on formulation. Exposed dosimeters were promptly placed in the commercial OCTOPUS™ laser CT scanner which was programmed to scan the central slice every 5 minutes for 20 hours (15 seconds per slice scan). This procedure was repeated several times. Reconstructed data were analyzed using the log-lin scale to determine the time range over which a monoexponential relaxation model could be applied. Next, a simple test plan was devised and delivered to each dosimeter. The OCTOPUS™ was programmed to rescan the central slice at the end of each volume scan, for signal relaxation reference. Monoexponential normalization was applied to sinograms before FBP reconstruction. Dose calibration was based on a volume-lookup table built within the central spherical volume of 12 cm diameter. 3D gamma and sigma passing rates were measured at 3%/3mm criteria down to 50% isodose**. Results:** Approximately monoexponential signal relaxation time

ranges from 25 minutes to 3.5 hours, depending on formulation, followed by a slower-relaxation component. Noise in reconstructed OD/cm images is less than 0.5%. Dose calibration accuracy is better than 99%. Measured proton PDDs demonstrate absence of Bragg-peak quenching. Estimated number of useful cycles is at least 20, with a theoretical limit above 100. 3D gamma and sigma passing rates exceed 95%**. Conclusion:** Monoexponential normalization was found to yield adequate dosimetric accuracy in the new class of commercial radiochromic polymer gel dosimeters for patient QA in proton therapy.

MO-FG-CAMPUS-T-13

Verification of Range, SOBP Width, and Output for Passive-Scattering Proton Beams Using a Liquid Scintillator Detector

T Henry*, D Robertson, F Therriault-Proulx, S Beddar, UT MD Anderson Cancer Center, Houston, TX

Purpose: Liquid scintillators have been shown to provide fast and high-resolution measurements of radiation beams. However, their linear energy transfer-dependent response (quenching) limits their use in proton beams. The purpose of this study was to develop a simple and fast method to verify the range, spread-out Bragg peak (SOBP) width, and output of a passive-scattering proton beam with a liquid scintillator detector, without the need for quenching correction**. Methods:** The light signal from a 20x20x20 cm3 liquid scintillator tank was collected with a CCD camera. Reproducible landmarks on the SOBP depth-light curve were identified which possessed a linear relationship with the beam range and SOBP width. The depth-light profiles for three beam energies (140, 160 and 180 MeV) with six SOBP widths at each energy were measured with the detector. Beam range and SOBP width calibration factors were obtained by comparing the depth-light curve landmarks with the nominal range and SOBP width for each beam setting. The daily output stability of the liquid scintillator detector was also studied by making eight repeated output measurements in a cobalt-60 beam over the course of two weeks**. Results:** The mean difference between the measured and nominal beam ranges was 0.6 mm (σ=0.2 mm), with a maximum difference of 0.9 mm. The mean difference between the measured and nominal SOBP widths was 0.1 mm (σ=1.8 mm), with a maximum difference of 4.0 mm. Finally an output variation of 0.14% was observed for 8 measurements performed over 2 weeks**. Conclusion:** A method has been developed to determine the range and SOBP width of a passive-scattering proton beam in a liquid scintillator without the need for quenching correction. In addition to providing rapid and accurate beam range and SOBP measurements, the detector is capable of measuring the output consistency with a high degree of precision.

This project was supported in part by award number CA182450 from the National Cancer Institute.

MO-FG-CAMPUS-T-14

Utilization of Optical Dosimeter for Modulated Spot-Scanning Particle Beam

W Hsi*, Y Li, Z Huang, Y SHENG, Y Deng, J Zhao, F Zhao, L Sun, and M Moyers, Shanghai Proton and Heavy Ion Center, Pudong, Shangai, China

Purpose: To present the utilization of an optical dosimeter for modulated spot-scanning carbon-ion and proton beams during the acceptance test of Siemens IONTRIS system.Method and Materials: An optical dosimeter using phosphor scintillation was developed to map and interactively analyze the shapes and sizes of spots over 190 energies for ProTom modulated-scanning system. The dose response to proton had been characterized with proper pixel calibration at ProTom system. The dose response was further studied at 0.7 cm depths by uniform 8cm in-diameter fields of 424.89 MeV/u (E290) carbon-ions and 215.18MeV (E282) protons at IONTRIS system. The virtual source axial distances (vSAD) of carbon-ions and protons of IONTRIS system was investigated by measuring either variations of spot position or field size at five different locations to Isocenter. By measuring lateral profiles of uniform doses with varied thin-thicknesses of chest-board pattern and placing the scintillation plate at near to the distal edge, range variations at different off-axis-distances (rOAD) were examined. Relative accuracy and reproducibility of beam range were measured for three beam ranges with a ramping block at front of scintillation plate**. Results:** Similar dose response was observed for high energies of carbon ions and protons. Mean vSAD at X and Y axes were 744.1 cm and 807.4cm with deviation of 7.4cm and 7.7cm, respectively. Variation of rOAD was within 0.35 mm over 10cm for both protons and carbon ions. Accuracy of measuring relative distal range using the ramping block was 0.2mm. Measured range over repeated three times for each range were within 0.25mm at same room, and within 1.0mm between four rooms**. Conclusions:** The optical dosimeter could efficiently measure the virtual source distance. And, to measure small range variation at different off-axial locations, and for the relative beam range between rooms during acceptance test of a modulated spot-scanning particle system.

MO-FG-CAMPUS-T-15

Design of An Innovative Beam Monitor for Particle Therapy for the Simultaneous Measurement of Beam Fluence and Energy

R Sacchi[1, 2]*, N Cartiglia[1], F Cenna[1], L Fanola Guarachi[1, 2], M Ferrero[2], S Giordanengo[1], F Marchetto[1], V Monaco[1, 2], A Vignati[1], M Varasteh Anvar[1, 2], R Cirio[1, 2], (1) Istituto Nazionale di Fisica Nucleare (INFN), Turin, Italy, (2) University of Torino, Turin, Italy

Purpose: Monitoring the prescribed dose in particle therapy is typically carried out by using parallel plate ionization chambers working in transmission mode. The use of gas detectors has several drawbacks: they need to be calibrated daily against standard dosimeters and their dependence on beam quality factors need to be fully characterized and controlled with high accuracy. A detector capable of single particle counting is proposed which would overcome all these limitations. Combined with a gas ionization chamber, it will allow determining the average particle stopping power, thus providing an effective method for the online verification of the selected particle energy and range**. Methods:** Low-Gain Avalanche Detectors (LGADs) are innovative n-in-p silicon sensors with moderate internal charge multiplication occurring in the strong field generated by an additional p+ doping layer implanted at a depth of a few μm in the bulk of the sensor. The increased signal-to-noise ratio allows designing very thin, few tens of microns, segmented LGADs, called Ultra Fast Silicon Detectors (UFSD), optimized for very fast signal, which would be suitable for charged particle counting at high rates. A prototype UFSD is being designed for this purpose**. Results:** Different LGAD diodes have been characterized both in laboratory and beam tests, and the results compared both with those obtained with similar diodes without the gain layer and with a program simulating the signal in the sensors. The signal is found to be enhanced in LGADs, while the leakage current and the noise is not affected by the gain. Possible alternative designs and implementations are also presented and discussed**. Conclusion:** Thanks to their excellent counting capabilities, UFSD detectors are a promising technology for future beam monitor devices in hadron-therapy applications. Studies are ongoing to better understand their properties and optimize the design in view of this application.

Joint Imaging - Therapy — Exhibit Hall Electronic Campus

Novel In-Treatment Imaging

MO-FG-CAMPUS-J-11

Acoustic Range Verification of Proton Beams: Simulation of Heterogeneity and Clinical Proton Pulses

K Jones, C Sehgal, S Avery*, Univ Pennsylvania, Philadelphia, PA

Purpose: Through simulation, to assess acoustic-based range verification of proton beams (protoacoustics) under clinical conditions. **Methods:** Pressure waves generated by the energy deposition of a 150 MeV, 8 mm FWHM pulsed pencil proton beam were numerically simulated through two **Methods:** 1) For a homogeneous water medium, an analytical wave-equation solution was used to calculate the time-dependent pressure measured at detector points surrounding the proton Bragg peak. 2) For heterogeneity studies, a CT tissue image was used to calculate the proton dose deposition and define the acoustic properties of the voxels through which numerical pressure wave propagation was simulated with the k-Wave matlab toolbox. The simulations were used to assess the dependence of the acoustic amplitude and range-verification accuracy on proton pulse rise time and tissue heterogeneity. **Results:** As the proton pulse rise time is increased from 1 to 40 μs, the amplitude of the expected acoustic emission decreases (a 60% drop distal to the Bragg peak), the central frequency of the expected signal decreases (from 45 to 6 kHz), and the accuracy of the range-verification decreases (from <1 mm to 16 mm at 5 cm distal to the Bragg peak). For a 300 nA pulse, the expected pressure range is on the order of 0.1 Pa, which is observable with commercial detectors. For the heterogeneous medium, our test case shows that pressure waves emitted by an anterior

pencil beam directed into the abdomen and detected posteriorly can determine the Bragg peak range to an accuracy of <2mm for a 1 μs proton pulse. **Conclusion:** For proton pulses with fast rise-times, protoacoustics is a promising potential method for monitoring penetration depth through heterogeneous tissue. The loss of range-verification accuracy with increasing rise-times, however, suggests the need for comparisons to modeling to improve accuracy for slower cyclotron proton sources.

MO-FG-CAMPUS-J-12

Commissioning of Radiofrequency Tracking for Gated SBRT of the Liver Using Novel Motion System

J James*, A Cetnar, V Nguyen, B Wang, University of Louisville, Louisville, KY

Purpose: Tracking soft tissue targets has recently been approved as a new application of the Calypso radiofrequency tracking system allowing for gated treatment of the liver based on the motion of the target volume itself. As part of the commissioning process, an end-to-end test was performed using a 3D diode array and 6D motion platform to verify the dosimetric accuracy and establish the workflow of gated SBRT treatment of the liver using Calypso**. Methods:** A 4DCT scan of the ScandiDos Delta4 phantom was acquired using the HexaMotion motion platform to simulate realistic breathing motion. A VMAT plan was optimized on the end of inspiration phase of the 4DCT scan and delivered to the Delta4 phantom using the Varian TrueBeam. The treatment beam was gated by Calypso to deliver dose at the end of inspiration. The expected dose was compared to the delivered dose using gamma analysis. In addition, gating limits were investigated to determine how large the gating range can be while still maintaining dosimetric accuracy. **Results:** The 3%/3mm and 2%/2mm gamma pass rate for the gated treatment delivery was 100% and 98.4%, respectively. When increasing the gating limits beyond the known extent of planned motion from the 4DCT, the gamma pass rates decreased as expected. The 3%/3mm gamma pass rate for a 1, 2, and 3mm increase in gating limits were measured to be 96.0%, 92.7%, and 78.8%, respectively. **Conclusion:** Radiofrequency tracking was shown to be an effective way to provide gated SBRT treatment of the liver. Baseline gating limits should be determined by measuring the extent of target motion during the respiratory phases used for planning. We recommend adding 1mm to the baseline limits to provide the proper balance between treatment efficiency and dosimetric accuracy.

MO-FG-CAMPUS-J-13

Development of a Human Brain PET for On-Line Proton Beam-Range Verification

Yiping Shao, Department of Imaging Physics, University of Texas M.D. Anderson Cancer Center, Houston, TX

Purpose: To develop a prototype PET for verifying proton beam-range before each fractionated therapy that will enable on-line re-planning proton therapy. **Methods:** Latest "edge-less" silicon photomultiplier arrays and customized ASIC readout electronics were used to develop PET detectors with depth-of-interaction (DOI) measurement capability. Each detector consists of one LYSO array with each end coupled to a SiPM array. Multiple detectors can be seamlessly tiled together to form a large detector panel. Detectors with 1.5x1.5 and 2.0x2.0 mm crystals at 20 or 30 mm lengths were studied. Readout of individual SiPM or signal multiplexing was used to transfer 3D interaction position-coded analog signals through flexible-print-circuit cables or PCB board to dedicated ASIC front-end electronics to output digital timing pulses that encode interaction information. These digital pulses can be transferred to, through standard LVDS cables, and decoded by a FPGA-based data acquisition of coincidence events and data transfer. The modular detector and scalable electronics/data acquisition will enable flexible PET system configuration for different imaging geometry**. Results:** Initial detector performance measurement shows excellent crystal identification even with 30 mm long crystals, ~18% and 2.8 ns energy and timing resolutions, and around 2-3 mm DOI resolution. A small prototype PET scanner with one detector ring has been built and evaluated, validating the technology and design. A large size detector panel has been fabricated by scaling up from modular detectors. Different designs of resistor and capacitor based signal multiplexing boards were tested and selected based on optimal crystal identification and timing performance. Stackable readout electronics boards and FPGA-based data acquisition boards were developed and tested. A brain PET is under construction. **Conclusion:** Technology of large-size DOI detector based on SiPM array and advanced readout has been developed. PET imaging performance and initial phantom studies of on-line proton beam-range measurement will be conducted and reported.

NIH grant R21CA187717; Cancer Prevention and Research Institute of Texas grant RP120326

MO-FG-CAMPUS-J-14

Radiation Heat Load On the MR System of the Elekta Atlantic System

S Towe[1]*, D Roberts[2], J Overweg[3], E Van Lanen[4], (1) Elekta Limited, Crawley, West Sussex, (2) Elekta Limited, Crawley, West Sussex, (3) Philips Innovative Technologies, Hamburg, Hamburg, (4) Philips Healthcare, Latham, NY

Purpose: The Elekta Atlantic system combines a digital linear accelerator system with a 1.5T Philips MRI machine.This study aimed to assess the energy deposited within the cryostat system when the radiation beam passes through the cryostat. The cryocooler on the magnet has a cooling capacity which is about 1 Watt in excess of the cryogenic heat leak into the magnet's cold mass. A pressure-controlled heater inside the magnet balances the excess refrigeration power such that the helium pressure in the tank is kept slightly above ambient air pressure. If radiation power is deposited in the cold mass then this heater will need less power to maintain pressure equilibrium and if the radiation heat load exceeds the excess cryocooler capacity the pressure will rise**. Methods:** An in-house CAD based Monte Carlo code based on Penelope was used to model the entire MR-Linac system to quantify the heat load on the magnet's cold mass. These results were then compared to experimental results obtained from an Elekta Atlantic system installed in UMC-Utrecht**. Results:** For a field size of 25 cm x 22 cm and a dose rate of 107 mu.min-1, the energy deposited by the radiation beam led to a reduction in heater power from 1.16 to 0.73 W. Simulations predicted a reduction to 0.69 W which is in good agreement. For the worst case field size (largest) and maximum dose rate the cryostat cooler capacity was exceeded. This resulted in a pressure rise within the system but was such that continuous irradiation for over 12 hours would be required before the magnet would start blowing off helium. **Conclusion:** The study concluded that the Atlantic system does not have to be duty cycle restricted, even for the worst case non-clinical scenario and that there are no adverse effects on the MR system.

