Development of analytical particle transport methods for biologically optimized light ion therapy

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ABSTRACT
A general objective in the treatment of cancer is to eradicate the tumour cells without inducing severe complications in healthy normal tissue. The use of light ions for radiation therapy increases the possibility to deliver tumour suicidal doses with very low probability of normal tissue injury, not least in cases where the target is unresectable, radio resistant and located to near organs at risk. The success in the application of such beams in radiation therapy is largely determined by a thorough understanding of particle transport, biological dose response relations and their accurate integration in the treatment planning system. The focus has therefore been on the radiation quality of the light ions, their transport and to develop analytical tools and theories for their application in biologically optimized radiation treatment planning.
New radiation quality results have been presented regarding the depth dose and LET (Linear Energy Transfer) distribution of different light ions. These results gives indications about the therpeutic efficiency and optimal choice of light ion beam depending on size, location and radiation resistance of the target volume. Frequently seen limitations in finding the optimal treatment plan for conventional sparsely ionizing radiation in the treatment of critical located and/or radiation resistant tumours, can probably be overcome by proper use the light ions and the most specific depth path ways that could be induced.
In order to make the best use of the light ions therapeutic advantages,
New energy and range relations in therapeutic particle beams have been developed and new range concepts have been defined. New analytical theories for the fluence, planar fluence, energy fluence, planar energy fluence, mean energy and absorbed dose of primary particles and their fragments in broad therapeutic light ion beams have been developed.
These results also allows identification of the more sparely and the densely ionizing regions in the developed six dimensional analytical theory for the primary particle and the associated fragments. Furthermore a refined version of the Monte Code SHIELD-HIT was developed and used for calculating fundamental physical transport quantities that could be directly compared with the analytical theories and methods as well as with experimental data.

The present results could be useful for biological optimized treatment planning, biologically optimized dose delivery techniques, dosimetry and for *in vivo* dose delivery verification. However, the theories presented could be applicable and useful beyond these limits.

Keywords: Radiotherapy, radiation quality, energy-range relations, light ion transport, pencil beam, Monte Carlo