Poster Viewing Abstract 3446; Table Median (range) volume brain tissue exposed to radiation

Isodose line (%)	I-125 (cc)	Cs-131 (cc)	*P* value
100	13.75 (3.49-52.6)	6.03 (143-32.96)	.0339
80	17.90 (4.82-67.10)	8.24 (2.46-43.50)	.0389
50	31.13 (8.87-109.40)	15.40 (5.10-76.10)	.0486
30	55.86 (16.86-182.00)	29.40 (10.12-135.90)	.0624

radio-isotopes when used as a permanent implant for patients with resected brain metastasis.

Materials/Methods: After the IRB-approval of the prospective trial, 24 patients with a single newly diagnosed and resected brain metastasis were implanted with Cs-131. In 2003, FDA cleared Cs-131 which has shorter half life ($T_{1/2} = 9.7$ days) as compared to I-125 ($T_{1/2} = 59.4$ days). It is likely more biologically efficient for tumor cell kill as the initial dose rate from Cs-131 is about 4.1 times higher than that of I-125 (I-125: 5.8 cGy/h; Cs-131: 23.9 cGy/h). Two days after the surgery, the patients underwent CT scans. Post-op dosimetry plans were generated for Cs-131, and the same CT data set was re-planed for each patient with I-125 seeds using model #6711. The prescription dose was 80 Gy to 5 mm depth from the surface cavity. The mean air kerma strength for the Cs-131 and I-125 seeds was 2.4 U (3.768 mCi) and 0.6985 U (0.55 mCi), respectively. The Dose Volume Histogram was generated, and from it the volume of brain tissue (cc) exposed to radiation at the 100%, 80%, 50%, and 30% isodose lines were compared for both radioactive isotopes.

Results: Table displays the median volume (cc) of brain tissue exposed to radiation and compares each median volume of the corresponding isodose line between two isotopes. There is a significantly smaller volume of brain tissue exposed to radiation with the use of Cs-131, as compared to I-125, for the 100% ($p = 0.0339$), 80% ($p = 0.0389$) and 50% ($p = 0.0486$) isodose lines, and is trending towards significance for the 30% isodose line ($p = 0.0624$).

Conclusions: In this analysis, we report that Cs-131 exposes less normal brain tissue to radiation, thus providing a dosimetric superiority and subjecting less tissue to RN. Further, with a median follow-up of 10 months, all 24 patients have 100% clinical local control while experiencing 0% incidence of RN.

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Optimizing 3D Conformal Plans for 4π Non-Coplanar Converging (4PiNC) Beams Using a Genetic Algorithm

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Purpose/Objective(s): 4PiNC beam delivery can significantly improve the plan quality for radiation therapy. We have proposed a novel 4PiNC beam delivery system, in which the X-ray source aims at the isocenter but rotates around a point on the superior-inferior axis in a conical fashion. In this study, we investigated an automatic beam optimization algorithm for the proposed system to select the beams that produce the best planning target volume (PTV) coverage while sparing the organs at risk (OARs).

Materials/Methods: Mathematically, each rotation of the proposed 4PiNC system forms a cone where the vertex is the isocenter and the base is the area bounded by the circular trajectory of the x-ray source. By changing the cone angle (90 - vertex angle), this system allows hundreds of non-coplanar beams to be delivered without couch rotation. Since not all beams are "good," we developed a genetic algorithm (GA) to select the beams that will minimize the cost function of predefined importance factors including PTV coverage, conformity index and dose to OARs. For each generation, the GA produces a number of offspring by randomly turning on or off a group of randomly selected beams from the parent. The cost function for each offspring is evaluated and the offspring with the minimum cost function is selected as the parent for the next generation. This process is repeated until all preset OAR constraints are met. We tested this GA on a prostate (600 cGy x 5) case and a pancreas (650 cGy x 5) case using 179 4PiNC beams distributed among 5 cone angles (−40°,−20°, 0°, 20°, 40°). Two beam openings were examined: (1) PTV, i.e., the beam eye view conformed to the PTV or (2) PTV-OAR which is similar to (1) except that the OAR was blocked. Traditional IMRT plans were also produced for both cases using the same OAR constraints. Mean PTV dose (D_{PTV}) and V95 of all plans were calculated for comparison.

