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Comparison of Aperture Complexity Between VMAT Plans Using Conventionally Flattened (FF) and Flattening-Filter-Free (FFF) Beams

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MEDICAL PHYSICS

TU-F115-IePD-F2-04, Assessment of MR-Generated Synthetic CT for Treatment Planning of Gamma Knife Radiosurgery: T Qu*, J Xue^, D Barbee*, D Kondziolka*, H Wang*, (*)NYU Langone Health, New York, NY, (^) Elekta Inc.

Purpose: Gamma knife (GK) radiosurgery is typically planned on MR images using water-equivalent dose calculation methods. The aim of this study is to evaluate MR-generated synthetic CT (synCT) for GK dose calculation with tissue inhomogeneity correction**. Methods:** The university-industry collaboration study consists of developing a deep-learning (DL) method to generate synCT from routine simulation MR images, and assessing the potential of synCT for GK dose calculation. Treatment planning T1-weighted MRI and CT images of fifty patients who received GK were provided to train a synCT generation algorithm using cycle generative adversarial network (cycleGAN) with mutual information constraints. synCT of 10 testing GK patients were generated from the MR and compared with corresponding CT. Using GammaPlan 11.3.1, the GK plans created on MRI using the TMR10 method were re-calculated using the convolution calculation algorithm with electron density maps from the CT and synCT. The doses were evaluated with CT-calculated doses by dose-volume histogram metrics on 20 brain tumor targets of the testing cases**. Results:** The mean absolute error (MAE ± std) between synCT and CT were 118 ± 30 HU within MR-delineated skulls for the testing cases, 48 ± 15 HU for the soft tissue and 297 ± 87 HU for the bone. Percentage differences in GTV D95% and V12Gy from CT-calculated doses were 3.6 ± 4.5%, 0.2 ± 1.2%, respectively, for synCT dose calculation, and became 9.3 ± 3.1%, 8.9 ± 1.1% when TMR10 was used**. Conclusion:** synCT and CT yield equivalent dose calculation for GK Plans, while the water-based TMR method shows appreciable dose discrepancies. MR-generated synCT may enable tissue inhomogeneity-corrected dose calculation for current MR-based GK Planning.

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TU-F115-IePD-F2-05, Ferumoxytol Relaxivity and Signal Enhancement for MR-Guided Radiation Therapy (MRgRT) at 0.35T: A Feasibility Study: J Pham*, C Colbert, M Cao, K Nguyen, Y Yang, University of California, Los Angeles, Los Angeles, CA

Purpose: To measure the relaxivity of ferumoxytol (Feraheme) on a 0.35T MR-guided radiation therapy (MRgRT) system and to evaluate the feasibility of using ferumoxytol for MRI signal enhancement**. Methods:** We prepared ferumoxytol phantoms at various concentrations (0.0, 0.16, 0.31, 0.63, 1.26, and 2.52mM) by diluting stock ferumoxytol in normal saline and imaging the phantoms using a 0.35T MRgRT system. To determine the r1 and r2 relaxivity, 2D inversion-recovery turbo spin echo (TSE) images (inversion times (TI):0-1000ms) and 2D TSE images (echo times (TE):6-100ms) were acquired at room temperature. T1 and T2 maps were generated from a voxel-wise exponential fit of the observed signal intensity over the range of TI and TE times. Mean R1 (1/T1) and R2 (1/T2) were measured for each ferumoxytol dilution. r1 and r2 relaxivity were computed via a linear regression between the observed R1 or R2 relaxation rate with contrast concentration. To evaluate the effect of ferumoxytol concentration on signal enhancement, high resolution (1mm) 2D T1-weighted (T1w) TSE, T1w spoiled gradient echo (SGE), and balanced steady state free precession (bSSFP) acquisitions were performed. Mean signal intensity for phantom was measured and normalized by the saline-only phantom. Coefficient of variations (CoV) of the mean signal intensity was calculated**. Results:** At 0.35T, r1 and r2 of ferumoxytol were 33.1mM^{-1}/s^{-1} (r-squared=0.98) and 85.0mM^{-1}/s^{-1} (r-squared=0.99) at room temperature. For T1w TSE and SGE acquisitions, signal intensity peaked at 0.16 mM with a signal enhancement of 5.81 and 5.68. For the bSSFP, the signal plateaued between 0.16-1.26 mM with a signal enhancement of 2. The average CoV for TSE, SGE, and bSSFP were 19%, 9%, and 5%**. Conclusion:** At low concentrations (0.16-1.26mM), ferumoxytol provides a 2-6-fold signal enhancement (relative to 0mM) on a 0.35T MRgRT system. Its r1 relaxivity may be exploited to improve vascular imaging for vessel sparing radiotherapy.

Dr. Yang received honoraria and consulting fees from ViewRay.

