TREATMENT PLANNING, OPTIMIZATION, AND BEAM DELIVERY TECHNIQUES FOR INTENSITY MODULATED PROTON THERAPY

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Physical properties of proton interactions in matter give them a theoretical advantage over photons in radiation therapy for cancer treatment, but they are seldom used relative to photons. The primary barriers to wider acceptance of proton therapy are the technical feasibility, size, and price of proton therapy systems. Several aspects of the proton therapy landscape are investigated, and new techniques for treatment planning, optimization, and beam delivery are presented. The results of these investigations suggest a means by which proton therapy can be delivered more efficiently, effectively, and to a much larger proportion of eligible patients.

An analysis of the existing proton therapy market was performed. Personal interviews with over 30 radiation oncology leaders were conducted with regard to the current and future use of proton therapy. In addition, global proton therapy market projections are presented. The results of these investigations serve as motivation and guidance for the subsequent development of treatment system designs and treatment planning, optimization, and beam delivery methods.

A major factor impacting the size and cost of proton treatment systems is the maximum energy of the accelerator. Historically, 250 MeV has been the accepted value, but there is minimal quantitative evidence in the literature that supports this standard. A retrospective study of 100 patients is presented that quantifies the maximum proton kinetic energy requirements for cancer treatment, and the impact of those results with regard to treatment system size, cost, and neutron production is discussed. This study is subsequently expanded to include 100 cranial

stereotactic radiosurgery (SRS) patients, and the results are discussed in the context of a proposed dedicated proton SRS treatment system.

Finally, novel proton therapy optimization and delivery techniques are presented. Algorithms are developed that optimize treatment plans over beam angle, spot size, spot spacing, beamlet weight, the number of delivered beamlets, and the number of delivery angles. These methods are evaluated via treatment planning studies including left-sided whole breast irradiation, lung stereotactic body radiotherapy, nasopharyngeal carcinoma, and whole brain radiotherapy with hippocampal avoidance. Improvements in efficiency and efficacy relative to traditional proton therapy and intensity modulated photon radiation therapy are discussed.