Cureus

When are Protons Appropriate for Radiosurgery?

Marc Bussiere [1] , Helen Shih [1] , Paula Chapman [2] , Juliane Daartz [1]

1. Radiation Oncology, Massachusetts General Hospital, Boston, USA 2. Neurosurgery, Massachusetts General Hospital, Boston, USA

Corresponding author: Marc Bussiere, bussiere.marc@mgh.harvard.edu

Categories: Radiation Oncology
Keywords: radiosurgery, proton

How to cite this abstract
Bussiere M, Shih H, Chapman P, et al. (February 11, 2022) When are Protons Appropriate for Radiosurgery?. Cureus 14(2): a742

Open Access
Abstract
Published 02/11/2022

Abstract

Objective: We provide insight into the technology and clinical application of proton radiosurgery for potential centers considering implementing such a program. Since 1961, our institution has treated more than 5600 patients with proton radiosurgery (PSRS). Over the past 6 decades the program has gone through several major technology changes. Most recently, we transitioned from passively scattered to pencil beam scanned (PBS) proton beams. Meanwhile, treatment techniques based on photon irradiation have also benefited from extensive technological improvements. When triaging radiosurgery patients between these modalities - photons and protons - the current state of technology has to inform the decision. We provide insight into proton radiosurgery, the technology, planning and delivery, describing potential pitfalls and benefits. We lay out our current triaging rationale with the aim to ensure the optimal treatment is delivered for each patient in an environment where proton and Linac based photon treatment options are available.

Methods: Commissioned radiosurgery platforms available in our clinic include a Varian TrueBeam and an IBA universal nozzle proton pencil beam scanning system. Linac techniques include static cone based arcs, dynamic conformal arcs and VMAT using 6 MV FFF. Proton beam delivery is performed using pencil beam scanning with beam-specific custom brass collimation. Treatment planning is performed using Raystation for photons and ASTROID for protons. Radiation Oncologists, Neurosurgeons, Physicists and Dosimetrists providing radiosurgery services are modality agnostic with a comprehensive knowledge of both photon and proton systems and characteristics. The technology available to deliver proton treatments vary widely and these can have a significant impact on resulting dose distributions. We describe the characteristics and impact of using passive scattering, pencil beam scanning, apertures, aperture thickness, compensators, range shifters of various thickness, air-gaps, PBS spot size, PBS dose re-painting and dose rate. Treatment planning system (TPS) functionality also has an impact on final optimization solutions and we describe desired features for PBS when used for radiosurgery. Common radiosurgery presentations are described in the context of proton therapy, including the treatment of pituitary and cavernous sinus lesions, acoustic neuromas, meningiomas, ependymoma, arterial venous malformations and metastatic disease. Using multiple case studies we describe our rationale for general exclusion for consideration of PSRS and what we look for when assessing cases that might initially be deemed viable candidates for this modality. Other, patient specific factors such as having surgical implants, high-density embolic material, and cardiac devices may also impact the triage process.

Results: Specific technological features impact the utility of proton radiosurgery for specific sites defined by lesion size, shape and location.

- Apertures are required to maximize beam penumbra - even with small PBS spot sizes, dose distributions will suffer significantly for deep seated lesions when not using apertures.
- The accuracy of the TPS dose calculation under various conditions may limit scenarios which can be treated with acceptable accuracy (> 95% gamma for 3%/1mm) - e.g. small (< 2 cc) inferior cerebellar lesion requiring a thick range shifter with a large air gap.
- Proton system imaging and non-isocentric robotic positioners may not achieve the overall setup accuracy achieved with conventional Linac.
- The dominating uncertainty for protons is the conversion of stopping power to range, requiring beam specific distal and proximal margins, typically adding an additional 3.5% to the required range. The additional margins, when using a discrete number of proton beams, compared to photon collimated arcs, results in a decreased conformality metrics which are more dramatic for small lesions.
- Density heterogeneity is of utmost importance. Permanent braids, implants and embolization material may have minimal impact with photons but increase proton range uncertainty beyond the usual 3.5%, potentially degrading conformality beyond acceptable limits.
- In general, and more so for radiosurgery, QA and treatment logistics are more complex for protons compared to well integrated vendor solutions provided for more widely used photon systems. This translates into more required resources and longer treatment times.

In general, small lesions typically do not benefit from using protons, excluding most pituitary adenomas and acoustic neuromas from the list of proton indications. Large, irregular arteriovenous malformations and superficial meningiomas may benefit the most from proton SRS.

Conclusion: Protons can provide an additional radiosurgical tool for clinics which have this option. Facility-specific systems should be thoroughly assessed to ensure all aspects of delivery and modeling are well understood. Class exclusions for proton radiosurgery should be established to ensure only patients that may benefit clinically from this modality are considered.