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Silicon-on-insulator microdosimetry: new domain of quality assurance in particle therapy

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Charged particle radiotherapy (CPT) with helium and deuterium was first used seventy years ago by Lawrence and Tobias [1]. CPT provides a better physical dose distribution than conventional X-ray treatment with a well-defined high dose region known as the Spread-Out Bragg Peak (SOBP) which can be positioned in the tumour with much lower doses to the surrounding tissues. This higher therapeutic ratio can be further enhanced by modifying the radiobiological properties of the beam. The Linear Energy Transfer (LET) is inversely related to the beam energy and associated with a higher Radiobiological Efficiency(RBE).This relationship is complex and can be described by several models including the microdosimetric kinetic model (MKM).

Proton therapy is the most developed CPT modality and the RBE is assumed to be 1.1 compared to X-rays. However this is not correct, and the full benefit of proton therapy depends on making good use of the variable RBE by maximising higher values in the tumour and lower ones in surrounding tissue.

The denser ionisation (higher LET) produced by Carbon Ion Therapy (CIT) is particularly effective in radioresistant or hypoxic tumours. Even greater benefitcan potentially be obtained by using several different ions to produce a uniform high LET distribution in the SOBPwhile keeping a lower dose and LETin other areas [2]. No single ion has the best dose distribution, oxygenenhancement ratio (OER), or overall hypoxic/radioresistant tumour kill. Incorporating the varying LET distributions of heavy-ions into a dose-LEToptimized composite treatment plan may allow new options for the irradiation of patients with complex cancers.

The LET and RBE are highest at the end of the range as the particles are slowing down and stopping so it is important that this effect is minimised in critical normal tissues.LET optimized robust planning can help achieve this. It is also necessary to have goodquality assurance of dose averaged LET (LETD) in addition to physical dose verification.

To achieve this in routine clinical practice, the Centre for Medical Radiation Physics (CMRP), University of Wollongong, has developed a portable semiconductormicrodosimeter called MicroPluswhich measures stochastic energy deposition by charged particles on a cellular level to calculatethe dose averaged lineal energy y_D and LETD.

A treatment plan was delivered to a phantom using protons, helium, carbon, oxygen, and neon ion or combination beams.We demonstrated that measurement with MicroPluscan predict biological effects, such as cell survival fraction, RBE, and RBE-weighted dose which were in good agreement (better than 5%) with the treatment planning system [3-5].

The MicroPlusprobe is already tested in clinics at several particle therapy centres and will guarantee the best treatment of cancer patients with proton and ion therapy when implemented as a tool for routine new domain of quality assurance in CPT.

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