Stephen Towe and David Roberts Both work for Elekta; Ezra Van Lanen works for Philips Healthcare; Johan Overweg works for Philips Innovative Technologies

MO-FG-CAMPUS-J-15

Verification for Prompt Gamma Ray Imaging During Proton Boron Fusion Therapy

H Shin*, D Yoon, J Jung, M Kim, H Jang, T Suh, Catholic University of Korea, Seoul

Purpose: The purpose of this study is to verify the acquisition of the three dimensional single photon emission computed tomography (SPECT) image using prompt gamma ray originated from proton boron fusion therapy (PBFT)**. Methods:** The real-time imaging system during the PBFT was simulated to acquire the tomographic image of the prompt gamma ray from treated tumor by the proton boron reaction, using Monte Carlo simulation (MCNPX). We acquired percentage depth dose (PDD) of the proton beam in the water phantom including the boron uptake region (BUR), the energy spectra of the prompt gamma ray and tomographic image which can show treated tumor regions. The prompt gamma ray image was reconstructed using maximum likelihood estimation maximization (MLEM) reconstruction algorithm with 64 projections. In addition, in order to evaluate the reconstructed image, the image profiles between BURs were extracted from the image**. Results:** In the PDD results, the Bragg-peak was amplified definitely when the proton's maximum dose level was located at the BUR. This amplification is based on the generation of alpha particles. In addition, the prompt gamma ray peak of 719 keV was observed from the energy spectrum. Through the previous process, the tomographic image of prompt gamma ray from the BUR was reconstructed. The line profile was extracted from image including BURs, and it shows high signal-to-noise ratio**. Conclusion:** We confirmed that the real-time prompt gamma ray image during the PBFT was successfully deducted, and results of quantitative image analysis show good agreement with the original pattern of the BUR. This study first verified the imaging capability of the PBFT-

SPECT system. In conclusion, the PBFT-SPECT system can realize the treated tumor monitoring during the PBFT.

Imaging Electronic Campus Exhibit Hall
Radiation Dose

MO-FG-CAMPUS-I-11

A System for Automatically Calculating Organ and Effective Dose for Fluoroscopically-Guided Procedures

Z Xiong*, s vijayan, V Rana, S Rudin, D Bednarek, Toshiba Stroke and Vascular Research Center, University at Buffalo, Buffalo, NY

Purpose: A system was developed that automatically calculates the organ and effective dose for individual fluoroscopically-guided procedures using a log of the clinical exposure parameters**. Methods:** We have previously developed a dose tracking system (DTS) to provide a real-time color-coded 3D-mapping of skin dose. This software produces a log file of all geometry and exposure parameters for every x-ray pulse during a procedure. The data in the log files is input into PCXMC, a Monte Carlo program that calculates organ and effective dose for projections and exposure parameters set by the user. We developed a MATLAB program to read data from the log files produced by the DTS and to automatically generate the definition files in the format used by PCXMC. The processing is done at the end of a procedure after all exposures are completed. Since there are thousands of exposure pulses with various parameters for fluoroscopy, DA and DSA and at various projections, the data for exposures with similar parameters is grouped prior to entry into PCXMC to reduce the number of Monte Carlo calculations that need to be performed**. Results:** The software developed automatically transfers data from the DTS log file to PCXMC and runs the program for each grouping of exposure pulses. When the dose from all exposure events are calculated, the doses for each organ and all effective doses are summed to obtain procedure totals. For a complicated interventional procedure, the calculations can be completed on a PC without manual intervention in less than 30 minutes depending on the level of data grouping**. Conclusion:** This system allows organ dose to be calculated for individual procedures for every patient without tedious calculations or data entry so that estimates of stochastic risk can be obtained in addition to the deterministic risk estimate provided by the DTS.

Partial support from NIH grant R01EB002873 and Toshiba Medical Systems Corp.

MO-FG-CAMPUS-I-12

Occupational Conceptus Doses From Fluoroscopically-Guided Interventional Procedures

J Damilakis[1]*, K Perisinakis[2], G Solomou[3], J Stratakis[4], (1) University of Crete, (2) University of Crete, (3) University of Crete, (4) University of Crete, Heraklion, Crete, GREECE

Purpose: The aim of this method was to provide dosimetric data on conceptus dose for the pregnant employee who participates in fluoroscopically-guided interventional procedures**. Methods:** Scattered air-kerma dose rates were obtained for 17 fluoroscopic projections involved in interventional procedures. These projections were simulated on an anthropomorphic phantom placed on the examination table supine. The operating theater was divided into two grids relative to the long table sides. Each grid consisted of 33 cells spaced 0.50 m apart. During the simulated exposures, at each cell, scatter air-kerma rate was measured at 110 cm from the floor i.e. at the height of the waist of the pregnant worker. Air-kerma rates were divided by the dose area product (DAP) rate of each exposure to obtain normalized data. For each projection, measurements were performed for 3 kVp and 3 filtration values i.e. for 9 different x-ray spectra. All measurements were performed by using a modern C-arm angiographic system (Siemens Axiom Artis, Siemens, Germany) and a radiation meter equipped with an ionization chamber. **Results:** The results consist of 153 iso-dose maps, which show the spatial distribution of DAP-normalized scattered air-kerma doses at the waist level of a pregnant worker. Conceptus dose estimation is possible using air-kerma to embryo/fetal dose conversion coefficients published in a previous study (J Cardiovasc Electrophysiol, Vol. 16, pp. 1-8, July 2005). Using these maps, occupationally exposed pregnant personnel may select a working position for a certain projection that keeps abdominal dose as low as reasonably achievable. Taking into consideration the regulatory conceptus dose limit for occupational exposure, determination of the maximum workload allowed for the pregnant personnel is also possible. **Conclusion:** Data produced in this work allow for the anticipation of conceptus dose and the determination of the maximum workload for a pregnant worker from any fluoroscopically-guided interventional procedure.

This study was supported by the Greek Ministry of Education and Religious Affairs, General Secretariat for Research and Technology, Operational Program 'Education and Lifelong Learning', ARISTIA (Research project: CONCERT).

MO-FG-CAMPUS-I-13

GPU Accelerated Monte Carlo Technique for Fast Concurrent Image and Dose Simulation

M Becchetti*, x tian, P Segars, E Samei, Clinical Imaging Physics Group, Department of Radiology, Duke University Me, Durham, NC

Purpose: To develop an accurate and fast Monte Carlo (MC) method of simulating CT that is capable of correlating dose with image quality using voxelized phantoms**. Methods:** A realistic voxelized phantom based on patient CT data, XCAT, was used with a GPU accelerated MC code for helical MDCT. Simulations were done with both uniform density organs and with textured organs. The organ doses were validated using previous experimentally validated simulations of the same phantom under the same conditions. Images acquired by tracking photons through the phantom with MC require lengthy computation times due to the large number of photon histories necessary for accurate representation of noise. A substantial speed up of the process was attained by using a low number of photon histories with kernel denoising of the projections from the scattered photons. These FBP reconstructed images were validated against those that were acquired in simulations using many photon histories by ensuring a minimal normalized root mean square error**. Results:** Organ doses simulated in the XCAT phantom are within 10% of the reference values. Corresponding images attained using projection kernel smoothing were attained with 3 orders of magnitude less computation time compared to a reference simulation using many photon histories. **Conclusion:** Combining GPU acceleration with kernel denoising of scattered photon projections in MC simulations allows organ dose and corresponding image quality to be attained with reasonable accuracy and substantially reduced computation time than is possible with standard simulation approaches.

MO-FG-CAMPUS-I-14

Patient Eye-Lens Dose Reduction in Routine Brain CT Examinations Using Organ-Based Tube Current Modulation and In-Plane Bismuth Shielding

Hui-Yu Tsai[1, 2]*, Ying-Lan Liao[1, 2], Nan-Ku Lai[3, 4], Jun-Rong Chen[2], Tou-Rong Chen[3, 4], (1) Chang Gung University, Taoyun, Taiwan, (2) Chang Gung University / Chang Gung Memorial Hospital, Taoyun, Taiwan, (3) Chung Shan Medical University Hospital, Taichung, Taiwan, (4) Chung Shan Medical University, Taichung, Taiwan

Purpose: The purpose of this study is to assess eye-lens dose for patients who underwent brain CT examinations using two dose reduction **Methods:** organ-based tube current modulation (OBTCM) and in-plane bismuth shielding method**. Methods:** This study received institutional review board approval; written informed consent to participate was obtained from all patients. Ninety patients who underwent the routine brain CT examination were randomly assigned to three groups, ie. routine, OBTCM, and bismuth shield. The OBTCM technique reduced the tube current when the X-ray tube rotates in front of patients' eye-lens region. The patients in the bismuth shield group were covered one-ply bismuth shield in the eyes' region. Eye-lens doses were measured using TLD-100H chips and the total effective doses were calculated using CT-Expo according to the CT scanning parameters. The surface doses for patients at off-center positions were assessed to evaluate the off-centering effect**. Results:** Phantom measurements indicates that OBTCM technique could reduced by 26% to 28% of the surface dose to the eye lens, and increased by 25% of the surface dose at the opposed incident direction at the angle of 180°. Patients' eye-lens doses were reduced 16.9% and 30.5% dose of bismuth shield scan and OBTCM scan, respectively compared to the routine scan. The eye-lens doses were apparently increased when the table position was lower than isocenter**. Conclusion:** Reducing the dose to the radiosensitive organs, such as eye lens, during routine brain CT examinations could lower the radiation risks. The OBTCM technique and in-plane bismuth shielding could be used

to reduce the eye-lens dose. The eye-lens dose could be effectively reduced using OBTCM scan without interfering the diagnostic image quality. Patient position relative the CT gantry also affects the dose level of the eye lens.

This study was supported by the grants from the Ministry of Science and Technology of Taiwan (MOST103-2314-B-182-009-MY2), and Chang Gung Memorial Hospital (CMRPD1C0682).

MO-FG-CAMPUS-I-15

Radiation Dosimetry of 99mTc-IDA-D-[c(RGDfK)]2, a SPECT Agent for Angiogenesis Imaging

J Kim[1]*, (1) Korea Research Institute of Standards and Science, Daejeon

Purpose: Tc-99m labeled IDA-D-[c(RGDfK)$_2$ (^{99m}Tc-RGD) is a recently developed radiotracer for gamma camera or single photon emission computed tomography (SPECT) imaging and promising agent for the visualization of angiogenesis. In this study, we investigated the internal radiation dosimetry of ^{99m}Tc-RGD in humans**. Methods:** Six normal controls (F:M=4:2; 68.3±3.2 years; 56.5±10.7 kg) were participated in this study. Simultaneous anterior and posterior scans of whole-body were performed using dual head gamma camera system. Before the emission scan, transmission scan was performed just before injection of ^{99m}Tc-RGD using Co-57 flood source. After an intravenous injection of 388.7±29.3 MBq of ^{99m}Tc-RGD, six serial emission scans were performed at 0, 1, 2, 4, 8 and 24 hours post-injection. The anterior and posterior images were geometrically averaged and attenuation correction was applied using transmission scan image. Regions of interest (ROIs) were drawn on liver, gallbladder, kidneys, urinary bladder, spleen, brain, and large intestine. Time activity curves were obtained from serial emission scan and ROIs. The number of disintegrations per unit activity administered (residence time) were calculated from the area under the curve of time activity curves and injected dose of each patient. Finally, the radiation dose for each organ and effective doses were obtained using OLINDA/EXM 1.1 software and residence time**. Results:** High radiation doses were reported on renal and biliary excretion tracks such as urinary bladder wall, upper large intestine, kidneys, liver and gallbladder wall and their doses were 19.15±6.84, 19.28±4.78, 15.67±0.90, 9.13±1.71 and 9.09±2.03 μGy/MBq, respectively. The effective dose and effective dose equivalent were 5.08±0.53 and 7.11±0.58 μSv/MBq, respectively**. Conclusion:** We evaluated the radiation dose of 99mTc-RGD, which has an acceptable effective radiation dose compare to the other Tc-99m labeled radio-tracers.

Therapy Electronic Campus Exhibit Hall
Out-of-field Dose, Risk Assessment and Shielding

TU-G-CAMPUS-T-01

Dose and Energy Spectra From Neutron Induced Radioactivity in Medical Linear Accelerators Following High Energy Total Body Irradiation

S Keehan[1]*, M Taylor[1], R Smith[2], L Dunn[3], T Kron[4], R Franich[1], (1) RMIT University, Melbourne, VIC, (2) William Buckland Radiotherapy Centre, Melbourne, VIC, (3) Australian Clinical Dosimetry Service, Yallambie, VIC, (4) Peter MacCallum Cancer Instit, Melbourne

Purpose: To assess the risk posed by neutron induced activation of components in medical linear accelerators (linacs) following the delivery of high monitor unit 18 MV photon beams such as used in TBI**. Methods:** Gamma spectroscopy was used to identify radioisotopes produced in components of a Varian 21EX and an Elekta Synergy following delivery of photon beams. Dose and risk estimates for TBI were assessed using dose deliveries from an actual patient treatment. A 1 litre spherical ion chamber (PTW, Germany) has been used to measure the dose at the beam exit window and at the total body irradiation (TBI) treatment couch following large and small field beams with long beam-on times. Measurements were also made outside of the closed jaws to quantify the benefit of the attenuation provided by the jaws**. Results:** The radioisotopes produced in the linac head have been identified as ^{187}W, ^{56}Mn, ^{24}Na and ^{28}Al, which have half-lives from between 2.3 min to 24 hours. The dose at the beam exit window following an 18 MV 2197 MU TBI beam delivery was 12.6 μSv in ten minutes. The dose rate at the TBI treatment couch 4.8 m away is a factor of ten lower. For a typical TBI delivered in six fractions each consisting of four beams and an annual patient load of 24, the annual dose estimate for a staff member at the treatment couch for ten minutes is 750 μSv. This can be further reduced by a factor of about twelve if the jaws are closed before entering the room, resulting in a dose estimate of 65 μSv**. Conclusion:** The dose resulting from the activation products for a representative TBI workload at our clinic of 24 patients per year is 750 μSv, which can be further reduced to 65 μSv by closing the jaws.

