Proton IMPT treatment with apertures: a case study.

N. Depauw¹, J. Daartz¹, B. Clasie¹, J. Adams¹, H. Kooy¹

¹Francis H. Burr Proton Therapy Center, Department of Radiation Oncology, Massachusetts General Hospital, Boston MA 02114, USA

Context: Proton pencil beam scanning (PBS) has high target conformality and increased sparing of organs-at-risk (OAR). These dosimetric features, however, are constrained by the spot sigma (size) which determines the penumbra. The current PBS spot size at Massachusetts General Hospital (MGH) is 8 mm to 14 mm as a function of energy (high to low). Thus, the penumbra is large but can be mitigated through an edge-limiting aperture. This work demonstrates, through a case study, the advantages of combining IMPT capabilities and aperture edges.

Methodology: The case is a 14 year old male with a pelvic osteoma. The volume size (35 x 20 cm² in BEV) requires two matched fields. A sharp penumbra is necessary to spare the testes and avoid infertility. Passive scattering (PS) delivery was considered but would have required gap-sheeting with 3 sets of expensive apertures, resulting in hot and cold spots along the match lines and cumbersome delivery management. PBS intensity modulation offers the possibility for gradual feathering with two split fields using only a single set of overlapping apertures. A treatment plan was generated in Astroid, the MGH PBS treatment planning system, with apertures and 8-cm range shifters on each field. The use of apertures in PBS fields was validated separately. Extensive PBS plan QA was performed, including film measurements.

Results: The IMPT plan show excellent tumor coverage and uniformity as well as excellent organ sparing. Figure 1 highlights the smooth gradual dose distribution obtained across the field match. A penumbra (20-80%) of ≈10 mm was achieved at isocenter as compared to ≈25 mm without aperture edges. PBS QA passed with, for each field, over a 95 % passing rate on 3 mm/3 %Rx_dose 3D gamma index analyses at three depths with devices in place. A sheet of Gafchromic film was irradiated, in air, at isocenter, in the treatment conditions where both fields were delivered with a longitudinal couch move. A projection of the apertures at isocenter showed great agreement with the irradiated field edges on the film, highlighting the correct plan delivery. The plan, its physical properties and QA, will be described.

Conclusions: A patient was treated at MGH with split PBS fields and apertures. The use of apertures decreased the penumbra to almost its physical limit and negated the effect of the physical spot size. Treatment planning and delivery with apertures allows for a more practical, more efficient, cheaper, and better treatment than conventional DS delivery.

Figure 1: (a) Uniform dose distribution achieved using 2 split PBS fields with overlapping apertures; (b) superior and (c) inferior field creating a smooth gradient.