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Proton Stereotactic Radiosurgery Using Pencil-Beam Scanning for Intracranial Tumors: Early Experience from a Single Institution

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Abstract

Objectives:

Stereotactic Radiosurgery (SRS) is particularly useful for tumors in inaccessible locations or in patients who are unfit for surgery. One of the main challenges with SRS is minimizing the volume of irradiated brain tissue susceptible to necrosis. Proton therapy yields no exit dose, and its unique dosimetric advantages over photon-based radiotherapy can be used in SRS delivery in an attempt to minimize late radiotherapy side effects. A previously published series from the Massachusetts General Hospital demonstrated low rates of late toxicity following proton SRS delivered using passive scattering. At our institution, we have recently implemented a proton SRS program using modern pencil-beam scanning technology. Here, we present our early experience and acute toxicity data.

Methods:

A retrospective review was performed examining patients treated with proton SRS or fractionated proton SRS at our institution. Proton SRS was planned with pencil-beam spot scanning with multifield optimization and delivered using patient-specific brass apertures to reduce lateral penumbra for enhanced healthy tissue sparing. A built-in range shifter facilitated treatment at shallower depths, and intracranial fiducials were used to ensure treatment setup accuracy. Demographic, dosimetric and acute toxicity data were collected from the institutional electronic medical records and treatment planning software. Acute toxicities were graded according to Common Terminology Criteria for Adverse Events (CTCAE) Version 5.

Results:

We reviewed 13 consecutive patients, and 15 courses of proton SRS treated between June 2023 and August 2024. The most common diagnosis was arteriovenous malformations (62%), followed by meningiomas (15%), solitary fibrous tumor (8%), pituitary adenoma (8%), and acoustic neuroma (8%). 2 patients received staged treatments for AVMs. SRS doses ranged from 17Gy to 20Gy and fractionated SRS dose was 25Gy over 5 fractions. Median target volume, conformity index, homogeneity index were 6.09 cm3 (range 0.39-30.6), 1.393 (range 0.641-2.912), and 1.166 (range 1.063-2.07), respectively. Median volume of uninvolved brain tissue receiving at least 12Gy (V12) was 7.175 cm3 (range 2.252-59.31). Following SRS, peri-lesional edema on imaging was identified in 3 patients, 1 of whom was asymptomatic (grade 1), and the other 2 patients developed headaches requiring steroid administration (grade 2). Almost two-thirds (62%) of patients did not receive prophylactic steroids during treatment, including 2 patients who eventually developed perilesional edema on imaging. No other acute toxicities were noted.

Conclusion(s):

Proton SRS delivered with pencil-beam scanning represents a promising option for the treatment of intracranial lesions and can be particularly useful for the treatment of benign lesions. Peri-lesional edema can occur shortly after SRS in a small proportion of patients, and more research is needed to examine the clinical and dosimetric predictors of this phenomenon.