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Monte Carlo (GATE/Geant4) Estimation of Clinician Hand Dose from Radionuclide Injection

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Purpose: To develop an API based automated treatment planning tool for lung stereotactic radiation therapy**Methods:** The automated treatment planning tool is a combination of two components: a patient anatomy dependent beam setup (including gantry, collimator and couch optimization) and an a priori model-based optimization setup. The initial component of the software creates two VMAT fields. The gantry angles, collimator angles, couch angles and isocenter placement depend on the patients' planning CT data and physician orders. Deciding factors include, but are not limited to, the request of gated delivery, number of targets, and presence and location of implanted cardiac devices.The second component of this software creates preliminary optimization goals depending on the size and location of both the targets and organs at risk. The priorities of the optimization objectives are determined from both previous plans generated in an a priori fashion and from proximity based analytical functions of targets to organs at risk. The physician orders for target coverage and organ at risk dose constraints are evaluated on the optimized plan. If any constraints are not met, the tool performed re-optimization automatically with appropriate updates to objective values and priorities**. Results:** The tool has successfully planned 20 lung SBRT patients including the following: both single and multiple targets in one isocenter, gated treatments, patients with implanted cardiac devices, and patients with prior thoracic radiation history. Two separate radiation oncologists reviewed the clinical acceptability of the plans generated by the treatment planning tool**. Conclusion:** Compared to a manual treatment planning workflow, an automated treatment planning tool demonstrated similar quality treatment plans. The goal of this tool is to decrease overall planning time for lung SBRT and to consolidate the process into a set of rules. Future goals for this tool include the improvement of plan consistency between patients.

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Dosimetric Evaluation of Different Rotating Gamma Ray System Designs

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Purpose: Rotating gamma ray systems have been developed for stereotactic radiosurgery (SRS) and fractionated stereotactic radiotherapy (SRT). Different designs are available commercially that differ in the source number, source dimensions, and source distribution/arrangement. In this study, we investigated two designs with regard to their capabilities and dosimetric parameters for SRS/SRT**. Methods:** The CybeRay system (OUR United RT Group, Xian, China) consists of a ring gantry containing 13 Co-60 sources focusing at the isocenter with 7 changeable collimators. The treatment head can also swing 35° in the superior direction. Galaxy RTi (Akesis, Concord, CA) contains 30 Co-60 sources, which can rotate as a group creating 30 non-overlapping arcs. It includes 4 changeable collimators. Both systems are equipped with inline cone beam CT for real-time image guidance, which share the same isocenter with the treatment beams. Ten previous patients treated on the GammaKnife were unarchived from our clinical database. Treatment plans were generated for the two machines using the Prowess TPS (Prowess, Concord, CA). Plans were evaluated based on the beam-on time, conformity index (CI), isodose distribution, and dose-volume histograms**. Results:** Comparable planes were achieved in most cases. The mean beam-on time for the studied cases was 25 minutes for CybeRay as compared to 17 minute for Galaxy. The mean CI was in the order of 1.9 for CybeRay as compared to 1.7 for Galaxy. Galaxy showed faster dose fall off in the axial view compared to CybeRay as can be seen by the spread of the lower isodose lines. On the other hand, the ring configuration of CybeRay allows treatment of extra-cranial body sites**. Conclusion:** Both systems were capable of producing superior clinical treatment plans to meet our clinical acceptance criteria although Galaxy is specific for intracranial SRS/SRT while CybeRay is also capable of stereotactic body radiotherapy (SBRT).

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Monte Carlo (GATE/Geant4) Estimation of Clinician Hand Dose from Radionuclide Injection

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Purpose: To determine the average absorbed hand dose to the administering clinician from radionuclide injection of Ra-223 dichloride (Xofigo) and Lu-177 dotatate (Lutathera) over a 1-minute injection**. Methods:** BD 10 mL and 60 mL syringes, radioactive sources, and 2 mm thick tungsten syringe shields were modeled utilizing the GATE/Geant4 environment language. Various simulations were conducted to approximate injections with and without syringe shields: the traditional case simulating a prototypical injection, and the extreme case in which a clinician clenches the syringe with their hand centered directly over the source. Each simulation transported 50 million particles using the emstandard_opt4 physics list. Alpha, beta, and gamma emission probabilities and radioactive materials were user-defined within GATE based on the literature and prescribing information**. Results:** For Lutathera, average absorbed dose to the hand was found to be on the order of 700 µGy/min and 20 µGy/min for the extreme and traditional cases respectively. For Xofigo, in the non-shielded syringe, average absorbed dose to the hand was found to be on the order of 3 µGy/min and 0.01 µGy/min for the extreme and traditional cases. Shielded Xofigo syringes produced average estimates of doses to the hand on the order of 0.05 µGy/min. In the extreme scenario, for the same clinician injecting one patient per day for 250 workdays, a total annual dose to the hand would be approximately 700 µGy for the unshielded syringe and 10 µGy for the shielded syringe. **Conclusion:** Syringe shields were found to reduce dose from Xofigo by a factor of 52 in the extreme case and 3.1 in the traditional case. We estimate that reaching the annual occupational exposure limit of 500 mSv would take approximately 12 hours of time clenching an unshielded Lutathera syringe- which is never recommended. Clinicians should take care while delivering radionuclides to observe ALARA principles.

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The Capabilities and Characteristics of Helical Tomotherapy and Volumetric-Modulated Arc Therapy in Sparing the Hippocampus During Prophylactic Cranial Irradiation

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Purpose: To investigate the capabilities and characteristics of helical tomotherapy (HT) and volumetric-modulated arc therapy (VMAT) in sparing the Bilateral hippocampal tissues (BHT) during prophylactic cranial irradiation (PCI). **Methods:** HT and VMAT treatment plans were generated with a prescription dose of 30Gy/10 fractions in 16 patients treated with PCI. The dosimetry parameters of BHT, organs at risk (OARs), and planning target volume (PTV) were determined when the average dose of BHT was reduced by about 4Gy to serve as an observation point. Statistical plots were used to present dosimetry changing trends when sparing the BHT with both HT and VMAT technologies**. Results:** HT plans spared BHT V7.3Gy by up to 40%, with the average Dmean-BHT = 8.42±0.41Gy, while VMAT plans failed to spare BHT V7.3Gy by such an amount. HT authored significantly lower doses to OARs, including Dmean-BHT (HT 16.37Gy vs. VMAT 17.81Gy, P=0.03), Dmean-inner ear (P=0.02), Dmean-parotid glands (P=0.02), Dmax-lens (P=0.02), and Dmax-brainstem (P=0.02), except for Dmax-optic nerves (P=0.87), compared to VMAT. Also, compared to VMAT, HT plans provided better target coverage, with lower average D2% (P=0.02), higher average D98% (P=0.02), and better conformal index (0.87 vs. 0.84, P=0.02) and homogeneity index (0.15 vs. 0.21, P=0.05). With smaller BHT doses, the dose distribution to PTV occurred in three dosimetry regions for both HT and VMAT plans; the plateau region (>20.0Gy for HT vs >16.0Gy for VMAT), gradient region (20.0-12.0Gy vs 16.0-11.0Gy), and falling region (<12.0Gy vs <11.0Gy). The average delivery duration for HT was determined at almost 7.7 times longer than VMAT**. Conclusion:** Compared to VMAT, HT was better at sparing the BHT and OARs and had better target coverage but much longer treatment duration. More BHT dose decreases would yield worse target dose coverage, which would present a 'three regions' stair-stepping characteristic.

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