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Dosimetric Comparison of Fractionated Radiosurgery (FSRS) Treatment Plans for Large Brain Metastases Using Gyroscopic Radiosurgery Delivery System

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Abstract
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Abstract

Objectives:

ZAP-X, a novel, self-shielded, non-invasive radiosurgery system, has significantly advanced since its inception through enhancements in imaging integration, treatment planning software, and overall delivery accuracy. The latest DP-1010 software release, along with hardware upgrades inclusive of an MV imager and a new couch model enabling a larger solid angle for beam delivery, introduces new features such as improved auto isocenter placement, robust linear inverse optimization, GPU-based dose calculation, increased virtual dose-shaping points for sharper dose fall-off, and additional beam paths compared to the currently available version (DP-1008). This study aims to quantify differences in treatment plan quality metrics between the ZAP-X treatment planning software DP-1008 and DP-1010 for large (>2 cm) brain metastases (BMs).

Methods:

Twenty patients (10 with large intact BMs treated to 27 Gy in 3 fractions and 10 post-operative resection cavities [RC] treated to 30 Gy in 5 fractions) were planned using the latest platform (DP-1010) and the previous version (DP-1008). Plans were optimized to meet organ-at-risk (OAR) dose constraints, achieve a minimum target coverage (TC) of ⩾ 99.5%, maximize the Paddick Conformity Index (PCI), and minimize beam-on time (BOT) and Gradient Index (GI) in this specific order of importance. Plan quality metrics and delivery parameters between the two software versions were compared for all patients using a paired Wilcoxon signed-rank test ($p< 0.05$) to evaluate statistical significance.

Results:

Mean volumes of Planning Target Volumes (PTVs) for BMs and RC were 12.5±7.3 cc and 31.9±9.1 cc, respectively. All plans met clinical goals with TC >99.5%, except for one lesion adjacent to the brainstem, where the coverage with DP-1010 was 98.4%. For BMs, the median PCI [interquartile range] was higher for DP-1008 (0.92 [0.89–0.93]) compared to DP-1010 (0.88 [0.86–0.90]), though not statistically significant ($p=0.14$). For RCs, DP-1010 plans had a significantly improved median PCI (0.93 [0.93–0.94]) compared to DP-1008 plans (0.90 [0.89–0.93]; $p< 0.05$). The median GI for BMs was 2.44 [2.37–2.51] for DP-1010 and 2.42 [2.36–2.51] for DP-1008 ($p=0.9$), while for RCs, it was 2.34 [2.32–2.36] for DP-1010 and 2.32 [2.24–2.36] for DP-1008 ($p=0.06$)—neither of which significantly different. There were no significant differences in normal brain volumes receiving 12 Gy (V12Gy) and 20 Gy (V20Gy) for BMs between DP-1010 (26.0 [22.8–51.7] cc and 13.2 [12.4–25.1] cc) and DP-1008 (24.4 [22.5–54.8] cc; $p=0.49$ and 13.6 [12.3–26.7] cc; $p=0.31$). For RCs, the mean normal brain volume receiving 24 Gy (V24Gy) was 40.4 [35.9–45.2] cc for DP-1010 and 41.1 [36.4–45.9] cc for DP-1008, with no significant difference observed ($p=0.49$). BOT were substantially longer for DP-1010 plans compared to DP-1008 for both BMs (49.0 [37.8–54.5] vs. 34.2 [26.7–41.4] minutes; $p< 0.05$) and RCs (67.0 [62.8–73] vs. 53.8 [51.1–57.9] minutes; $p< 0.05$). The number of isocenters for BMs was not significantly different between DP-1010 (12 [8–15]) and DP-1008 (10 [8–11]; $p=0.054$), whereas the number of beams was significantly greater for DP-1010 (252 [206–307]) compared to DP-1008 (194 [146–247]; $p< 0.05$). For RCs, both the number of isocenters (22 [19–24] vs. 17 [15–18]; $p< 0.05$) and beams (371 [337–438] vs. 320 [288–341]; $p< 0.05$) were significantly greater for DP-1010 compared to DP-1008

Conclusion(s):

The DP-1010 platform provides improved flexibility in beam delivery via an increased solid angle leading to additional beam paths, improved ability to target inferior and posterior regions, and offers automated tools to improve the efficiency of treatment planning. For large intracranial targets investigated in this study, plan quality metrics derived from DP-1010 were better or comparable to those in the previous version. However, DP-1010 plans were noted to exhibit longer treatment times and a higher number of isocenters and beams used compared to DP-1008. Future development initiatives in the treatment planning software may lead to future improvements in these parameters.