Exhibit Hall | Forum 3: Therapy Interactive ePoster Discussion; External Beam Modeling

TU-F115-IePD-F3-01, Comparison of Aperture Complexity Between VMAT Plans Using Conventionally Flattened (FF) and Flattening-Filter-Free (FFF) Beams: Q Liu*, J Liang, William Beaumont Hospital, Royal Oak, MI

Purpose: VMAT plans with high amount of complex apertures could lead to less confidence in dose calculation accuracy due to machine modelling and dose algorithm limitations. It was hypothesized that VMAT plans generated with FFF beams would result in more complex aperture shapes due to the non-flattened beam profile. The purpose of this study was to test this hypothesis by assessing various plan complexity metrics**. Methods:** Target and organ-at-

risk structures were created on an anthropomorphic phantom in various sites: lung, prostate, spine, pancreas, breast, rectum and HN. Hypo-fractioned VMAT plans were generated using Elekta Agility MLC in Pinnacle TPS. Both FF and FFF plans were optimized using the same objectives and constraints. The following plan complexity metrics were assessed: total plan MU, mean aperture area (MAA), mean leaf gap (MLG), mean perimeter area ratio (MPAR), and modulation complexity score (MCS). Paired 2-sided Wilcoxon signed-rank test was used to test for differences**. Results:** A total of 20 pairs of plans were generated. Similar plan qualities were achieved between FF and FFF plans. FFF plans resulted in higher aperture complexities, as indicated by larger MU/MPAR and smaller MAA/MLG/MCS values. The differences were: 278 ± 178 for total plan MU ($p < 0.01$), -2.0 ± 2.6 cm^2 for MAA ($p < 0.01$), -0.2 ± 0.2 cm for MLG ($p < 0.001$), 0.18 ± 0.17 cm^{-1} for MPAR ($p < 0.001$) and -0.02 ± 0.02 for MCS ($p < 0.001$). Similar results were observed when divided all plans into two subgroups based on PTV volumes (Vptv < 100 cm^3 and > 200 cm^3, 10 cases each)**. Conclusion:** There were small but statically significant differences in all complexity metrics suggesting slightly more complex aperture shapes in FFF plans. However, the differences were quite small and not likely to cause any difference in dose calculation uncertainties.

TU-F115-IePD-F3-02, Standardized Commissioning Approach for VersaHD Linacs to Use a Single Beam Model: L Fisher, P Potrebko, A Sutter, T Nurushev, T Fox, S Patton*, GenesisCare, Fort Myers, Florida

Purpose: To validate the commissioning and feasibility of using a single beam model for IMRT and VMAT treatments across multiple VersaHD linacs (Elekta AB). **Methods:** Ten linacs underwent standardized commissioning, and a single beam model was utilized in the Monaco treatment planning system (TPS). Profile data was matched to within 0.5% of the accelerated go-live (AGL) data. Vendor-supplied MLC modeling test fields (ExpressQA) were used to evaluate the accuracy of MLC modeling parameters such as leaf transmission, tip leakage, and offsets for each beam energy. The fields were irradiated using the MapCheck3 (Sun Nuclear). A gamma criterion of 2%/2mm with an expected pass rate of > 95% was used for ExpressQA analysis. Seven AAPM TG-119/TG-244 test plans were used to validate model accuracy for both IMRT and VMAT deliveries. The validation data was collected using a MapCheck3 or ArcCheck. The plans were compared using a gamma criterion of 3%/2mm with a pass rate of >95%. **Results:** For ExpressQA, the mean passing rate was 96.1±3.1%, 93.7±3.7%, 96.7±4.2%, and 96.2±2.9% for 6X, 10X, 6FFF, and 10FFF, respectively. For TG-119/TG-244 plan validation, the mean passing rate for all the energies ranged from 95.8±2.4% to 98.5±1.3%. The gamma (3%/2mm) passing rate averaged over the 10 linacs and QA devices was 97.3±1.6% for all validation plans. By utilizing identical parameters in the MLC TPS model, the commissioning time for physics effort was reduced by 33% (~40 hours of time savings). **Conclusion:** This study demonstrated that a single beam model (AGL model) for VMAT/IMRT delivery is a feasible option for clinics with multiple VersaHD machines. Dosimetric matching to the standard AGL data, without MLC model manipulation, produced excellent passing rates, shortened commissioning times, and facilitated centralized planning.

TU-F115-IePD-F3-03, Clinical Validation of a User Defined Ethos Flattening Filter Free Beam Model in RayStation: D McClatchy*, C Foote, S Yan, J Pursley, Massachusetts General Hospital, Boston, MA

Purpose: Varian Ethos and Halcyon ring delivery system (RDS) linacs come with preconfigured and locked beam models on the Ethos and Eclipse treatment planning systems (TPSs), forcing users to rely on the vendor-supplied models. Here we report on clinical validation of a user defined RDS beam model in a third party TPS (RayStation 10A, RaySearch), which gives the user flexibility to match their clinical linac**. Methods:** A RayStation 6MV FFF collapsed cone beam model was created for an Ethos RDS based on clinical commissioning data. A total of 17 VMAT plans with a range of large and small target sizes were generated for 10 previously treated genitourinary patients by certified medical dosimetrists according to clinical standards. Dose was recalculated in the Ethos TPS when the plans were imported into Ethos. Plans underwent point-based second dosimetry check (Radcalc, LAP) and 3D comparison against a preconfigured beam model (Mobius, Varian). Next, plans were delivered on a 3D diode array (ArcCheck, SunNuclear) with a centrally located micro-ion chamber (PinPoint, PTW), and trajectory log files were used to reconstruct 3D delivered dose in Mobius**. Results:** The mean difference between RadCalc and RayStation point-dose calculations was 1.2%. The mean 3D gamma between RayStation dose versus plan based and trajectory log file-based Mobius dose was 99.9% and 99.8%, respectively. The mean 3D gamma at 3%/3mm between the ArcCheck measurement versus RayStation and Ethos dose was 99.0% and 99.1%, respectively, with a mean absolute difference of 0.8%. The mean 3D gamma at 1%/3mm and 2%/2mm between the ArcCheck measurement versus RayStation was 93.5% and 92.4%, respectively. The mean difference between measured micro-ion chamber point-dose and RayStation planned dose for the chamber was 0.9%**. Conclusion:** A third party TPS can accurately model RDS linacs and be used to generate treatment plans for an otherwise single vendor standalone system.