Results: Each plan was renormalized to max out the OAR dose constraints. For the prostate case, the PTV optimization selected 68 beams and produced a 3D conformal plan ($D_{PTV} = 3048$ cGy, V95 = 93%) comparable to the IMRT plan ($D_{PTV} = 3117$ cGy, V95 = 95%). The PTV-OAR optimization selected 136 beams and had the best OAR sparing but the PTV coverage was insufficient ($D_{PTV} = 3553$ cGy, V95 = 63%). For the pancreas case, the PTV plan (85 beams, $D_{PTV} = 3305$ cGy, V95 = 90%) was also comparable to the IMRT plan ($D_{PTV} = 3297$ cGy, V95 = 90%).

Conclusions: The developed GA provides a simple but effective method for selecting "good" 4PiNC beams that are conformed to PTV with minimal OAR exposure. The selected beams can produce 3D conformal plans comparable to traditional IMRT plans. This GA can also be used to select beams for 4PiNC IMRT planning to reduce the computation burden for IMRT optimization. We are currently comparing 4PiNC 3D conformal plans with VMAT plans for other treatment sites.

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An Innovative Method for Patient-Specific Pretreatment Plan Verification (PTPV) in Head and Neck Radiation Therapy Treatments: Preliminary Results

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Purpose/Objective(s): The purpose of this study is to present preliminary results of a novel and innovative methodology for a personalized PTPV in head and neck radiation therapy treatments. The proposed methodology aims to overcome the well-known problems that current PTPV methods exhibit, among which is that they are not actually patient specific at least in terms of patient geometry.

Materials/Methods: The core innovative idea of the proposed method is to use each individual patient CT-planning images and 3D-printing technology in order to construct a patient-specific 3D-hollow phantom that will duplicate the patient external and internal geometry (in terms bone structures). A patient-specific head phantom has been constructed and then filled with VIPET polymer gel substance, acting therefore also as a 3D-dosimeter. The patient-specific phantom-dosimeter was then treated as the real patient, i.e., was positioned and irradiated using the real patient plan. The irradiated phantom was then MRI-scanned in order to extract the 3D high spatial resolution actually delivered dose distribution. The MR-images of the patient-specific phantom containing the measured dose distributions were subsequently registered to the treatment planning (TP) real patient CT-images that contained the dose distribution calculations. A 3D gamma-index comparison between the measured and calculated dose distributions was followed.

Results: The proposed methodology revealed, via the 3D gamma-index analysis, a satisfying matching between the measured and the TP calculated 3D-dose distribution. Moreover, the dose pattern position relative to the patients anatomical bone structures was found to be delivered with ∼ 1.8 mm spatial deviation relative to the corresponding calculated position using TP data (combined delivery and set-up errors estimation).

Conclusions: Preliminary results of a real personalized pre treatment plan verification methodology are presented for the first time. It is a promising method that overcomes currently present PTPV problems and that could be useful in selected difficult and demanding head and neck radiation therapy treatments.

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Effect of Dose Gradient on the Incident Probability of Brain Metastases in Hippocampal-Sparing Whole Brain Irradiation

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Purpose/Objective(s): Whole-brain irradiation (WBI) for brain metastases can result in cognitive side effects. Hippocampal sparing WBI is one strategy to decrease morbidity, but it carries the likelihood of underdosing lesions near the hippocampus due to the unavoidable dose gradient from the hippocampal surface to a prescription isodose surface such as 30 Gy. The primary objective of this study was to examine the potential impact of such dose gradients on the hippocampal sparing WBI, under variable low doses that can be delivered to spare the hippocampi.