TU-G-CAMPUS-T-02

Risk Assessment of Scattered Neutrons for a Fetus From Proton Therapy of a Brain Tumor During Pregnancy

C Geng[1, 2*], M Moteabbed[1], X Xu[3], H Paganetti[1], (1) Massachusetts General Hospotal and Harvard Medical School, Boston, MA, (2) Nanjing University of Aeronautics and Astronautics, Nanjing, China, (3) Rensselaer Polytechnic Inst., Troy, NY

Purpose: To determine the scattered neutron dose and the resulting risk for a fetus from proton therapy for brain tumors during pregnancy**. Methods:** Using the Monte Carlo platform TOPAS, the ICRP reference parameters based anthropomorphic pregnancy phantoms for three stages (3-, 6-, 9-month) were applied to evaluate the scattered neutron dose and dose equivalent. To calculate the dose equivalent, organ specific linear energy transfer (LET) based quality factor was used. Treatment plans from both passive scattering (PS) and pencil beam scanning (PBS) methods were considered in this study. **Results:** For pencil beam scanning, the neutron dose equivalent in the soft tissue of the fetus increases from $1.53\text{x}10^{-3}$ to $2.84\text{x}10^{-3}$ mSv per treatment Gy with increasing stage of gestation. This is due to scattered neutrons from the patient as the main contaminant source in PBS and a decrease in distance between the soft tissue of the fetus and GTV with increasing stage of gestation. For passive scattering, neutron dose equivalent to the soft tissue of the fetus shows a decrease from 0.17 to 0.13 mSv per treatment Gy in different stages, while the dose to the brain shows little difference around 0.18 mSv per treatment Gy because scattered neutrons from the treatment head contribute predominantly in passive scattering**. Conclusion:** The results show that the neutron dose to the fetus assuming a prescribed dose of 52.2 Gy is negligible for PBS, and is comparable to the scattered dose (0-10 mSv) from a head and neck CT scan for PS. It can be concluded that the dose to fetus is far lower than the thresholds of malformation, SMR and lethal death. The excess relative risk of childhood cancer induction would be increased by 0.48 and 0.103 using the Oxford Survey of Childhood Cancers and Japanese atomic model, respectively.

Changran Geng is supported by the Chinese Scholarship Council (CSC) and the National Natural Science Foundation of China (Grant No. 11475087).

TU-G-CAMPUS-T-03

Commissioning of a Custom Fetal Lead Shield for Radiotherapy

A Owrangi*, D Roberts, E Covington, J Hayman, K Masi, C Lee, J Moran, J Prisciandaro, Univ Michigan Medical Center, Ann Arbor, MI

Purpose: To evaluate the peripheral dose (PD) to a fetus during radiation therapy of pregnant patients when using a newly designed fetal lead shield (FLS)**. Methods:** A custom FLS has been designed and fabricated for our department. The FLS (1.1 TVLs for 6 MV) is mounted on a mobile frame and can be adjusted vertically with a motor actuator. PD measurements were acquired for multiple simple square fields and for a variety of potential treatment sites a pregnant patient may be treated for including brain, head and neck (H&N) and thorax. For measurements of the brain, H&N, and thorax, an ionization chamber and OSLDs were positioned on average at a distance of 48, 29 and 26 cm, respectively, from the edge of treatment fields to mimic the approximate position of the fundus**. Results:** Based on our measurements, applying a 90° collimator rotation and using tertiary MLCs to define the field aperture in combination with jaws resulted in an average dose reduction of 60%. When using these planning strategies in combination with the FLS, on average, the PD was reduced by additional 25% for simple square fields and 20% for clinical plans. **Conclusion:** The custom FLS is a safe, effective, and relatively easy system to position. Commissioning measurements have demonstrated that the PD to the fetus can be significantly reduced when using the FLS. The comprehensive dataset obviates the need for individual patient pre-treatment dose measurements as long as the geometry falls within the commissioning limits.

TU-G-CAMPUS-T-04

An Evaluation of Out-Of-Field Doses for Electron Beams From Modern Varian and Elekta Linear Accelerators

C Cardenas*, P Nitsch, R Kudchadker, R Howell, S Kry, UT MD Anderson Cancer Center, Houston, TX

Purpose: Accurately determining out-of-field doses when using electron beam radiotherapy is of importance when treating pregnant patients or patients with implanted electronic devices. Scattered doses outside of the applicator field in electron beams have not been broadly investigated, especially since manufacturers have taken different approaches in applicator designs**. Methods:** In this study, doses outside of the applicator field were measured for electron beams produced by a 10x10 applicator on two Varian 21iXs operating at 6, 9, 12, 16, and 20 MeV, a Varian TrueBeam operating at 6, 9, 12, 16, and 20 MeV, and an Elekta Versa HD operating at 6, 9, 12 and 15 MeV. Peripheral dose profiles and percent depth doses were measured in a Wellhofer water phantom at 100 cm SSD with a Farmer ion chamber. Doses were compared to peripheral photon doses from AAPM's Task Group #36 report**. Results:** Doses were highest for the highest electron energies. Doses typically decreased with increasing distance from the field edge but showed substantial increases over some distance ranges. Substantial dose differences were observed between different accelerators; the Elekta accelerator had much higher doses than any Varian unit examined. Surprisingly, doses were often similar to, and could be much higher than, doses from photon therapy. Doses decreased sharply with depth before becoming nearly constant; the dose was found to decrease to a depth of approximately E(MeV)/4 in cm. **Conclusion:** The results of this study indicate that proper shielding may be very important when utilizing electron beams, particularly on a Versa HD, while treating pregnant patients or those with implanted electronic devices. Applying a water equivalent bolus of Emax(MeV)/4 thickness (cm) on the patient would reduce fetal dose drastically for all clinical energies and is a practical solution to manage the potentially high peripheral doses seen from modern electron beams.

Funding from NIH Grant number: #CA180803

TU-G-CAMPUS-T-05

Replacement Computational Phantoms to Estimate Dose in Out-Of-Field Organs and Tissues

K Gallagher[1, 2]*, J Tannous[3], R Nabha[3], J Feghali[3], Z Ayoub[3], W Jalbout[3], B Youssef[3], P Taddei[3, 4], (1) Oregon State University, Corvallis, Oregon, (2) Oregon Health and Science University, Portland, Oregon, (3) American University of Beirut Medical Center, Beirut, Lebanon, (4) The University of Texas MD Anderson Cancer Center, Houston, TX

Purpose: To estimate the absorbed dose in organs and tissues at risk for radiogenic cancer for children receiving photon radiotherapy for localized brain tumors (LBTs) by supplementing their missing body anatomies with those of replacement computational phantoms. Applied beyond the extent of the RT Images collected by computed tomography simulation, these phantoms included RT Image and RT Structure Set objects that encompassed sufficient extents and contours for dosimetric calculations**. Method:** Nine children, aged 2 to 14 years, who received three-dimensional conformal radiotherapy for low-grade LBTs, were randomly selected for this study under Institutional-Review-Board protocol. Because the extents of their RT Images were cranial only, they were matched for size and sex with patients from a previous study with larger extents and for whom contours of organs at risk for radiogenic cancer had already been delineated. Rigid fusion was performed between the patients' data and those of the replacement computational phantoms using commercial software. In-field dose was calculated with a clinically-commissioned treatment planning system, and out-of-field dose was estimated with an analytical model**. Results:** Averaged over all nine children and normalized for a therapeutic dose of 54 Gy prescribed to the PTV, where the PTV is the GTV, the highest mean organ doses were 3.27, 2.41, 1.07, 1.02, 0.24, and 0.24 Gy in the non-tumor remainder, red bone marrow, thyroid, skin, breasts, and lungs, respectively. The mean organ doses ranged by a factor of 3 between the smallest and largest children**. Conclusion:** For children receiving photon radiotherapy for LBTs, we found their doses in organs at risk for second cancer to be non-negligible, especially in the non-tumor remainder, red bone marrow, thyroid, skin, breasts, and lungs. This study demonstrated the feasibility for patient dosimetry studies to augment missing patient anatomy by applying size- and sex-matched replacement computational phantoms with pre-contoured organs.

Funding is in part by the Fogarty International Center award K01TW008409, and the Portland Chapter of the Achievement Rewards for College Scientists. The content is solely the responsibility of the authors, and does not necessarily represent the official views of the sponsors. The authors declare no conflict of interest.

Joint Imaging – Therapy Exhibit Hall
Electronic Campus
The Dynamic Patient

TU-G-CAMPUS-J-01

Inference of Prostate PTV Margins in VMAT Delivery From Intra-Fraction Prostate Motion During SBRT Delivery

K Thind[1]*, R Wong[2], D Wong[3], C Gerdes[4], T Chow[5], (1) Juravinski Cancer Centre, Hamilton, Ontario, (2) Juravinski Cancer Centre, Hamilton, Ontario, (3) McMaster University, Hamilton, Ontario, (4) Juravinski Cancer Centre, Hamilton, Ontario, (5) Juravinski Cancer Centre, Hamilton, Ontario

Purpose: To retrospectively quantify the intra-fraction prostate motion during stereotactic body radiation therapy (SBRT) treatment using CyberKnife's target tracking system, which may provide insight into expansion margins from GTV to PTV used in gantry-based treatments. CyberKnife is equipped with an active tracking system (InTempo) that tracks the four fiducials placed in the prostate gland. The system acquires intra-fraction orthogonal kV images at 45° and 315° in a sequential fashion. **Methods:** A total of 38 patients treated with SBRT using CyberKnife between 2011 and 2013 were studied. Dose-regime was 36.25 Gy in 5 fractions (7.25 Gy/fraction, twice per week) as per RTOG 0938 guidelines. The CyberKnife image tracking logs for all SBRT treatments using InTempo were examined. A total of 13663 images were examined for the superior/inferior (SI), anterior/posterior (AP) and left/right (LR) translation as well as roll, pitch and yaw rotations for the target position relative to the last known model position. **Results:** The mean ± 2 SD of intra-fraction motion was contained within 3 mm for SI and LR and 4.5 mm for AP directions at 5 minutes into the treatment delivery. It was contained within 4 mm for SI and LR and 5 mm for AP at 10 minutes. At 15 minutes into delivery, all translations were contained within 5 mm. The mean ± 2 SD of prostate roll, pitch and yaw increased with time but were contained within 5 degree at 5, 10 and 15 minutes into treatment. Additionally, target translations and rotations were within ± 1 mm and ± 1 degree for 90% and 78% of the time. **Conclusion:** The organ motion component of PTV margin for 10 minute VMAT delivery is contained within 4 mm in SI and LR direction and within 5 mm in the AP direction.

TU-G-CAMPUS-J-02

Mooney-Rivlin Biomechanical Modeling of Lung with Inhomogeneous Material Property

J Nasehi Tehrani[1]*, X Guo[2], J Wang[1], (1) UT Southwestern Medical Center, Dallas, TX, (2) University of Texas, Richardson, TX

Purpose: The Mooney-Rivlin material with hyperelastic strain energy has been proposed for realistic biomechanical modeling of lung. In this study, the lung is modeled as an inhomogeneous Mooney-Rivlin material with the incompressibility factors being optimized to improve the tumor center of mass (TCM) motion simulation accuracy during respiration. **Method:** ITK-SNAP was used to segment lungs of eight lung cancer patients from the 4D-CT images and tetrahedral volume meshes of the lungs in phase 50% were created by using adaptive mesh generation toolkit. The interphase deformation vector fields (DVFs) are calculated by demons deformable registration algorithm and the barycentric coordinate system of tetrahedral elements is obtained from the resulted DVFs. Mooney-Rivlin hyperelastic material is used to model the lung volume. Each element is considered unique where the incompressibility factor (k-factor) for each element is assumed to be proportional to the magnitude of normalized DVF. The incompressibility factor for each element was optimized by minimizing the tumor center of mass motion simulation error. **Results:** If lung is considered as a homogenous material in Mooney-Rivlin modeling, the average TCM motion simulation error is 2.26 mm. By considering inhomogeneous properties of lung in the proposed strategy, the average TCM motion simulation error is reduced to 2.04 mm. **Conclusions:** We proposed a method for assigning the inhomogeneous biomechanical material in the Mooney-Rivlin model of lung based on the lung regional deformation vector fields. Inhomogeneous material property of lung improves the simulation accuracy.

TU-G-CAMPUS-J-03

Prediction of Respiratory Motion Using State Space Models

J Kotoku[1]*, S Kumagai[1], A Haga[2], S Nakabayashi[1], N Arai[3], T Kobayashi[6], (1) Teikyo University, Tokyo, JP, (2) (2) University of Tokyo Hospital, Tokyo, JP, (3) Teikyo University Hospital, Tokyo, JP

Purpose: The purpose of this study is to predict respiratory motion for a few seconds ahead by use of dynamic linear models. The models describe trends and periodic components of time series of respiratory curves obtained on patient's body**. Methods:** To measure spatial coordinates of multiple points on patient's body during respiratory motion, we used a consumer depth camera (Microsoft Kinect) and obtained depth data via triangulation from infrared random dots patterns.To describe a dynamics of respiratory motion, we selected a symplectic form of a harmonic oscillator. As a filter, we selected a particle filter. Particle filter is a technique for implementing a recursive Bayesian filter by Monte Carlo simulations. The key idea is to represent the required posterior density function by a set of random samples and to compute estimates based on these samples. **Results:** Filtered values were calculated as a mean of a filtered distribution. The prediction values were well correlated with the values to be observed.To validate accuracy of our model, predicted depth values were compared with measured ones. The accuracy of our model was roughly 20 % for 4 seconds ahead in average, while the measurement depth accuracy is within 1 mm**. Conclusion:** Time-series modeling using Bayesian inference technique is useful for prediction of respiratory motion.Although prediction accuracy became worse along with the length of forecasting time, we can conclude this method is a promising tool for prediction of patient's motion.

This work was partly supported by the JSPS Core-to-Core Program (No. 23003).

TU-G-CAMPUS-J-04

Setup Uncertainties in the Mediastinum Area for IMRT Treatment of Lymphoma Patients

M Aristophanous*, L Court, UT MD Anderson Cancer Center, Houston, TX

Purpose: Despite daily image guidance setup uncertainties can be high when treating large areas of the body. The aim of this study was to measure local uncertainties inside the PTV for patients receiving IMRT to the mediastinum region**. Methods:** Eleven lymphoma patients that received radiotherapy (breath-hold) to the mediastinum were included in this study. The treated region could range all the way from the neck to the diaphragm. Each patient had a CT scan with a CT-on-rails system prior to every treatment. The entire PTV region was matched to the planning CT using automatic rigid registration. The PTV was then split into 5 regions: neck, supraclavicular, superior mediastinum, upper heart, lower heart. Additional auto-registrations for each of the 5 local PTV regions were performed. The residual local setup errors were calculated as the difference between the final global PTV position and the individual final local PTV positions for the AP, SI and RL directions. For each patient 4 CT scans were analyzed (1 per week of treatment)**. Results:** The residual mean group error (M) and standard deviation of the inter-patient (or systematic) error (Σ) were lowest in the RL direction of the superior mediastinum (0.0mm and 0.5mm) and highest in the RL direction of the lower heart (3.5mm and 2.9mm). The standard deviation of the inter-fraction (or random) error (σ) was lowest in the RL direction of the superior mediastinum (0.5mm) and highest in the SI direction of the lower heart (3.9mm) The directionality of local uncertainties is important; a superior residual error in the lower heart for example keeps it in the global PTV**. Conclusion:** There is a complex relationship between breath-holding and positioning uncertainties that needs further investigation. Residual setup uncertainties can be significant even under daily CT image guidance when treating large regions of the body.

