A Dose-Painting Technique for Rotating Gamma SRS/SBRT Systems

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PURPOSE / OBJECTIVES

Conventional sphere-packing techniques (Figure 1) for Gamma Knife treatment plan optimization often produce less conformal dose distributions for non-spherical targets and are inefficient for dose delivery. This work investigates a dose-painting technique to improve dose conformity and delivery efficiency for rotating Gamma SRS/SBRT systems.

MATERIAL & METHODS

This technique is based on the CybeRay system (OUR United RT Group, Xian, China), which consists of a ring gantry and a focusing treatment head with 16 Co-60 sources of 6.22 mm diameter. Each source has 7 collimators of 6, 9, 12, 16, 20, 25 and 35 mm diameter. The treatment head can swing 35° superiorly, allowing a total of 43° non-coplanar beam incident. The kV CBCT system provides real-time target/fiducial tracking and the EPID system verifies the delivered dose for auto-quality assurance. The dose-painting technique scans the focused Gamma beams via an optimized isocenter trajectory inside the target volume (Figure 1) combining gantry rotation (speed: 1.25 - 3.5 °/s) and couch movement (speed: 0.03 - 0.47 mm/s). Ten previously treated brain, lung and liver patients were re-planned with the same clinical goals and evaluated based on target coverage (%PTV receiving prescription dose), CI (prescription isodose volume/PTV) and beam-on time.

RESULTS

Table 1 show plan comparison results using different planning techniques. Ensuring good target coverage (97 ± 1 %) for all treatment plans, the dose-painting technique provided better dose conformity for all patients investigated (mean CI = 1.12) than the manual and auto sphere-packing techniques (mean CI = 1.36 and 1.21, respectively). The beam-on time was also significantly reduced with the dose-painting technique (mean T = 14.8 min) compared to manual and auto sphere-packing techniques (mean T = 21.3 min and 17.3 min, respectively). The dose-painting technique also ensured hot spots to be inside the CTV for large and irregularly shaped targets (Figures 2-5).

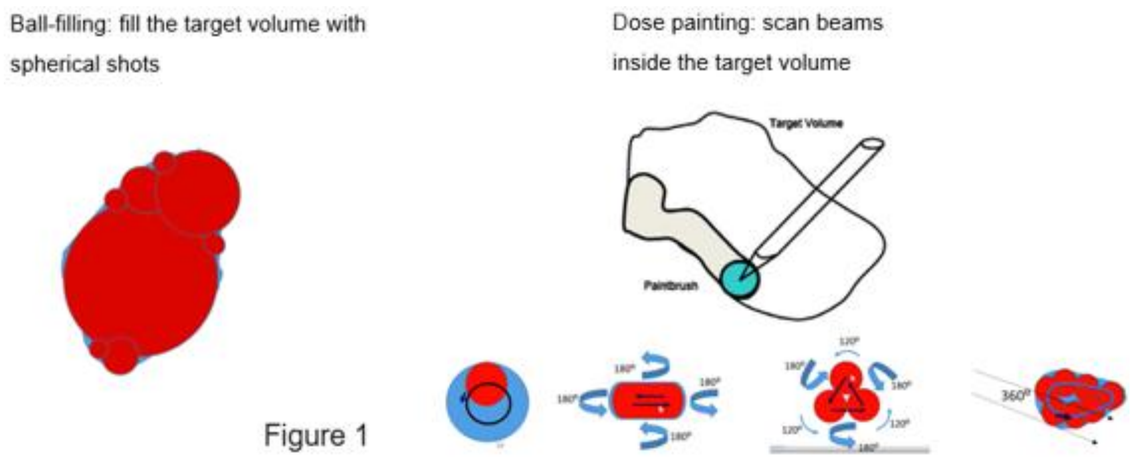

Figure 1

	Coverage Index	Conformity Index	Beam-on time
Dose Painting (time driven)	96.9%	1.17	**14.84**
Dose painting (CI driven)	96.0%	1.12	19.76
Ball-filling (inverse)	96.6%	1.19	17.3
Ball-filling (manual)	**97.8%**	1.36	21.29

Table 1 Mean values for target coverage (percent PTV receiving the prescription dose), target dose conformity CI (prescription isodose volume/PTV) and total beam-on time for treatment plans using different planning techniques: (1) dose painting focusing on delivery time, (2) dose painting focusing on dose conformity CI, (3) automated ball-filling optimization, and (4) manual planning using ball-filling technique.