Materials/Methods: Helical intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) treatment plans for a whole-brain hippocampi-sparing treatment were developed for a sample patient. For all plans, 30 Gy were prescribed in 10 fractions to result in mean hippocampal doses ranging from 10 Gy to 6 Gy. The helical IMRT plans were developed for a field width of 1 cm, a 0.3 pitch, and a modulation factor of 2. The VMAT plans were calculated using 4 coplanar arcs with a high definition 120 MLC. From a series of expanded red shells (Yang et al., IJROBP 77:903 2010), we determined the distance from the hippocampus at which the parenchyma would receive less than specified doses (30, 25, 20, 15, and 10 Gy, etc). Using data from Ghia et al. (IJROBP 68:971 2007), the incident probabilities of potential brain metastases receiving these doses were calculated.

Results: For a desired low dose to the hippocampi such as 10 Gy, the dose coverage for the whole-brain volume including hippocampi was $> 95\%$, while the maximum dose was $< 110\%$ for both helical IMRT and VMAT treatment plans. The distance for the dose fall-off from 30 Gy to 10 Gy was on the order of 25 mm for the helical IMRT plan and 35 mm for the VMAT treatment plan. Within these dose fall-off distances, the incident probability of brain metastases was calculated to be 17% for the helical IMRT and 26% for the VMAT treatments. For all treatment plans, regardless of treatment modality, dose gradients were found to decrease sharply (by almost a factor of 4 from 4.1% per mm to less than 1% per mm) at a distance of approximately 15 mm from the hippocampi.

Conclusions: Dose gradients near hippocampi must be sufficiently sharp (e.g., 4% per mm or higher) in order to achieve reasonable hippocampal-sparing WBI. Our results can aid in weighing the benefit of decreased dose to the hippocampi against the cost of decreased dose to potential brain metastases when deciding on the treatment approach.

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A Dosimetric Feasibility Study Using Forward Planning Segmental Field Technique for Stationary Craniospinal and Spinal–Sacral Junctions in Craniospinal Axis Irradiation

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Purpose/Objective(s): Moving junctions, referred to as "field feathering," are currently used in craniospinal axis irradiation to improve dose uniformity across the craniospinal (CS) or spinal-sacral (SS) junctions at match lines. The technique requires complex planning, time-consuming treatment verification and dose delivery. The purpose of this study is to incorporate forward planned segmented field (FPSF) technique to deliver homogenous dose at the proposed stationary CS and SS junctions, while simplifying CSI treatment planning, verification, and delivery.

Materials/Methods: Two pediatric and three adult patients treated with field feathering craniospinal irradiation for medulloblastoma were retrospectively re-planned with a stationary single match line at CS and SS junctions. The two pediatric patients were treated in a supine position while the three adults were treated prone. A matched stationary junction was created at the CS junction where collimated opposed lateral cranial fields were matched or minimally overlapped with the superior border of the spinal PA field for all pediatric and adult patients. Similarly, a matched stationary junction at the SS junction was created where the static spinal PA beam abutted or minimally overlapped with the superior border of the static PA sacral field in adult patients. The dose homogeneity index (HI) for the length of the cord 3 cm above and below each junction was compared between FPSF and field feathering techniques. (Homogeneity index is defined as HI = [Dmax-Dmin]/[Dmax+Dmin] x 100% where Dmax and Dmin represents maximum and minimum dose covering the regions of interest, respectively.)

Results: The average HI obtained with field feathering and FPSF techniques at the junctions were $7.67\% \pm 2.84\%$ and $8.05\% \pm 2.93\%$, respectively, without significant statistical difference ($p = 0.6$).

Conclusions: The results show that uniform dose distribution within junctions of a craniospinal axis irradiation plan can be achieved by FPSF technique without the need for feathering, creating gaps, or applying additional patch fields. FPSF technique offers efficiency in time required for planning, dose delivery, and daily or weekly port imaging. To minimize random positioning errors while delivering superior dosimetry to stationary junctions, daily image guided radiation therapy and dose delivery verification prior to initiation of treatment is recommended. FPSF technique should be further evaluated for cranial spinal axis irradiation.

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