TU-G-CAMPUS-J-05

Fast Volumetric MRI On An MRI-Linac Enables On-Line QA On Dose Deposition in the Patient

S Crijns[1]*, M Glitzner[1], B Denis de Senneville[1, 2], C Kontaxis[1], M Maenhout[1], G Bol[1], J Lagendijk[1], B Raaymakers[1], (1) University Medical Center Utrecht, Utrecht, The Netherlands, (2) Mathematical Institute of Bordeaux, University of Bordeaux, Talence Cedex, France

Purpose: The introduction of the MRI-linac in radiotherapy brings MRI-guided treatment with daily plan adaptions within reach. This paradigm demands on-line QA. With its ability to perform continuous volumetric imaging in an outstanding soft-tissue contrast, the MRI-linac promises to elucidate the dose deposition process during a treatment session. Here we study for a prostate case how dynamic MRI combined with linac machine parameters and a fast dose-engine can be used for on-line dose accumulation**. Methods:** Prostate imaging was performed in healthy volunteer on a 1.5T MR-scanner (Philips, Best, NL) according to a clinical MR-sim protocol, followed by 10min of dynamic imaging (FLASH, 4s/volume, FOV 40x40x12cm³, voxels 3x3x3mm³, TR/TE/α=3.5ms/1.7ms/5°). An experienced radiation oncologist made delineations, considering the prostate CTV. Planning was performed on a two-compartment pseudoCT (air/water density) according to clinical constraints (77Gy in PTV) using a Monte-Carlo (MC) based TPS that accounts for magnetic fields. Delivery of one fraction (2.2Gy) was simulated on an emulator for the Axesse linac (Elekta, Stockholm, SE). Machine parameters (MLC settings, gantry angle, dose rate, etc.) were recorded at 25Hz. These were re-grouped per dynamic volume and fed into the MC-engine to calculate a dose delivered for each of the dynamics. Deformations derived from non-rigid registration of each dynamic against the first allowed dose accumulation on a common reference grid**. Results:** The DVH parameters on the PTV compared to the optimized plan showed little changes. Local deformations however resulted in local deviations, primarily around the air/rectum interface. This clearly indicates the potential of intra-fraction adaptations based on the accumulated dose. Application in each fraction helps to track the influence of plan adaptations to the eventual dose distribution. Calculation times were about twice the delivery time. **Conclusion:** The current **Result** paves the way to perform on-line treatment delivery QA on the MRI-linac in the near future.

Imaging Electronic Campus Exhibit Hall

MDCT, CBCT

TU-G-CAMPUS-I-01

Statistical Iterative Reconstruction for Perfusion CT with a Prior-Image Induced Hybrid Nonlocal Means Regularization

B Li[1, 2]*, Q Lyu[1, 2], J Ma[2], J Wang[1], (1) UT Southwestern Medical Center, Dallas, TX, (2) Southern Medical University, Guangzhou, China

Purpose: In CT perfusion imaging, an initial phase CT acquired with a high-dose protocol can be used to improve the image quality of later phase CT acquired with a low-dose protocol. For dynamic regions, signals in the later low-dose CT may not be completely recovered if the initial CT heavily regularizes the iterative reconstruction process. To overcome the limitation of the conventional prior image induced penalty, we propose a hybrid nonlocal means (NLM) regularization for iterative reconstruction of perfusion CT**. Methods:** The hybrid penalty is constructed by combining the NLM of initial high-dose CT in the stationary region and later low-dose CT in the dynamic region. The stationary and dynamic regions are determined by the similarity between the initial high-dose scan and later low-dose scan, where the similarity is defined as Gaussian distance between patch-window of the same pixel of the two scans. The similarity measure is then used to weight the influence of the initial high-dose CT. For regions with high similarity (e.g., stationary region), initial high-dose CT will play a dominant role in regularizing the solution. For regions with low similarity (e.g., dynamic region), the regularization will rely on low-dose scan itself. This new hybrid NLM (hNLM) penalty is then incorporated into the penalized weighted least-squares (PWLS) for perfusion CT reconstruction. Digital and anthropomorphic phantom studies were performed to evaluate the PWLS-hNLM algorithm**. Results:** Both phantom studies show that the PWLS-hNLM algorithm is superior to the conventional penalty term without considering the signal changes within dynamic region. In the dynamic region, the reconstruction error measured by root mean square error is reduced by 50% in PWLS-hNLM reconstructed image**. Conclusion:** The PWLS-hNLM algorithm can effectively use initial high-dose CT to reconstruct low-dose perfusion CT in the stationary region while avoiding its influence in the dynamic region.

TU-G-CAMPUS-I-02

Contrast Enhanced Cone Beam CT Imaging with Dual-Gantry Image Acquisition and Constrained Iterative Reconstruction- a Simulation Study for Liver Imaging Application

Y Zhong*, S Gupta, C Lai, T Wang, C Shaw, UT MD Anderson Cancer Center, Houston, TX

Purpose: Contrast time-density curves may help differentiate malignant tumors from normal tissues or benign tumors. Repetitive scans using conventional CT or cone beam CT techniques, which **Result** in unacceptably high dose, may not achieve the desired temporal resolution. In this study we describe and demonstrate a 4D imaging technique for imaging and quantifying contrast flows requiring only one or two 360° scans**. Methods:** A dual-gantry system is used to simultaneously acquire two projection images at orthogonal orientations. Following the scan, each or both of the two 360° projection sets are used to reconstruct an average contrast enhanced image set which is then segmented to form a 3D contrast map. Alternatively, a pre-injection scan may be made and used to reconstruct a pre-injection image set which is subtracted from the post-injection image set to form the 3D contrast map. Each of the two 360° projection sets is divided into 12 subsets, thus creating 12 pairs of 30° limited angle projection sets, each corresponding to a time spanning over 1/12 of the scanning time. Each pair of the projection sets are reconstructed as a time specific 3D image set with the maximum likelihood estimation iterative algorithm using the contrast map as the constraint. As a demonstration, a 4D abdominal phantom was constructed from clinical CT images with blood flow through the normal tissue and a tumor modeled and imaging process simulated. **Results:** We have successfully generated a 4D image phantom, and calculated the projection images. The time density curves derived from the reconstructed image set matched well with the flow model used to generate the phantom**. Conclusion:** Dual-gantry image acquisition and constrained iterative reconstruction algorithm may help to obtain time-density curves of contrast agents in blood flows, which may help differentiate malignant tumors from normal tissues or benign tumors.

TU-G-CAMPUS-I-03

Enhancement of 4D CBCT Image Quality Using An Adaptive Prior Image Constrained Compressed Sensing

H Lee[1]*, J Yoon[1], E Lee[1], S Cho[1], K Park[1], W Choi[1], K Keum[1], (1) Department of Radiation Oncology, Yonsei University College of Medicine, Seoul, Korea

Purpose: To develop an iterative reconstruction algorithm using a compressed sensing with adaptive prior image constraints to solve 4D CBCT reconstruction problem**. Methods:** The images reconstructed by the FDK algorithm with a full set of unsorted projections are served as prior images for partial projections in each phase group and are utilized as an initial guess. Additionally, the prior images are clustered into several regions by applying intensity-based thresholding, which is referred to as the segmented prior images. The segmented prior images are employed to detect any possible mismatched areas compared with the target images generated by partial projection data. With these two prior images, our algorithm alternately performs the simultaneous algebraic reconstruction technique and anisotropic total variation regularization while adjusting a weighted relaxation map during the iterative reconstruction process. The weighted relaxation map depends on binary images created by the voxel-dependent comparison between the segmented prior and segmented target images. For the segmented target images, the k-means clustering with a geometric weighting is applied on the reconstruction images generated in each iteration step. The inverse values of the distance map converted from binary images are assigned to be the values of the relaxation map. Evaluations using Catphan504 phantom with a motion platform were carried out**. Results:** Qualitative and quantitative analyses showed that the method provides high-quality CBCT reconstruction images when compared with those generated by the FDK, CS, and PICCS algorithms, with higher contrast-to-noise ratio and faster convergence caused by minimizing data fidelity. Especially, the proposed method was superior to PICCS in the aspect of updating locally-mismatched region. **Conclusion:** The proposed method not only improves the image quality of 4D CBCT by adaptive updates during the reconstruction process, but also leads to a lower imaging dose and faster acquisition time by using a regular 3D CBCT scan.

TU-G-CAMPUS-I-04

Fully Automated Evaluation of CT AEC Performance Using a Novel Automated Noise Level Measurement Technique

M Chun*, J Kim, Seoul National University, Seoul, Seoul

Purpose: To assess the performance of CT automatic exposure control (AEC) system by using a newly developed automated noise level measurement technique**. Methods:** Twenty pediatric patients' CT image data of chest routine protocol taken with AEC (CARE Dose4D, Siemens Healthcare) were collected. A newly developed automated noise level measurement technique was applied to assess the noise level consistency across the varying body size. Subcutaneous fat region was segmented by applying thresholding of predefined intensity range followed by morphology operation on noise filtered image. A novel structure feature was calculated by combining sum of gradient and directional entropy of gradient at each pixel within the segmented subcutaneous fat. Five ROIs were randomly selected which have feature values less than 10 percentiles. The representative noise level was determined as an average of the HU standard deviations on 5 ROIs. Variation of noise levels were evaluated for the 20 CT data with the above noise measurements. In addition, 3 body factors such as water-equivalent body diameter (WBD), AP, and LAT diameter were extracted on each slice, and Pearson correlation coefficients between the noise measurements and body factors were compared**. Results:** Most of the ROI placement (98%) by automated technique were accepted by an expert observer. Variation of noise standard deviation per patient ranged from 0.83 to 2.17 HU, whereas the mean noise ranged from 5.80 to 12.38 HU. Pearson correlation coefficient was highest between WBD and noise level by showing 0.76±0.06**. Conclusion:** Performance of CT AEC system could be assessed with a fully automated technique. Our proposed technique is a potentially useful tool for investigating various characteristics and optimal use of AEC system in clinical setting.

TU-G-CAMPUS-I-05

Investigation of An EMCCD Detector with Variable Gain in a Micro-CT System

S Bysani Krishnakumar[1, 2]*, C Ionita[1, 2], S Setlur Nagesh[2], S Rudin[1, 2], D Bednarek[2], (1) Department of Biomedical Engineering, SUNY Buffalo, Buffalo, NY, (2) Toshiba Stroke and Vascular Research Center at SUNY Buffalo, Buffalo, NY

Purpose: To investigate the performance of a newly built Electron Multiplying Charged Coupled Device (EMCCD) based Micro-CT system, with variable detector gain, using a phantom containing contrast agent of different concentrations**. Methods:** We built a micro-CT system with an EMCCD having 8 microns pixels and on-chip variable gain. We tested the system using a phantom containing five tubes filled with different iodine contrast solutions (30% to 70%). First, we scanned the phantom using various x-ray exposures values at 40 kVp and constant detector gain. Next, for the same tube currents, the detector gain was increased to maintain the air value of the projection image constant. A standard FDK algorithm was used to reconstruct the data. Performance was analyzed by comparing the signal-to-noise ratio (SNR) measurements for increased gain with those for the low constant gain at each exposure**. Results:** The high detector gain reconstructed data SNR was always greater than the low gain data SNR for all x-ray settings and for all iodine features. The largest increases were observed for low contrast features, 30% iodine concentration, where the SNR improvement approached 2**. Conclusion:** One of the first implementations of an EMCCD based micro-CT system was presented and used to image a phantom with various iodine solution concentrations. The analysis of the reconstructed volumes showed a significant improvement of the SNR especially for low contrast features. The unique on-chip gain feature is a substantial benefit allowing the use of the system at very low x-ray exposures per frame.Partial support: NIH grant R01EB002873 and Toshiba Medical Systems Corp.

Partial support: NIH grant R01EB002873 and Toshiba Medical Systems Corp.

Therapy Electronic Campus — Exhibit Hall

QA Methods and Devices

TU-G-CAMPUS-T-06

Calculation of KQ for a Variety of Commercially Available Ionization Chambers in the Presence of An External Magnetic Field for MR-Linac Dosimetry

D J O'Brien[1]*, M V P Mathis[1], D A Roberts[2], G Ibbott[1], G O Sawakuchi[1], (1) UT MD Anderson Cancer Center, Houston, TX, (2) Elekta Limited, Crawley, West Sussex

Purpose: The strong magnetic fields associated with MRI have a significant impact on the dosimetry of radiotherapy beams as well as on the response of the detectors used to measure it. In order to calibrate the dose delivered by these beams, it is necessary to correct for these effects when performing measurements with ionization chambers. **Methods:** Detailed models of 16 commercially-available ionization chambers were implemented in Geant4. To validate these models, calculations of the beam quality correction factor kQ (defined by TG-51) were performed using the spectrum from a 6 MV Elekta SL25. kQ values were then recalculated for each detector with a 1.5 T external magnetic field applied uniformly across the geometry. Chamber, beam and B-field were all orthogonal**. Results:** The comparison between the kQ calculations and TG-51 showed agreement within 1.4%. The B-field calculations indicate that the change in kQ values due to the B-field is strongly affected by the volume and material of the ionization chamber. All large volume (>0.5 cm^3) ionization chambers had lower kQ values when used in a B-field. The kQ values for small volume chambers were very sensitive to the chambers' collecting volume and could be higher or lower when used in a B-field**. Conclusions:** Of the chambers tested, the PTW 30011 demonstrated the smallest correction of just 1.2%. The next step is to calculate kQ using the energy spectrum from an actual MR-linac. Further validation of these results against measurements will be paramount before they can be used.

Funding provided by Elekta Limited. The MR-linac spectrum will be provided by Elekta Limited based on a machine they have designed.

