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Dosimetric results for stereotactic radiosurgery using a self-shielded gyroscopic radiosurgery system for meningioma patients

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ABSTRACT

Purpose: This study presents dosimetric results for stereotactic radiosurgery (SRS) using a self-shielded gyroscopic radiosurgery system for meningioma patients.

Methods: Eighteen single-lesion meningioma patients, who were treated using ZAP-X® Gyroscopic Radiosurgery® platform, were selected and divided into two groups (Group A [thirteen patients]: 25 Gy in 5 fractions, fractionated SRS (FSRS); Group B [five patients]: 15 Gy in a single fraction, SRS). Clinical plans performed in the ZAP-X treatment planning system and independent dose calculations performed using an in-house tool and patient-specific quality assurance (PSQA) performed using SRS MapCHECK were reviewed and analyzed for each group.

Results: For Group A, mean age (range) was 60 years (35 years - 80 years) and mean planning target volume (PTV) (range) was 4.78 cc (2.10 cc - 9.38 cc). Mean (range) PTV coverage, prescribed isodose line, Paddick conformity index, gradient index, number of isocenters, number of beams, delivery time estimate per fraction and PSQA gamma passing rate were 99.5% (99.5% - 99.6%), 53.5% (50.1% - 61.3%), 0.89 (0.83 - 0.93), 2.64 (2.54 - 2.88), 11.8 (5 - 19), 208.5 (91 - 332), 43.6 min (24.5 min - 61.0 min) and 95.0% (91.5% - 98.4%), respectively. For Group B, corresponding values were 70 years (62 years - 75 years), 1.12 cc (0.77 cc - 1.99 cc), 99.5% (99.5% - 99.5%), 56.4% (50.6% - 62.8%), 0.89 (0.85 - 0.93), 2.95 (2.63 - 3.22), 7.2 (5 - 9), 102.4 (81 - 132), 33.9 min (27.3 min - 38.9 min) and 95.3% (91.1% - 100.0%). For all beams in both groups, independent dose calculations were <±0.02% of treatment planning system dose calculations.

Conclusion: Our experience with SRS and FSRS using the ZAP-X system for meningioma patients demonstrated that treatment plans met our institutional planning goals and were concordant with independent dose calculations and PSQA.

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INTRODUCTION

The ZAP-X® Gyroscopic Radiosurgery® platform (Zap Surgical Systems, Inc., San Carlos, CA) is a novel self-shieled image-guided radiotherapy device developed for frameless stereotactic radiosurgery (SRS) and fractionated stereotactic radiosurgery (FSRS) of intracranial and cervical spine lesions.[1] Early dosimetry/physics characterization work and the first two-year machine performance have demonstrated safety and accuracy of the system for SRS.[2-3]

Since early 2019, the ZAP-X has been in clinical operation worldwide. Despite the brief history of the system, various intracranial conditions, including malignant tumors (e.g., brain metastases), benign tumors (e.g., meningioma, pituitary adenoma, neurocytoma, and hemangioma), functional disorders (e.g., trigeminal neuralgia) and vascular disorders (e.g., arteriovenous malformation) have been treated using the ZAP-X.[4-5] Dosimetric performance, patient satisfaction, and short-term outcomes reported by the users have suggested the suitability of this device for SRS.[4-5]

In 2024, a ZAP-X unit was installed and commissioned at our institution (Figure 1), and since then, many meningioma patients have been treated. Here, we report dosimetric results for SRS using this novel delivery system for meningioma patients.

Figure 1. ZAP-X unit

MEMTHODS AND MATERIALS

Eighteen (n = 18) single-lesion meningioma patients, who were treated using our treatment workflow (Figure 2), were included in this report. While thirteen patients received FSRS to a planning target volume (PTV) (=gross tumor volume + 1-mm margin), with a regimen of 25 Gy in 5 fractions (Group A), the rest received SRS to the PTV to 15 Gy in a single fraction (Group B). These regimens were specifically selected using institutional prescription guidelines. This study was approved by our Institutional Review Board.

Clinical plans, performed in the ZAP-X treatment planning system and independent dose calculations performed using an in-house tool and patient-specific quality assurance (PSQA) performed using SRS MapCHECK (Sun Nuclear, Corp., Malborne, FL), were reviewed and analyzed for each group.