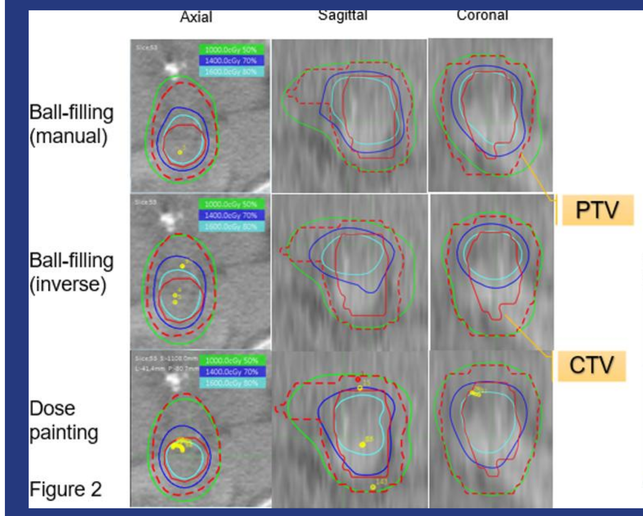

Figure 2

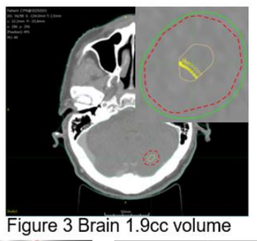

Figure 3 Brain 1.9cc volume

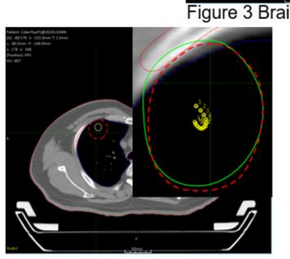

Figure 4 Lung 33.5cc volume

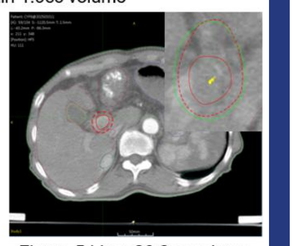

Figure 5 Liver 26.2cc volume

As is shown in Figures 6 and 7, the gantry rotation and couch motion variations are well within the machine specifications for CybeRay. The gantry rotation speed varies between 1 and 3.5 degrees per second, which is below the typical rotation speed limit of 6 degrees per second, and the couch movement speed is below 1.4 mm per second.

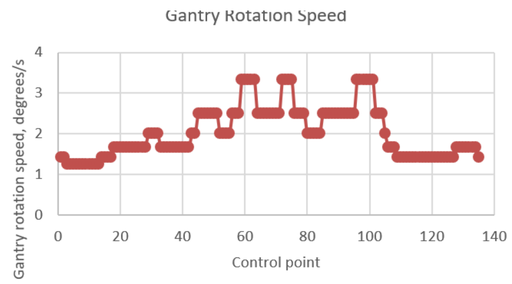

Figure 6

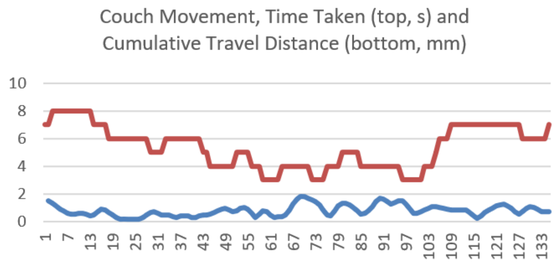

Figure 7

SUMMARY / CONCLUSION

The new dose-painting technique can deliver high-quality treatments with superior target coverage, high dose conformity and significantly reduced treatment time for rotational Gamma SRS/SBRT systems compared to conventional sphere-packing techniques commonly used in Gamma Knife SRS/SRT planning.