TU-G-CAMPUS-T-07

Vernier Picket Fence Test: A Non-Imaging Method to Localize the Radiation Isocenter with Submillimeter Accuracy

J Wong*[1, 2], K Gallagher[1, 2], J Zhang[1], (1) Oregon Health & Science University, Portland, OR, (2) Oregon State University, Corvallis, OR

Purpose: The purpose of this study is to propose a new non-imaging method to localize the radiation isocenter with submillimeter accuracy. **Methods:** The Vernier picket fence (VPF) is a multileaf collimator (MLC) picket fence sequence in which the fence spacing is 1/N smaller than the detector spacing of the QA phantom, where N is the magnification factor, typically set to 10 or 20. Similar to reading a Vernier caliper, the user can easily achieve the resolution of 1/N of the detector spacing by visually inspecting the maximum signal. To achieve higher accuracy, a Gaussian model was used to interpolate the peak position, which can fall between adjacent detectors. In two separate tests, precise MLC offsets and imprecise couch offsets were applied to a 2D detector array (MapCheck, Sun Nuclear Corp., Melbourne, Florida) to introduce setup errors. Two vertical VPF fields were delivered with collimator angles at 0° and 90° to detect the lateral and longitudinal setup errors, respectively. For a rotational QA phantom, an additional lateral VPF field is needed to detect the vertical setup error for three-dimensional capabilities**. Results:** With N set to 20 and a detector spacing of 5 mm for MapCheck, the resolution of the VPF's visual analysis is 0.25 mm. With the Gaussian interpretation, the VPF can achieve an accuracy of 0.02 mm, as shown by the MLC offset test. The couch offset test measured the couch hysteresis and demonstrated that the setup error detected by the VPF differed from the ExacTrac™ (Brainlab AG, Feldkirchen, Germany) optical tracking by 0.055 mm in the lateral direction and 0.041 mm in the longitudinal direction on average. The VPF was also shown to be feasible in the vertical direction as well**. Conclusion:** This study verified the VPF as a non-imaging method to localize the radiation isocenter with submillimeter accuracy.

Funding is in part by the Portland Chapter of the Achievement Rewards for College Scientists. The content is solely the responsibility of the authors, and does not necessarily represent the official views of the sponsors. The authors declare no conflict of interest.

TU-G-CAMPUS-T-08

A Novel Iris Quality Assurance Phantom for the CyberKnife Radiosurgery System

M Descovich[1]*, D Pinnaduwage[1], A Sudhyadhom[1], B Nelson[2], (1) University of California San Francisco, San Francisco, CA, (2) Logos Systems Int'l, Scotts Valley, CA

Purpose: A novel CCD camera and conical scintillator based phantom that is capable of measuring the targeting and field size accuracy of a robotic radiosurgery system has been developed. This work investigates its application in measuring the field sizes and beam divergence of the CyberKnife variable aperture collimator (Iris). **Methods:** The phantom was placed on the treatment couch and the robot position was adjusted to obtain an anterior-posterior beam perpendicular to the cone's central axis. The FWHM of the 12 Iris apertures (5, 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 50, and 60 mm) were measured from the beam flux map on the conical scintillator surface as seen by the CCD camera. For each measurement 30 MU were delivered to the phantom at a dose rate of 1000 MU/min. The measurements were repeated at 4 SAD distances between 75 and 85 cm. These readings were used to project the aperture size as if the flux map on the scintillator were located 80 cm from the source (SSD). These projected FWHM beam diameters were then compared to the commissioning data**. Results:** A series of 12 beam divergence equations were obtained from the 4 sets of data using linear trend lines on Excel scatter plots. These equations were then used to project the FWHM measurements at 80 cm SSD. The average aperture accuracy for beams from 5 through 40 mm was 0.08 mm. The accuracy for the 50 and 60 mm beams were 0.33 and 0.58 mm when compared to film commissioning data. **Conclusion:** The experimental results for 10 apertures agree with the stated Iris accuracy of ±0.2 mm at 80 cm SAD. The results for the 50 and 60 mm aperture were repeatable and can serve as a reliable trend indicator of any deviations away from the commissioning values.

Brett Nelson is President/CTO of Logos Systems

TU-G-CAMPUS-T-09

Variations in Nominally Identical Small Fields From Photon Jaw Reproducibility and Associated Effects On Small Field Dosimetric Parameters

B R Muir, M R McEwen, Measurement Science and Standards, National Research Council, Ottawa, ON, CA

Purpose: To investigate uncertainties in small field output factors and detector specific correction factors from variations in field size for nominally identical fields using measurements and Monte Carlo simulations**. Methods:** Repeated measurements of small field output factors are made with the Exradin W1 (plastic scintillation detector) and the PTW microDiamond (synthetic diamond detector) in beams from the Elekta Precise linear accelerator. We investigate corrections for a 0.6x0.6 cm² nominal field size shaped with secondary photon jaws at 100 cm source to surface distance (SSD). Measurements of small field profiles are made in a water phantom at 10 cm depth using both detectors and are subsequently used for accurate detector positioning. Supplementary Monte Carlo simulations with EGSnrc are used to calculate the absorbed dose to the detector and absorbed dose to water under the same conditions when varying field size. The jaws in the BEAMnrc model of the accelerator are varied by a reasonable amount to investigate the same situation without the influence of measurements uncertainties (such as detector positioning or variation in beam output)**. Results:** For both detectors, small field output factor measurements differ by up to 11 % when repeated measurements are made in nominally identical 0.6x0.6 cm² fields. Variations in the FWHM of measured profiles are consistent with field size variations reported by the accelerator. Monte Carlo simulations of the dose to detector vary by up to 16 % under worst case variations in field size. These variations are also present in calculations of absorbed dose to water. However, calculated detector specific correction factors are within 1 % when varying field size because of cancellation of effects**. Conclusion:** Clinical physicists should be aware of potentially significant uncertainties in measured output factors required for dosimetry of small fields due to field size variations for nominally identical fields.

TU-G-CAMPUS-T-10

A Cloud-Based Monte Carlo Dose Calculation for Electron Cutout Factors

T Mitchell*, K Bush, Stanford School of Medicine, Stanford, CA

Purpose: For electron cutouts of smaller sizes, it is necessary to verify electron cutout factors due to perturbations in electron scattering. Often, this requires a physical measurement using a small ion chamber, diode, or film. The purpose of this study is to develop a fast Monte Carlo based dose calculation framework that requires only a smart phone photograph of the cutout and specification of the SSD and energy to determine the electron cutout factor, with the ultimate goal of making this cloud-based calculation widely available to the medical physics community**. Methods:** The algorithm uses a pattern recognition technique to identify the corners of the cutout in the photograph as shown in Figure 1. It then corrects for variations in perspective, scaling, and translation of the photograph introduced by the user's positioning of the camera. Blob detection is used to identify the portions of the cutout which comprise the aperture and the portions which are cutout material. This information is then used define physical densities of the voxels used in the Monte Carlo dose calculation algorithm as shown in Figure 2, and select a particle source from a pre-computed library of phase-spaces scored above the cutout. The electron cutout factor is obtained by taking a ratio of the maximum dose delivered with the cutout in place to the dose delivered under calibration/reference conditions**. Results:** The algorithm has been shown to successfully identify all necessary features of the electron cutout to perform the calculation. Subsequent testing will be performed to compare the Monte Carlo results with a physical measurement**. Conclusion:** A simple, cloud-based method of calculating electron cutout factors could eliminate the need for physical measurements and substantially reduce the time required to properly assure accurate dose delivery.

Joint Imaging – Therapy Exhibit Hall
Electronic Campus
Image Features for Therapy Applications

TU-G-CAMPUS-J-06

Dosimetric Effects of HU Changes During the Course of Proton Therapy for Lung Cancer

C Teng*, L Yin, C Ainsley, C Simone, B Teo, A Kassaee, University of Pennsylvania, Philadelphia, PA

Purpose: To characterize the changes in Hounsfield unit (HU) in lung radiotherapy with proton beams during the course of treatment and to study the effect on the proton plan dose distribution. **Methods:** Twenty consecutive patients with non-small cell lung cancer treated with proton radiotherapy who underwent multiple CT scans including the planning CT and weekly verification CTs were studied. HU histograms were computed for irradiated lung volumes in beam paths for all scans using the same treatment plan. Histograms for un-irradiated lung volume were used as control to characterize inter-scan variations. HU statistics were calculated for both irradiated and un-irradiated lung volumes for each patient scan. Further, multiple CT scans based on the same planning CT were generated by replacing the HU of the lung based on the verification CT scans HU values. Using the same beam arrangement, we created plans for each of the altered CT scans to study the dosimetric effect using the dose volume histogram. **Results:** Lung HU decreased for irradiated lung volume during the course of radiotherapy. The magnitude of this change increased with total irradiation dose. On average, HU changed by -53.8 in the irradiated volume. This change resulted in less than 0.5mm of beam overshoot in tissue for every 1cm beam traversed in the irradiated lung. The dose modification is about +3% for the lung, and less than +1% for the primary tumor**. Conclusion:** HU of the lung decrease throughout the course of radiation therapy. This change results in a beam overshoot (e.g. 3mm for 6cm of lung traversed) and causes a small dose modification in the overall plan. However, this overshoot does not affect the quality of plans since the margins used in planning, based on proton range uncertainty, are greater. HU needs to change by 150 units before re-planning is warranted.

TU-G-CAMPUS-J-07

Evaluation of Textural Feature Extraction for Radiotherapy Response Assessment of Early Stage Breast Cancer Patients Using Diffusion Weighted MRI and Dynamic Contrast Enhanced MRI

Y Xie*, C Wang, J Horton, Z Chang, Duke University Medical Center, Durham, NC

Purpose: To investigate the feasibility of using classic textural feature extraction in radiotherapy response assessment, we studied a unique cohort of early stage breast cancer patients with paired pre- and post-radiation Diffusion Weighted MRI (DWI-MRI) and Dynamic Contrast Enhanced MRI (DCE-MRI). **Methods:** 15 female patients from our prospective phase I trial evaluating preoperative radiotherapy were included in this retrospective study. Each patient received a single-fraction radiation treatment, and DWI and DCE scans were conducted before and after the radiotherapy. DWI scans were acquired using a spin-echo EPI sequence with diffusion weighting factors of b = 0 and b = 500 mm^2/s, and the apparent diffusion coefficient (ADC) maps were calculated. DCE-MRI scans were acquired using a T_1-weighted 3D SPGR sequence with a temporal resolution of about 1 minute. The contrast agent (CA) was intravenously injected with a 0.1 mmol/kg bodyweight dose at 2 ml/s. Two parameters, volume transfer constant (K^{trans}) and k_{ep} were analyzed using the two-compartment Tofts kinetic model. For DCE parametric maps and ADC maps, 33 textural features were generated from the clinical target volume (CTV) in a 3D fashion using the classic gray level co-occurrence matrix (GLCOM) and gray level run length matrix (GLRLM). Wilcoxon signed-rank test was used to determine the significance of each texture feature's change after the radiotherapy. The significance was set to 0.05 with Bonferroni correction**. Results:** For ADC maps calculated from DWI-MRI, 24 out of 33 CTV features changed significantly after the radiotherapy. For DCE-MRI pharmacokinetic parameters, all 33 CTV features of K^{trans} and 33 features of k_{ep} changed significantly**. Conclusion:** Initial results indicate that those significantly changed classic texture features are sensitive to radiation-induced changes and can be used for assessment of radiotherapy response in breast cancer.

TU-G-CAMPUS-J-08

Elasticity Functions Based On 4DCT Images to Predict Tumor and Normal Tissue Response to Radiation for Patients with Lung Cancers

H Zhong*, H Li, J Gordon, I Chetty, Henry Ford Health System, Detroit, MI

Purpose: To investigate radiotherapy outcomes by incorporating 4DCT-based physiological and tumor elasticity functions for lung cancer patients. **Methods:** 4DCT images were acquired from 28 lung SBRT patients before radiation treatment. Deformable image registration (DIR) was performed from the end-inhale to the end-exhale using a B-Spline-based algorithm (Elastix, an open source software package). The resultant displacement vector fields (DVFs) were used to calculate a relative Jacobian function (RV) for each patient. The computed functions in the lung and tumor regions represent lung ventilation and tumor elasticity properties, respectively. The 28 patients were divided into two groups: 16 with two-year tumor local control (LC) and 12 with local failure (LF). The ventilation and elasticity related RV functions were calculated for each of these patients**. Results:** The LF patients have larger RV values than the LC patients. The mean RV value in the lung region was 1.15 (±0.67) for the LF patients, higher than 1.06 (±0.59) for the LC patients. In the tumor region, the elasticity-related RV values are 1.2 (±0.97) and 0.86 (±0.64) for the LF and LC patients, respectively. Among the 16 LC patients, 3 have the mean RV values greater than 1.0 in the tumors. These tumors were located near the diaphragm, where the displacements are relatively large.. RV functions calculated in the tumor were better correlated with treatment outcomes than those calculated in the lung. **Conclusion:** The ventilation and elasticity-related RV functions in the lung and tumor regions were calculated from 4DCT image and the resultant values showed differences between the LC and LF patients. Further investigation of the impact of the displacements on the computed RV is warranted**. Result**s suggest that the RV images might be useful for evaluation of treatment outcome for lung cancer patients.

TU-G-CAMPUS-J-09

Impact of Voxel Anisotropy On Statistic Texture Features of Oncologic PET: A Simulation Study

F Yang*, D Byrd, S Bowen, P Kinahan, G Sandison, University of Washington, Seattle, WA

Purpose: Texture metrics extracted from oncologic PET have been investigated with respect to their usefulness as definitive indicants for prognosis in a variety of cancer. Metric calculation is often based on cubic voxels. Most commonly used PET scanners, however, produce rectangular voxels, which may change texture metrics. The objective of this study was to examine the variability of PET texture feature metrics resulting from voxel anisotropy**. Methods:** Sinograms of NEMA NU-2 phantom for 18F-FDG were simulated using the ASIM simulation tool. The obtained projection data was reconstructed (3D-OSEM) on grids of cubic and rectangular voxels, producing PET images of resolution of 2.73x2.73x3.27mm3 and 3.27x3.27x3.27mm3, respectively. An interpolated dataset obtained from resampling the rectangular voxel data for isotropic voxel dimension (3.27mm) was also considered. For each image dataset, 28 texture parameters based on grey-level co-occurrence matrices (GLCOM), intensity histograms (GLIH), neighborhood difference matrices (GLNDM), and zone size matrices (GLZSM) were evaluated within lesions of diameter of 33, 28, 22, and 17mm**. Results:** In reference to the isotopic image data, texture features appearing on the rectangular voxel data varied with a range of -34-10% for GLCOM based, -31-39% for GLIH based, -80-161% for GLNDM based, and -6-45% for GLZSM based while varied with a range of -35-23% for GLCOM based, -27-35% for GLIH based, -65-86% for GLNDM based, and -22-18% for GLZSM based for the interpolated image data. For the anisotropic data, GLNDM_cplx exhibited the largest extent of variation (161%) while GLZSM_zp showed the least (<1%). As to the interpolated data, GLNDM_busy varied the most (86%) while GLIH_engy varied the least (<1%)**. Conclusion:** Variability of texture appearance on oncologic PET with respect to voxel representation is substantial and feature-dependent. It necessitates consideration of standardized voxel representation for inter-institution studies attempting to validate prognostic values of PET texture features in cancer treatment.

