CHARGED PARTICLE IN ONCOLOGY: FROM NUCLEAR PHYSICS TO CANCER TREATMENT

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High-energy charged particles are considered today the most advanced, cutting-edge technology in radiotherapy. The physical advantages (Bragg peak) combined to the special biological properties of densely ionizing radiation makes them the elective choice for tumors close to organs at risk, and a potential breakthrough for different cancers with high incidence and mortality. The main hindrance to a widespread use of ions in therapy is the high cost/benefit ratio. Compact, cheaper accelerators and the extension of the diseases eligible for particle therapy treatments are necessary to decrease this ratio.

Introduction

Radiotherapy is used in more than 50% of the cancer patients, with a strong increasing trend. The goal of radiotherapy is to deliver a high dose to the planning target volume (PTV), while keeping the dose to the surrounding normal tissue as low as possible. In fact, both the tumor control probability (TCP) and the normal tissue complication probability (NTCP) increase with the dose: the main objective of medical physics is to widen the therapeutic window between TCP and NTCP vs. dose curves (see Box 1 for definitions of the units used in this paper).

In conventional X-ray therapy, including the most advanced intensity-modulated radiation therapy (IMRT), this can only be achieved by cross-firing the tumors from several angles using appropriate multi-leaf collimators for conformal delivery.Beam direction and intensity are optimized during treatment planning and delivered by rotating gantries, while the patient comfortably lies on a couch. The photon dose decreases exponentially with the depth (Fig. 1), and as a consequence the use of several beams results in a very high integral dose (ID) to the normal tissue (Fig. 2), with

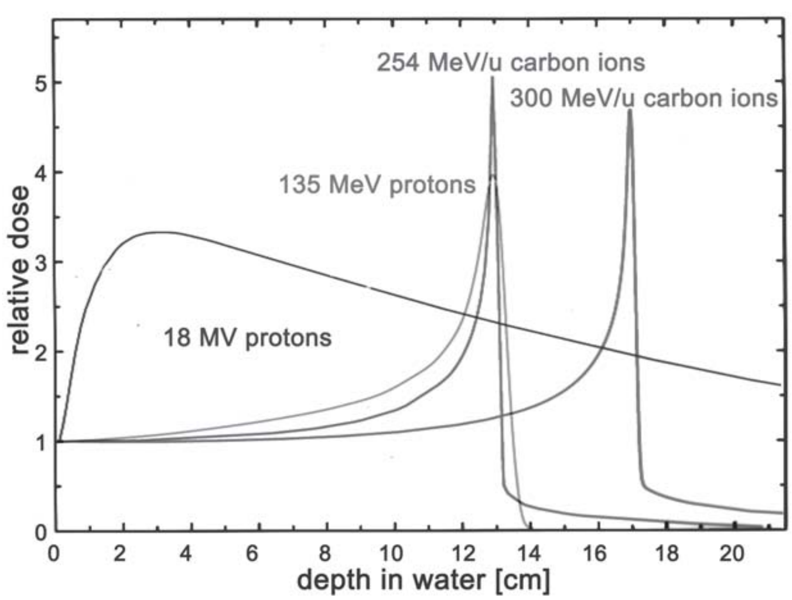

Figure 1.Depth-dose distribution for monoenergetic protons, carbon ions, and photons. The C-ion Bragg peak is sharper than protons at the same range, because of the reduced straggling. However, a tail of projectile nuclear fragments (Z<6) is present in the C-ion curve. Different depths can be reached by changing the beam energy: in the example, 254 MeV/n is compared to 300 MeV/n C-ions. Image from GSI.

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