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Delivery and Online Monitoring of Proton Dose at Rates Exceeding 100 Gy/s

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Abstract

OBJECTIVES: Radiation delivery at very high dose rates has demonstrated enhanced biological effect which may be exploited to enhance the therapeutic ratio. Precise dose administration at very high dose rates (~100 Gy/s) requires accurate control of beam flux on a millisecond time scale and online monitoring of the integral and dose delivery time structure. To this end, we have developed and validated a technique to deliver and monitor precise millisecond bursts of proton radiation with a clinical radiotherapy system.

METHODS: The IBA Proteus Plus proton therapy system at the University of Pennsylvania was used to deliver a range 32.0 g/cm2 (~226 MeV) beam on the fixed beam line in the dedicated research room. The proton flux was modulated by an arbitrary waveform generator driving a 0-20 mA current pulse, with pulse widths ranging from 10-100 milliseconds, to the beam current regulation unit of the IBA system. Maximum beam current from the cyclotron was varied within clinical operating parameters, 5-300 nA. Absolute dose was measured according to the Code of Practice TRS-398 (IAEA, 2001) using a parallel plate chamber with NIST traceable calibration certificate. An online transmission parallel plate chamber was cross calibrated with the absolute dose measurements and both sets of readings were validated against an absolute integral charge measurement using a Faraday cup (Cascio and Gottschalk, IEEE, 2009). Time structure of the proton flux was obtained using a NaI detector to measure prompt gamma rays emitted from nuclear excitations at the beam line exit window.

RESULTS: The measured dose varies linearly with pulse width and dose rate. Dose rates exceeding 100 Gy/s can be delivered with variations less than 5%. The beam current response latency is approximately 50 microseconds.

CONCLUSIONS: A clinical proton therapy system operating within clinical range of cyclotron operating parameters can be adapted to deliver very high therapeutic dose levels exceeding 100 Gy/s at with low uncertainty. The dose delivery and online monitoring system can be used for radiobiological investigation of effects of very high dose rate proton radiation.

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