Figure 2. ZAP-X treatment workflow in our clinic

RESULTS

For Group A, the mean (range) age was 60 years (35 years - 80 years) and the mean (range) PTV was 4.78 cc (2.10 cc - 9.38 cc). The mean (range) PTV coverage (COV), prescribed isodose line (Rx IDL), Paddick conformity index (PCI), gradient index (GI), number of isocenters, number of beams, delivery time estimate per fraction and PSQA gamma passing rate were 99.5% (99.5% - 99.6%), 53.5% (50.1% - 61.3%), 0.89 (0.83 - 0.93), 2.64 (2.54 - 2.88), 11.8 (5 - 19), 208.5 (91 - 332), 43.6 min (24.5 min - 61.0 min) and 95.0% (91.5% - 98.4%), respectively (Figures 3 and 5). For Group B, corresponding values were 70 years (62 years - 75 years), 1.12 cc (0.77 cc - 1.99 cc), 99.5% (99.5% - 99.5%), 56.4% (50.6% - 62.8%), 0.89 (0.85 - 0.93), 2.95 (2.63 - 3.22), 7.2 (5 - 9), 102.4 (81 - 132), 33.9 min (27.3 min - 38.9 min) and 95.3% (91.1% - 100.0%) (Figures 4 and 5). For all beams in both groups, independent dose calculations were <±0.02% of treatment planning system dose calculations (Figure 5).

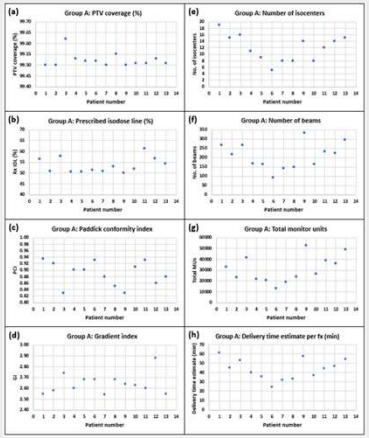

Figure 3. (a) Plan quality metrics of ZAP-X treatment plans for thirteen meningioma patients with a single lesion in Group A (5 fractions)

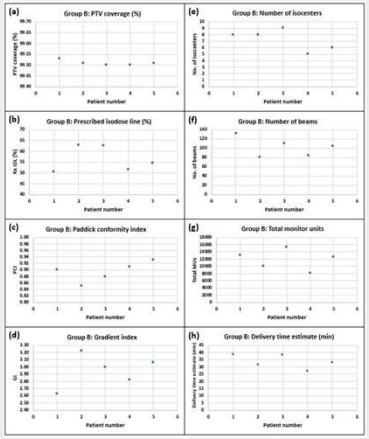

Figure 4. (a) Plan quality metrics of ZAP-X treatment plans for five meningioma patients with a single lesion in Group B (single fraction)

RESULTS

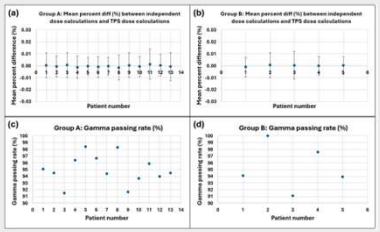

Figure 5. Mean differences (%) between independent dose calculations performed by our in-house tool and ZAP-X TPS dose calculations for all beams for (a) Group A (5 fractions) and (b) Group B (single fraction) and gamma passing rates (%) of PSQA with gamma criteria of 2%/1 mm for (c) Group A and (d) Group B

DISCUSSION

While all treatment plans for Group A (5 fractions) met our institutional planning goals, two of the five plans for Group B (single fraction) had GI greater than 3.0. Both of these plans (GI >3.0) had PTV <1.0 cc. Ehret et al conducted a prospective study for SRS treatments using the ZAP-X system and reported analysis for the first 100 patients with 155 lesions.[6] Their study included brain metastases, vestibular schwannomas and meningiomas treated in a single fraction but analysis was performed for the three diseases combined.[6] For PTV of 0.34 cc - 2.69 cc (25% - 75% interquartile range), PCI and GI ranged from 0.78 to 0.84 and from 2.88 to 3.41, respectively, with PTV COV of 96.7% - 99.1%.[6] In contrast, for Group B (PTV of 0.77 cc - 1.99 cc) in our patient population, PCI and GI were 0.85 - 0.93 and 2.63 - 3.22 respectively, with a higher PTV COV ≥99.5%. Smaller PCI and greater GI in Ehret et al's study could be attributed to irregular shape of PTV (vestibular schwannoma) and smaller PTV (brain metastases). Rx IDL in their study (52.0% - 62.0%) was comparable to that in our cohort (50.6% - 62.8%).[6] It is noted that there were only five patients in Group B and PTVs in Group A were too large (2.10 cc - 9.38 cc) to compare analysis for those (25% - 75% interquartile range) in Ehret et al.

CONCLUSIONS

Our experience with SRS and FSRS using the ZAP-X system for meningioma patients demonstrated that treatment plans met our institutional planning goals and were concordant with independent dose calculations and PSQA.

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