TU-G-CAMPUS-J-10

Effect of Uncorrelated Noise Texture On Computed Tomography Quantitative Image Features

J Oliver[1, 2]*, M Budzevich[1, 2], D Hunt[1], E Moros[1, 2], G Zhang[1, 2], (1) University of South Florida, Tampa, FL, (2) H. Lee Moffitt Cancer Center, Tampa, FL

Purpose: To investigate the relationship between quantitative image features (i.e. radiomics) and statistical fluctuations (i.e. electronic noise) in clinical Computed Tomography (CT) using the standardized American College of Radiology (ACR) CT accreditation phantom and patient images. **Methods:** Three levels of uncorrelated Gaussian noise were added to CT images of phantom and patients (20) acquired in static mode and respiratory tracking mode. We calculated the noise-power spectrum (NPS) of the original CT images of the phantom, and of the phantom images with added Gaussian noise with means of 50, 80, and 120 HU. Concurrently, on patient images (original and noise-added images), image features were calculated: 14 shape, 19 intensity (1st order statistics from intensity volume histograms), 18 GLCM features (2nd order statistics from grey level co-occurrence matrices) and 11 RLM features (2nd order statistics from run-length matrices). These features provide the underlying structural information of the images. GLCM (size 128x128) was calculated with a step size of 1 voxel in 13 directions and averaged. RLM feature calculation was performed in 13 directions with grey levels binning into 128 levels**. Results:** Adding the electronic noise to the images modified the quality of the NPS, shifting the noise from mostly correlated to mostly uncorrelated voxels. The dramatic increase in noise texture did not affect image structure/contours significantly for patient images. However, it did affect the image features and textures significantly as demonstrated by GLCM differences**. Conclusion:** Image features are sensitive to acquisition factors (simulated by adding uncorrelated Gaussian noise). We speculate that image features will be more difficult to detect in the presence of electronic noise (an uncorrelated noise contributor) or, for that matter, any other highly correlated image noise. This work focuses on the effect of electronic, uncorrelated, noise and future work shall examine the influence of changes in quantum noise on the features.

J. Oliver was supported by NSF FGLSAMP BD award HRD #1139850 and the McKnight Doctoral Fellowship.

Imaging Electronic Campus — Exhibit Hall

Multi-detector CT

TU-G-CAMPUS-I-06

Investigation of the Effective Dose From Bolus Tracking Acquisitions at Different Anatomical Locations in the Chest for CT

P Nowik*, R Bujila, D Merzan, Dept. of Medical Physics, Karolinska University Hospital, Stockholm, Sweden

Purpose: Stationary table acquisitions (Bolus tracking) in X-ray Computed Tomography (CT) can **Result** in dose length products (DLP) comparable to spiral scans. It is today unclear whether or not the effective dose (E) for Bolus Tracking can be approximated using target region specific conversion factors (E/DLP). The purpose of this study was to investigate how E depends on the anatomical location of the Bolus Tracking in relation to Chest CT scans with the same DLP**. Methods:** Effective doses were approximated for the ICRP 110 adult Reference Male (AM) and adult Reference Female (FM) computational voxel phantoms using software for CT dose approximations (pre-simulated MC data). The effective dose was first approximated for a Chest CT scan using spiral technique and a CTDIvol (32 cm) of 6 mGy. The effective dose from the spiral scan was then compared to E approximated for contiguous Bolus Tracking acquisitions (1 cm separation), with a total collimation of 1 cm, over different locations of the chest of the voxel phantoms. The number of rotations used for the Bolus Tracking acquisitions was adjusted to yield the same DLP (32 cm) as the spiral scan**. Results:** Depending on the anatomical location of the Bolus Tracking, E ranged by factors of 1.3 to 6.8 for the AM phantom and 1.4 to 3.3 for the AF phantom, compared to the effective dose of the spiral scans. The greatest E for the Bolus Tracking acquisitions was observed for anatomical locations coinciding with breast tissue. This can be expected as breast tissue has a high tissue weighting factor in the calculation of E**. Conclusion:** For Chest CT scans, the effective dose from Bolus Tracking is highly dependent on the anatomical location where the scan is administered and will not always accurately be represented using target region specific conversion factors.

TU-G-CAMPUS-I-07

Validation of a CT X-Ray Source Characterization Technique for Dose Computation Using An Anthropomorphic Thorax Phantom

M Sommerville[1]*, Y Poirier[2], M Tambasco[1], (1) San Diego State University, San Diego, CA, (2) CancerCare Manitoba, Winnipeg, MB

Purpose: To experimentally validate a rotational kV x-ray source characterization technique by computing CT dose in an anthropomorphic thorax phantom using an in-house dose computation algorithm (kVDoseCalc)**. Methods:** The lateral variation in incident energy spectra of a GE Optima big bore CT scanner was found by measuring the HVL along the internal, full bow-tie filter axis. The HVL and kVp were used to generate the x-ray spectra using Spektr software, while beam fluence was derived by dividing the integral product of the spectra and in-air mass-energy absorption coefficients by in-air dose measurements along the bow-tie filter axis. Beams produced by the GE Optima scanner were modeled at 80 and 140 kVp tube settings. kVDoseCalc calculates dose by solving the linear Boltzmann transport equation using a combination of deterministic and stochastic methods. Relative doses in an anthropomorphic thorax phantom (E2E SBRT Phantom) irradiated by the GE Optima scanner were measured using a (0.015 cc) PTW Freiburg ionization chamber, and compared to computations from kVDoseCalc. **Results:** The agreement in relative dose between dose computation and measurement for points of interest (POIs) within the primary path of the beam was within experimental uncertainty for both energies, however points outside the primary beam were not. The average absolute percent difference for POIs within the primary path of the beam was 1.37% and 5.16% for 80 and 140 kVp, respectively. The minimum and maximum absolute percent difference for both energies and all POIs within the primary path of the beam was 0.151% and 6.41%, respectively. **Conclusion:** The CT x-ray source characterization technique based on HVL measurements and kVp can be used to accurately compute CT dose in an anthropomorphic thorax phantom.

TU-G-CAMPUS-I-08

Preliminary Study of Size-Specific Dose Estimates in Adult Abdomenal CT Examinations in Taiwan

H Tsai[1]*, Y Hwang[2], Y Hu[1], (1) Department of Medical Imaging and Radiological Sciences, Chang Gung University, Taoyuan, Taiwan, (2) Department of Medical Imaging and Intervention, Chang Gung Memorial Hospital at Linkou, Taoyuan, Taiwan.

Purpose: This study was to investigate size-specific dose estimates (SSDE) for routine adult abdominal CT examinations in Taiwan**. Methods:** A national survey was conducted in Taiwan in 2014 to investigate SSDEs for routine adult abdominal CT examinations. The hospitals involved in this study provided CT images of their typical patients. The CT image in the level of the middle liver was selected to record the corresponding tube current, slice mAs or effective mAs. The image was also used to estimate the dimensions of patient as measuring the lengths in the anterior to posterior (AP) and lateral (LAT) directions. The effective diameter was then calculated from AP and LAT, and used to look up conversion factors in the AAPM 204 report. The volume CTDI (CTDIvol) for each CT unit was measured on sites using a 32-cm cylindrical standard dose phantom and a calibrated pencil-type ionization chamber. Individual patient's SSDEs were then calculated from the corresponding SSDE conversion factor and the CTDIvol**. Results:** The study cohort included 111 CT units. The ratio of turning on automatic tube current modulation (ATCM) or not is 88:23. Effective diameters are 258.7±25.1 mm (167-366 mm). 99.3% of typical patients selected by each hospital have smaller effective diameter than the 32-cm dosimetry phantom. Adult abdomenal SSDE is 17.5 ± 8.8 mGy (1.9-58 mGy). The SSDE seems to decrease as the effective diameter increases as the ATCM turns off, and independent with the effective diameter as the ATCM turns on. **Conclusion:** The SSDE for typical patients in Taiwan was investigated. We continue to complete this investigation in 2015 to include more valid data to establish SSDE reference level in Taiwan.

This study was financially supported by the Atomic Energy Council in Taiwan.

TU-G-CAMPUS-I-09

A Novel Phantom to Evaluate Longitudinal and Angular Automatic Tube Current Modulation (ATCM) in CT

D Merzan*, R Bujila, P Nowik, Dept. of Medical Physics, Karolinska University Hospital, Stockholm, Sweden

Purpose: To manufacture a phantom specifically designed for the purpose of evaluating the performance of the longitudinal and angular automatic tube current modulation (ATCM) on modern CT scanners**. Methods:** In order to evaluate angular ATCM, the phantom has an elliptical cross section (aspect ratio 3:2). To evaluate longitudinal ATCM, the phantom consists of 3 sections, with different major axes (25 cm, 30 cm and 35 cm). Each section is 15 cm long in the longitudinal direction. Between each section is a smooth transition. The phantom was milled from a solid block of PMMA. ATCM performance is evaluated by 1) analyzing the applied tube current for each slice of the phantom and 2) analyzing the distribution of image noise (σ) along the scan direction at different positions in the phantom. A demonstration of the ATCM performance evaluation is given by investigating the effects of miscentering during a CT scan**. Results:** The developed phantom has proven useful for evaluating both the longitudinal and angular ATCM on modern CT scanners (spiral collimations ≥ 4 cm). Further benefits are the smooth transitions between the sections that prevent abnormal responses in the ATCM and the invariant sections that provide a means for investigating the stability of image noise. The homogeneity of the phantom makes image noise at different positions along the scan direction easy to quantify, which is crucial to understand how well the applied ATCM can produce a desired image quality**. Conclusion:** It is important to understand how the ATCM functions on CT scanners as it can directly affect dose and image quality. The phantom that has been developed is a most valuable tool to understand how different variables during a scan can affect the outcome of the longitudinal and angular ATCM.

TU-G-CAMPUS-I-10

Parameterization of the Noise Power Spectrum in X-Ray Computed Tomography

R Bujila*, G Poludniowski, A Fransson, Dept. of Medical Physics, Karolinska University Hospital, Stockholm, Sweden

Purpose: The purpose of this work was to develop a method so that the noise power spectrum (NPS) can be approximated for arbitrary levels of mAs, from a single determination in CT. **Methods:** The NPS is factorized into 2 components, 1) a parameterized function representing the 1D normalized spatial frequency distribution and 2) a function to scale the magnitude of 1) for arbitrary values of mAs. The 1D NPS, normalized by image variance (NNPS), was determined for 2 FBP reconstruction kernels (smoothing and edge enhancing) for 400 mAs. The NNPS were fit to the parameterized function and a scaling function was established to approximate the image variance at arbitrary values of mAs. Using the root mean square error normalized by the maximum value (NRMSE), the NPS approximated with the factorization method was compared to the NPS determined at 5 different mAs levels**. Results:** The factorization resulted in a set of 7 coefficients that can be used to approximate the 1D NPS, for arbitrary levels of mAs, for the convolution kernels studied in this work. The approximated NPS (factorization) agreed well with the determined NPS for all mAs levels. The greatest NRMSE was 0.02 and was observed for the edge enhancing kernel**. Conclusion:** The proposed factorization method has been demonstrated as applicable for FBP reconstruction. It can be used to approximate the 1D NPS for arbitrary levels of mAs, from a single NPS determination. Furthermore, approximations of the 1D NPS can conveniently be distributed since the factorization method only used 7 coefficients in the approximation.

Therapy Electronic Campus Exhibit Hall

Nanoparticles in Radiotherapy

TU-G-CAMPUS-T-11

Potential of Using Cerium Oxide Nanoparticles (CONP) for Protecting Healthy Tissue During Accelerated Partial Breast Irradiation (APBI)

m mainali[1]*, W Ngwa[2], G Cifter[3], J Celli[4], (1)University of Massachusetts Boston/Dana Farber cancer institute, Boston, MA, (2) Harvard Medical School, Boston, MA, (3) University of Massachusetts Lowell/ Dana Farber cancer institute, Boston, MA, (4) University of Massachusetts Boston, Boston, MA

Purpose: The purpose of this research is to investigate the feasibility of using targeted cerium oxide nanoparticles (CONP) during APBI to protect healthy cells. **Methods:** In one approach, CONP are assumed to be incorporated in a micrometer-thick polymer film on the surface of routinely used mammosite balloon applicators for sustained in-situ release of the CONP. In case two, CONPs are administered directly into the lumpectomy cavity. The concentration of H_2O_2 produced by ionizing radiation was estimated from previously published work using short range linear extrapolation. The assessment of CONPs concentration required to absorb corresponding H_2O_2 to protect healthy tissue was calculated. Fick's Second law of diffusion was employed to determine the initial concentration of CONP needed to achieve the minimum concentration for radioprotection at distance 1 cm and 2 cm from the lumpectomy cavity during APBI. The study was carried out for different nanoparticle sizes. **Results:** The initial concentration of CONPs required to get desired radioprotection concentration at 1 cm and 2 cm after 7 days was found to be 0.4089 mg per Kg and 59.7605 g per Kg respectively for 2 nm size nanoparticles. Using concentrations of 5 mg per kg of CONP that have been shown to be used to confer radioprotection (for about 7.97 Gy) in experiments it was observed that 4.5631, 8.5286, 10.9247, 22.0408, 43.6796 and 65.5618 number of days are required to achieve radioprotection at 1 cm for CONP of sizes 2 nm, 3.8 nm, 5 nm, 10 nm, 20 nm, 30 nm, respectively**. Conclusion:** Our preliminary results show that smaller size (2 nm and 3.8 nm) CONP would be suitable as radio protectant during APBI because they took a reasonable number of days, i.e. less than 10 days to reach tissues of 1 cm or 2 cm thickness.

