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Objectives

Despite the dosimetric advantages offered by the Bragg peak, the lateral penumbra of proton therapy can often be less sharp than advanced forms of X-ray therapy. In situations where the target volume is in very close proximity to a dose limiting organ at risk (OAR), target volume coverage with equivalent limiting OAR dose may be slightly superior with X-ray therapy relative to proton therapy. This must be weighed with the significant dose sparing to other OARs often achieved with proton therapy.

In previous work we have demonstrated the penumbra advantages made possible with the use of transmission proton beams. In the current work we explore the potential advantages of combining the sharp penumbra of transmission proton arc beams with the efficiency and linear energy transfer (LET) enhancement of proton monoenergetic arc beams.

Methods

A script was developed for RayStation 2024A to generate proton arc treatment plans that incorporate both (i) a transmission proton beam and (ii) a monoenergetic Bragg peak proton beam at regular angular intervals. The transmission beams were set to 220 MeV with only spots retained at the edge of the target volume from the beam's eye view to ensure a small proton pencil beam diameter for sharp penumbra. The energy of the Bragg peak beams at each angle were selected according to the method of Bertolet and Carabe (Phys. Med. Biol. 65, 165006, 2020). The concept was demonstrated on a simple geometric phantom and translated to a base of skull patient data set.

Results

A comparison of conventional intensity modulated proton therapy (IMPT) dose and LETd distribution with the newly proposed concept for a simple geometrical phantom is shown in Attachment 1. The same comparisons are shown for the base of skull clinical case in Attachment 2. As expected, the newly proposed PMAT technique increases the low dose wash, and sharpens lateral penumbra. The largest differences, however, can be seen in the shift of higher LETd values from the area surrounding the target volume, to the centre of the target volume with the newly proposed technique. This effect was achieved without any LETd objective functions in the optimization.

Conclusions

The combination of low LET transmission proton beams to provide a sharp lateral penumbra, with the higher LET monoenergetic Bragg peak beams preferentially delivered to the centre of the target volume may provide an efficient and LET enhanced method of proton therapy arc delivery.