TU-G-CAMPUS-T-12

Monte Carlo Evaluation of Kilovoltage Radiosurgery with AuNPs for Age Related Macular Degeneration (AMD)

D Brivio[1]*, P Zygmanski[2], E Sajo[3], G Makrigiorgos[4], W Ngwa[5], (1) (2) Brigham & Women's Hospital, Boston, MA, (3) Univ Massachusetts Lowell, Lowell, MA, (4) Dana Farber Cancer Institute, Boston, MA, (5) Harvard Medical School, Boston, MA

Purpose: To evaluate the benefit of gold nanoparticles (AuNP) in radiosurgery of Age related Macular Degeneration (AMD) using Monte Carlo (MC) simulation. AMD disease causes vision loss due to a leaky vasculature of the endothelial cells. Radiosurgical therapy aims to destroy this vasculature while minimizing the delivered dose to healthy tissues of the eye. AuNP known to enhance local dose have been targeted to the macular choroidal endothelial cells to increase the therapeutic efficacy. **Methods:** Dose enhancement ratio (DER) in macula endothelial cells due to a thin layer of AuNP has been calculated by a MC radiation transport simulation. AuNP layer (10-100nm) has been placed on the bottom of the macula at 2.4cm depth in a water parallelepiped 3x3x6cm3. This layer has been modeled considering various concentrations of AuNP ranging from 5.5-200mg per gram of endothelial cell (volume 10x10x2um3). The x-ray source is 100kVp 4mm diameter beam tilted 0°-30° with respect to the lens**. Results:** DER in endothelial cell for AuNP concentration of 31mg/g (shown experimentally feasible) and 10-100nm sizes is about 1.8. Tilting 4mm-beam does not reduce the enhancement but allows to avoid the surrounding tissues. Dose distribution in the AuNP vicinity has a significant increase within 30um, peaked at AuNP interface. DER inside and outside of the irradiation 4mm-field are the same while the actual delivered dose is more than one order of magnitude lower outside the field. Compared to 100kVp, usage of filtered spectra with enhanced flux in the region 20keV-40keV shows further increase of DER by about 20%. Dose to the neighboring organs such as retina/optic nerve are reduced accordingly**. Conclusion:** The results of this MC simulation provide further confirmation of the potential to enhance DER with AuNP from previous analytical calculations. This study provides impetus to improve treatment effectiveness of AMD disease with radiotherapy.

TU-G-CAMPUS-T-13

Enhancing the Tumor Specific Radiosensitization Using Molecular Targeted Gold Nanorods

P Diagaradjane[1]*, A Deorukhkar[2], M Sankaranarayanapillai[3], N Manohar[4], P Singh[5], G Goodrich[6], R Tailor[7], S Cho[8], S Krishnan[9], (1) M.D. Anderson Cancer Center, Houston, TX, (2) The UT MD Anderson Cancer Center, Houston, TX, (3) The UT MD Anderson Cancer Center, Houston, TX, (4) UT MD Anderson Cancer Center, Houston, TX, (5) The UT MD Anderson Cancer Center, Houston, TX, (6) Nanospectra Biosciences Inc, Houston,

TX, (7) UT MD Anderson Cancer Center, Houston, TX, (8) UT MD Anderson Cancer Center, Houston, TX, (9) The University of Texas MD Anderson Cancer Center, Houston, TX

Purpose: Gold nanoparticle (GNP) mediated radiosensitization has gained significant attention in recent years. However, the widely used passive targeting strategy requires high concentration of GNPs to induce the desired therapeutic effect, thus dampening the enthusiasm for clinical translation. The purpose of this study is to utilize a molecular targeting strategy to minimize the concentration of GNPs injected while simultaneously enhancing the tumor specific radiosensitization for an improved therapeutic outcome. **Methods:** Cetuximab (antibody specific to the epidermal growth factor receptor that is over-expressed in tumors) conjugated gold nanorods (cGNRs) was used for the tumor targeting. The binding affinity, internalization, and in vitro radiosensitization were evaluated using dark field microscopy, transmission electron microscopy, and clonogenic cell survival assay, respectively. In vivo biodistribution in tumor (HCT116-colorectal cancer cells) bearing mice were quantified using inductively coupled plasma mass spectrometry. In vivo radiosensitization potential was tested using 250-kVp x-rays and clinically relevant 6-MV radiation beams**. Results:** cGNRs displayed excellent cell-surface binding and internalization (~31,000 vs 12,000/cell) when compared to unconjugated GNRs (pGNRs). In vitro, the dose enhancement factor at 10% survival (DEF10) was estimated as 1.06 and 1.17, respectively for both 250-kVp and 6-MV beams. In vivo biodistribution analysis revealed enhanced uptake of cGNRs in tumor (1.3 μg/g of tumor tissue), which is ~1000-fold less than the reported values using passive targeting strategy. Nonetheless, significant radiosensitization was observed in vivo with cGNRs when compared to pGNRs, when irradiated with 250-kVp (tumor volume doubling time 35 days vs 25 days; p=0.002) and 6 MV (17 days vs 13 days; p=0.0052) beams. **Conclusion:** The enhanced radiosensitization effect observed with very low intratumoral concentrations of gold and megavoltage x-rays using the active targeting strategy holds promise for clinical translation of this strategy from a toxicity and cost-effectiveness perspective and could evolve as a paradigm-changing approach in the field of radiation oncology.

TU-G-CAMPUS-T-14

Using Gold Nanoparticles to Target Mitochondria in Radiation Therapy

A McNamara[1]*, S McMahon[2], Y Lin[3], H Paganetti[4], Z Kuncic[5], J Schuemann[6], (1) Massachusetts General Hospital & Harvard Med. Sch., Boston, MA, (2) Massachusetts General Hospital, Boston, Ma, (3) Massachusetts General Hospital and Harvard Medical School, Boston, MA, (4) Massachusetts General Hospital, Boston, MA, (5) University of Sydney, Sydney, NSW, (6) Massachusetts General Hospital, Boston, MA

Purpose: The mitochondrion, like the cell nucleus, contains genetic material and plays several critical roles that determine the cell viability, including neutralization of free radicals within the cell. Studies have shown that irradiated cells with impaired mitochondria will incur more damage to the cell nucleus. This study investigates the potential use of GNPs to enhance radiation-induced damage to the organelle. **Methods:** The compositions of the organelles of a JURKAT cell were determined experimentally. Using Monte Carlo simulations, we investigate the significance of dose enhancement in a monoenergetic (10 - 50 keV and 6 MeV) x-ray irradiated cell cytoplasm, consisting of the experimentally determined composition. We also investigate the track structure of secondary electrons in the mitochondria using Geant4-DNA in the presence and absence of GNPs for incident protons and photons. The biological effect was determined using an approach based on the local effect model, assuming the mitochondrial DNA (mtDNA) was the primary target. **Results:** Adding 0.01% of gold to the cell cytoplasm material can cause substantial dose enhancement, dependent on the incident x-ray energy. Track structure Monte Carlo (MC) simulations show an increased number of ionization events within the mitochondrion structure. The close proximity of GNPs to the mtDNA storing nucleoid may cause the mtDNA to receive doses above ~100 Gy for keV x-rays, leading to mitochondrial dysfunction**. Conclusion:** A substantial increase in ionization events can occur in the mitochondria in the presence of GNPs. If GNPs can be delivered to tumors and attached to a sufficient number of mitochondria inside the tumor cells, mitochondrial induced cell death could be a prevalent cause of cell death. The biological structures developed here will be included in the biological MC toolkit, TOPAS-nBio.

TU-G-CAMPUS-T-15

Dose Escalation to Biological Tumor Volumes of Prostate Cancer Patients Using Gold Nanoparticles

M Jermoumi[1, 2]*, E Sajo[1], K Houari[2], W Ngwa[1, 2]
(1)Department of Physics and Applied Physics, Medical Physics Program, University of Massachusetts Lowell
(2)Department of Radiation Oncology, Dana Farber Cancer Insitute, Brigham and Women's Hospital, Harvard Medical, Boston, MA

Purpose: Studies have shown that radiation boosting could help reduce prostate cancer (PCa) recurrence. Biological tumor volumes (BTV) are a high priority for such radiation boosting. The purpose of this study is to investigate the potential of radiation boosting of real patient BTVs using gold nanoparticles (GNP) released from gold-loaded brachytherapy spacers (GBS) during brachytherapy. **Methods:** The BTVs of 12 patients having prostate adenocarcinoma identified with positron emission tomography (PET) and CT scanner using C-11 labeled tracer [11C]acetate were investigated. The initial GNP concentration and time to achieve a dose enhancement effect (DEF) of 2 was simulated using the freely downloadable software RAID APP. The investigations were carried out for low dose rate (LDR) brachytherapy sources (BTS) described in AAPM Task Group report 43: Cs-131, I-125, and Pd-103. In first case, we used 7 mg/g and 18 mg/g of GNP initial concentrations to estimate the time needed for released GNP to achieve a DEF of 2 for the different BTS, and compare with clinically relevant treatment times. In second case, we calculated the initial concentration of GNPs needed to achieve a DEF of 2 during the time the BTS would typically deliver 50%, 70% and 90% of the total dose**. Results:** For an initial concentration of 18 mg/g, when using Cs-131, and Pd-103, a DEF of 2 could only be achieved for BTV of 3.3 cm3 and 1 cm3 respectively. Meanwhile a DEF of 2 could be achieved for all 12 BTVs when using I-125. To achieve a DEF of 2 for all patients using Cs-131 and Pd-103, much higher initial concentrations would have to be used than have been typically employed in pre-clinical studies. **Conclusion:** The I-125 is the most viable BTS that can be employed with GBS to guide dose painting treatment planning for localized PCa.

Joint Imaging - Therapy — Exhibit Hall Electronic Campus

Imaging for RT Treatment Planning

TU-G-CAMPUS-J-11

A Formulation of 4D Treatment Planning for Tumour Tracking Volumetric Modulated Arc Therapy for Lung Cancer

Michael L M Cheung[1, 2]*, Louis K Y Lee[1], Anthony T C Chan[1, 2] (1) Prince of Wales Hospital, Hong Kong (2) The Chinese University of Hong Kong

Purpose: To develop a formulation for 4D treatment planning for a tumour tracking volumetric modulated arc therapy treatment (VMAT) plan for lung cancer**. Methods:** A VMAT plan was optimized based on a reference phase of the 4DCT of a lung cancer patient. The PTV was generated from the GTV of the reference phase. The collimator angle was set to 90 degrees such that the MLC travels along superior-inferior direction which is the main component of movement of a lung tumour. Then, each control point of the VMAT plan was assigned to a particular phase of the 4DCT in chronological order. The MLC positions of each control point were shifted according to the position of the tumour centroid of its assigned phase to form a tumour tracking VMAT plan. The control points of the same phase were grouped to form a pseudo VMAT plan for that particular phase. Dose calculation was performed for each pseudo VMAT plan on the corresponding phase of the 4DCT. The CTs of all phases were registered to the reference phase CT according to the displacement of the tumour centroid. The individual dose distributions of the pseudo VMAT plans were summed up and displayed on the reference phase of the 4DCT. A control VMAT plan was optimized based on a PTV generated from the ITV of all phases and compared with the tumour tracking VMAT plan**. Results:** Both plans achieved >95% volume coverage at the prescription dose level (96% for the tumour tracking plan and 97% for the control plan). But the normal lung volume irradiated at the prescription dose level was 39% less for the tumour tracking plan than the control plan**. Conclusion:** A formulation of 4D treatment planning for tumour tracking VMAT plans for lung cancer was developed.

TU-G-CAMPUS-J-12

Developing a Phenomenological Model of the Proton Trajectory Within a Heterogeneous Medium Required for Proton Imaging

CA Collins-Fekete[1-4]*, P Doolan[2], M Dias[3], L Beaulieu[4], J Seco[5], (1) Massachussetts General Hospital, Quebec, Quebec, (2) University College London Hospital, London, London, (3) Politecnico di Milano, Milano, Lombardia, (4) Centre Hospitalier Univ de Quebec, Quebec, QC, (5) Mass General Hospital; Harvard Medical, Boston, MA

Purpose: To develop an accurate phenomenological model of the cubic spline trajectory (CST) estimate of the proton path, accounting for the initial proton energy and water equivalent thickness (WET) traversed**. Methods:** Geant4 Monte Carlo (MC) simulations were used to calculate the path of protons crossing various slabs (5-30 cm WET) of different material (LN300, water and CB2-50% CaCO3) for a range of initial energies (150-330MeV). For each MC trajectory, CST was constructed based on the proton entrance and exit information and compared with the MC using the root mean square (RMS) metric. The CST path is dependent on the direction vector magnitudes (|P0,1|). First, |P0,1| is set to the proton path length. Then, a factor Λ is introduced to modify |P0,1|. The factor is varied to minimize the RMS with MC paths for every configuration. Finally, a set of Λopt factors that minimizes the RMS is presented. These are dependent on the ratio between WET and water equivalent path length (WEPL). The resolution along the path is investigated with a set of slabs. MTF analysis is performed on proton radiographs of a line-pair phantom reconstructed using the CST trajectories (Λopt and Λ1). **Results:** Λopt was fitted to the ratio of WET/WEPL using a power function (Y=1-AXB where A=0.36, B=4.07). The RMS deviation calculated along the path, between the CST and the MC path, increases with the WET. The increase is larger when using Λ1 than Λopt (difference of 5.0% with WET/WEPL=0.86). For 230(330) MeV protons, the MTF10% was found to increase by 40%(6%) respectively for a thick phantom (30cm) and by 25%(1%) for thinner phantom (25cm) when using the Λopt model compared to the Λ1 model**. Conclusion:** Based on these results, using CST with the Λopt factor reduces the RMS deviation and increases the spatial resolution when reconstructing proton trajectories.

TU-G-CAMPUS-J-13

Evaluation of a New GE Device-Less Cine 4D-CT

R Martin[1]*, A Chandler[2], D Doan[3], C Rowland[3], T Pan[1], (1) UT MD Anderson Cancer Center, Houston, TX, (2) MICT Research, GE Healthcare, Waukesha, WI, (3) GE Healthcare, Waukesha, WI

Purpose: Standard cine 4D-CT (S-4DCT) is the cine CT scan of the thorax followed by image sorting with the respiratory signal recorded by the RPM. Although the feasibility of cine 4D-CT without RPM or device-less 4DCT (DL-4DCT) has been reported in a laboratory setting, the only commercial implementation of DL-4DCT was made recently by GE based on the measurements of the lung, body and air area and density. We report the initial results of this new DL-4DCT on its determination of gross tumor volume (GTV)**. Methods:** 30 stereotactic body radiation therapy (SBRT) patients with NSCLC were included in the study. All patients received the S-4DCT for their treatment planning. Their cine CT data without the respiratory signal from RPM were submitted to the DL-4DCT. The DL-4DCT image quality was assessed in reference to S-4DCT. Using maximum intensity projection (MIP) images, the GTVs of the S-4DCT and DL-4DCT were compared on a subset of 9 patients whose tumors in the low density lung regions could be contoured using a region growing algorithm in MIM without contouring bias from the user. A lower threshold of -424 HU was used for all patients and other algorithm parameters were held constant for each patient. **Results:** The DL-4DCT was able to produce the 4DCT images on 29 out of the 30 SBRT cases. One case failed due to the enhanced calcification surrounding both the breast implants. The GTVs determined on the 9 patients with DL-4DCT were 4.2 ± 4.8% smaller than the GTVs with S-4DCT. However, this was statistically insignificant (p=0.15). The Dice similarity coefficients were 95.1 ± 1.8%. The image quality of DL-4DCT and S-4DCT was similar on the 29 cases**. Conclusion:** The first commercial DL-4DCT was promising in generating 4D-CT images without a respiratory monitoring device in this preliminary study of 30 patients.

TU-G-CAMPUS-J-14

Evaluation of Metal Artifact Reduction Technique for the Radiation Therapy Planning

K Jeong[1]*, H Kuo[2], J Ritter[3], J Shen[4], A Basavatia[5], R Yaparpalvi[6], S Kalnicki[7], W Tome[8], (1) Montefiore Medical Center, Bronx, NY, (2) Montefiore Medical Center, Bronx, NY, (3) Montefiore Medical Center, Bronx, NY, (4) Montefiore Medical Center, Bronx, NY, (5) Montefiore Medical Center, Bronx, NY, (6) Montefiore Medical Center, Bronx, NY, (7) Montefiore Medical Center, Bronx, NY, (8) Montefiore Medical Center, ALBERT EINSTEIN COLLEGE OF MEDICINE, Bronx, NY

Purpose: To evaluate the feasibility of using a metal artifact reduction technique in depleting metal artifact and its application in improving dose calculation in External Radiation Therapy Planning**. Methods:** CIRS electron density phantom was scanned with and without steel drill bits placed in some plug holes. Meta artifact reduction software with Metal Deletion Technique (MDT) was used to remove metal artifacts for scanned image with metal. Hounsfield units of electron density plugs from artifact free reference image and MDT processed images were compared. To test the dose calculation improvement after the MDT processed images, clinically approved head and neck plan with manual dental artifact correction was tested. Patient images were exported and processed with MDT and plan was recalculated with new MDT image without manual correction. Dose profiles near the metal artifacts were compared**. Results:** The MDT used in this study effectively reduced the metal artifact caused by beam hardening and scatter. The windmill around the metal drill was greatly improved with smooth rounded view. Difference of the mean HU in each density plug between reference and MDT images were less than 10 HU in most of the plugs. Dose difference between original plan and MDT images were minimal. **Conclusion:** Most metal artifact reduction methods were developed for diagnostic improvement purpose. Hence Hounsfield unit accuracy was not rigorously tested before. In our test, MDT effectively eliminated metal artifacts with good HU reproduciblity. However, it can introduce new mild artifacts so the MDT images should be checked with original images.

TU-G-CAMPUS-J-15

Quantitative Evaluation of the Relationship Between Tissue Velocity and Motion-Artifacts of Free-Breathing Low-Dose Fast-Helical CT Scans

Liu (Lisa) Yang*, Tai Dou, Dylan O'Connell, David Thomas, Dan Ruan, James Lamb, Daniel A. Low, University of California, Los Angeles, Los Angeles, CA 90024

Purpose: The process of characterizing breathing motion has recently advanced by employing repeated fast-helical scans as the free-breathing CT images. While the scans are acquired using state-of-the-art CT scanners operating at nearly their highest couch-speeds, it still requires 0.23 s to scan any specific tissue-region. During quiet respiration, tissue velocities of up to 4 cm per second have been observed; leading to the residual motion-artifacts in the fast helical CT scans. This work evaluates the magnitude and characteristics of the motion-artifacts and correlates against model-calculated tissue velocities. **Methods:** 10 Patients were scanned 25 successive times using a low-dose fast-helical protocol with scans acquired in alternating directions. A 64-slice CT scanner with a pitch of 1.2 and table speed of 161.7 mm/s was used. The first scan was selected as the reference scan and deformable registrations were performed to register the other 24 scans to the reference scan. Motion-blur was quantified using blurring metrics and doubling-artifacts were further quantified using edge-response width to determine the mean edge-width of each lung diaphragm. The model-predicted velocities were correlated against the quantified artifacts. **Results:** Motion-artifacts appeared with the increased tissue velocity, from artifact-free to blurring-artifacts and then doubling-artifacts. Increasing amounts of doubling-artifacts were observed with tissue velocities > 18.2±1.3 mm/s. Regional blurring-artifacts occurred with velocities > 3.8±2.3 mm/s. The relationship between tissue velocity and motion-artifact severity was linear. There was no statistically significant difference in artifact magnitude between inhalation and exhalation phases**. Conclusion:** In spite of employing fast-helical acquisition with table speeds of 161.7 mm/s, motion-artifacts remained. The relationship between motion-artifact amplitude and tissue-velocity was linear with free-breathing fast-helical scans. This relationship will be used to aid in reference image selection, guide 5DCT accuracy assessments, and determine which images are averaged to produce the reference phase image used for treatment planning.

TU-G-CAMPUS-I-11

Head and Neck Squamous Cell Carcinoma: Short-Term Repeatability of Apparent Diffusion Coefficient and Intravoxel Incoherent Motion Parameters at 3.0T

Y Ding*, C Fuller, A Mohamed, J Wang, J Hazle, UT MD Anderson Cancer Center, Houston, TX

Purpose: Many published studies have recently demonstrated the potential value of intravoxel incoherent motion (IVIM) analysis for disease evaluation. However, few have questioned its measurement repeatability/reproducibility when applied. The purpose of this study was to determine the short-term measurement repeatability of apparent diffusion coefficient ADC, true diffusion coefficient D, pseudodiffusion coefficient D* and perfusion fraction f, in head and neck squamous cell carcinoma (HNSCC) primary tumors and metastatic nodes**. Methods:** Ten patients with known HNSCC were examined twice using echo-planar DW-MRI with 12 b values (0 to 800 s/mm2) 1hour to 24 hours apart before radiation treatment. All patients were scanned with the customized radiation treatment immobilization devices to reduce motion artifacts and to improve image registration in repeat scans. Regions of interests were drawn in primary tumor and metastases node in each patient (Fig. 1). ADC and IVIM parameters D, D* and f were calculated by least squares data fitting. Short-term test–retest repeatability of ADC and IVIM parameters were assessed by measuring Bland–Altman limits of agreements (BA-LA). **Results:** Sixteen HNSCC lesions were assessed in 10 patients. Repeatability of perfusion-sensitive parameters, D* and f, in HNSCC lesions was poor (BA-LA: -144% to 88% and -57% to 96% for D* and f, respectively); a lesser extent was observed for the diffusion-sensitive parameters of ADC and D (BA-LA: -34% to 39% and -37% to 40%, for ADC and D, respectively) (Fig. 2)**. Conclusion:** Poor repeatability of D*/f and good repeatability for ADC/D were observed in HNSCC primary tumors and metastatic nodes. Efforts should be made to improve the measurement repeatability of perfusion-sensitive IVIM parameters.

TU-G-CAMPUS-I-12

Phosphorus Metabolite Differences Between Type 2 Diabetic and Normal Skeletal Muscle

E Ripley*, G Clarke, UT Health Sciences Center, San Antonio, TX

Purpose: Type 2 diabetes mellitus (T2DM) is implicated with impaired ATP production in skeletal muscle. Phosphorus-31 magnetic resonance spectroscopy (31P-MRS) was used to measure the baseline concentrations of phosphocreatine (PCr), inorganic phosphate (Pi), and adenosine triphosphate (ATP) in the vastus lateralis (VL) muscle. **Methods:** Six T2DM subjects (6 male, age = 51±12) and three normal glucose tolerant (NGT) subjects (2 male, age = 40±16) were studied. A slice-selective 31P-MRS sequence (TR=10s, TE=2.3 ms, NSA=16, 25mm slice) was performed to determine the absolute concentrations, [PCr], [Pi], [ATP]. After the legs were scanned, a leg phantom (15 cm diameter, 4 L cylinder with 35 mM phosphoric acid (H_3PO_4)), was scanned using the same slab positioning. A 6 mL vial with 850 mM of methylenediphosphonic acid (MDP)) was the external reference standard. The tissue volumes were calculated from a five-slice MRI scan. The jMRUI software package was used to measure the areas under spectral peaks. A two-tailed t-test was performed, with significance deemed as $p<0.05$**. Results:** The subjects with T2DM had an average absolute [PCr] = 24.9±4.5 mM while for the NGT subjects [PCr] = 31.9±1.9 mM. The t-test showed a significant difference ($p=0.04$) between the means of the two groups. There was no significant difference between the means for [Pi] and [ATP] between T2DM and NGT subjects. For all nine subjects the average and standard deviation of [Pi] and [ATP] were 2.86±0.45 mM and 6.99±1.30 mM, respectively**. Conclusion:** Subjects with T2DM have lower baseline values of PCr than subjects with normal glucose tolerance. This has not been previously reported and the mechanisms for this need to be studied further. Future studies will investigate the PCr utilization under exercise conditions.

Funding: NIH K Grant 1K25DK089012.

TU-G-CAMPUS-I-13

Quantitative Cardiac MRI Reveals Functional Abnormalities in Intrauterine Growth Restricted (IUGR) Baboons

G Clarke*, J Li, A Kuo, P Nathanielsz, UT Health Sciences Center, San Antonio, TX

Purpose: Developmental programming occurs in utero, when epigenetic adaptations **Result** in offspring phenotypes that lead to health consequences persisting throughout life. Programming of cardiac health, due to prenatal malnutrition, has been reported in rodents but not in primate species. Our aim was to determine IUGR is associated with impaired cardiac function in later life in a baboon model**. Methods:** Intrauterine growth restricted (IUGR, mothers were subjected to a 30% calories reduction) baboons were scanned with cine cardiac MRI measuring ejection fraction, left ventricular (LV) volumes, LV peak filling rate (LVPFR) and the LV 3D sphericity index (3DSI). Baboons were anesthetized and the respirator was turned off during scans. Three groups of baboons were studied: adult control (CTR): N=21 (11M, 10 F), age = 5.9±1.3 yr., IUGR: N=9(4M, 5F), age = 4.6±0.5 yr., and normal elderly adults (ELD): N=11(5M, 6 F), age = 15.3±2.4 yr. Images were analyzed using CMR42 software. LV end-diastolic volume (EDV) and end-systolic volumes (ESV) were referenced to body-surface areas (BSA). Linear regression, correlation and ANOVA with Bonferroni correction were performed between for each of the three groups ($p<.05$ deemed significant)**. Results:** Systolic LV function in all three groups was normal. There were significant differences between the three groups for 3DSI and LVPFR by ANOVA. ($p<.01$) Linear regression and correlation were performed between 3DSI and LVFR data for each of the three groups. CTR: $r=0.01$(p=NS); IUGR: $r=0.881$ ($p<.02$); ELD: $r=0.724$ ($p<.05$)**. Conclusions:** All subjects had normal systolic function but diastolic dysfunction was associated with IUGR and aging. Results are consistent with reports of increased fibrosis and changes in the distribution of titin isoforms in IUGR fetal baboon heart tissues. The data suggest that developmental programming, due to IUGR, accelerates processes leading to diastolic heart dysfunction, which is common with aging.

GDC:NIH/K25-KDK089012A. AJK:NIH/R25-EB016631 PN: EU/BRAINAGE-IMPACT OF PRENATAL STRESS ON BRAIN AGE(FP7-HEALTH-2011).

TU-G-CAMPUS-I-14

Head-Only Asymmetric Gradient System Evaluation: ACR Image Quality and Acoustic Noise

P Weavers[1]*, Y Shu[1], S Tao[1], S Lee[2] J Piel[2], J-B Mathieu[3], T Foo[2], M Bernstein[1], (1) Mayo Clinic, Rochester, Minnesota, (2) GE Global Research, Niskayuna, NY, (3) GE Healthcare, Florence, SC

Purpose: A high-performance head-only magnetic resonance imaging gradient system with an acquisition volume of 26 cm employing an asymmetric design for the transverse coils has been developed. It is able to reach a magnitude of 85 mT/m at a slew rate of 700 T/m/s, but operated at 80 mT/m and 500 T/m/s for this test. A challenge resulting from this asymmetric design is that the gradient nonlinearly exhibits both odd- and even-ordered terms, and as the full imaging field of view is often used, the nonlinearity is pronounced. The purpose of this work is to show the system can produce clinically useful images after an on-site gradient nonlinearity calibration and correction, and show that acoustic noise levels fall within non-significant risk (NSR) limits for standard clinical pulse sequences**. Methods:** The head-only gradient system was inserted into a standard 3T wide-bore scanner without acoustic damping. The ACR phantom was scanned in an 8-channel receive-only head coil and the standard American College of Radiology (ACR) MRI quality control (QC) test was performed. Acoustic noise levels were measured for several standard pulse sequences**. Results:** Images acquired with the head-only gradient system passed all ACR MR image quality tests; Both even and odd-order gradient distortion correction terms were required for the asymmetric gradients to pass. Acoustic noise measurements were within FDA NSR guidelines of 99 dBA (with assumed 20 dBA hearing protection) A-weighted and 140 dB for peak for all but one sequence. Note the gradient system was installed without any shroud or acoustic batting. We expect final system integration to greatly reduce noise experienced by the patient**. Conclusion:** A high-performance head-only asymmetric gradient system operating at 80 mT/m and 500 T/m/s conforms to FDA acoustic noise limits in all but one case, and passes all the ACR MR image quality control tests.

This work was supported in part by the NIH grant 5R01EB010065

TU-G-CAMPUS-I-15

Semi-Automated, Open Source MRI Quality Assurance and Quality Control Program for Multi-Unit Institution

J Yung*, W Stefan, D Reeve, RJ Stafford, UT MD Anderson Cancer Center, Houston, TX

Purpose: Phantom measurements allow for the performance of magnetic resonance (MR) systems to be evaluated. Association of Physicists in Medicine (AAPM) Report No. 100 Acceptance Testing and Quality Assurance Procedures for MR Imaging Facilities, American College of Radiology (ACR) MR Accreditation Program MR phantom testing, and ACR MRI quality control (QC) program documents help to outline specific tests for establishing system performance baselines as well as system stability over time. Analyzing and processing tests from multiple systems can be time-consuming for medical physicists. Besides determining whether tests are within predetermined limits or criteria, monitoring longitudinal trends can also help prevent costly downtime of systems during clinical operation. In this work, a semi-automated QC program was developed to analyze and record measurements in a database that allowed for easy access to historical data**. Methods:** Image analysis was performed on 27 different MR systems of 1.5T and 3.0T field strengths from GE and Siemens manufacturers. Recommended measurements involved the ACR MRI Accreditation Phantom, spherical homogenous phantoms, and a phantom with an uniform hole pattern. Measurements assessed geometric accuracy and linearity, position accuracy, image uniformity, signal, noise, ghosting, transmit gain, center frequency, and magnetic field drift. The program was designed with open source tools, employing Linux, Apache, MySQL database and Python programming language for the front and backend**. Results:** Processing time for each image is <2 seconds. Figures are produced to show regions of interests (ROIs) for analysis. Historical data can be reviewed to compare previous year data and to inspect for trends**. Conclusion:** A MRI quality assurance and QC program is necessary for maintaining high quality, ACR MRI Accredited MR programs. A reviewable database of phantom measurements assists medical physicists with processing and monitoring of large datasets. Longitudinal data can reveal trends that although are within passing criteria indicate underlying system issues.