Entropic closure for MRI-guided radiotherapy

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Résumé

Introduction:
The majority of patients affected by cancer are nowadays treated by radiotherapy, which consists in delivering a homogeneous dose with energetic particles. Magnetic Resonance Imag-
ing (MRI)-guided radiotherapy shows precisely the tumor position in real time and allows to direct the photon beams to the tumor while sparing organs at risks. Our work consists in the
validation of a new model developped to simulate the energy deposition of the particles used in
radiotherapy (electrons, photons and protons) in the presence of strong magnetic field, within human tissues, and its adaptation to this new technology.

Material and methods:

This model is based on a kinetic entropic closure of the linearized Boltzmann equation [1] , which describes the transport of energetic particles in the matter. This equation takes a lot of
computation time to be solved due to the high number of variables. To simplify this, we replace
fluences by angular moments, which allows getting rid of the angular variables and improve the
calculation time. We obtain a set of angular moments equations, and we close this set using the Boltzmann's principle of entropy maximization on the two first equations of the set. This model has an accuracy comparable to references Monte-Carlo (MC) codes [2] (Geant4, MC-NPx,
Penelope), and is less time-consuming than these ones. We added the Lorentz force into our code to study the influence of a magnetic field on the dose deposition, and compared it to the
reference full MC code FLUKA.
To further validate our model, we have carried out an experimental campaign in which we irra-
diated a composition of materials of different mass densities, with 6 and 18 MV photon beams

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of a Varian Clinac 21Ex accelerator, without and with the influence of a 0.87 T magnetic field
of amplitude induced by a permanent magnet.

Results:

We show a good agreement between our model and the FLUKA code (Fig. 1). We highlight the effects that occur on the propagation of particles in the matter in presence of a magnetic field of a few Tesla. Indeed, it modifies the dose deposition by shifting the deposition of energy,
leading to an increased diffusion depending on the orientation of the magnetic field. Moreover,
it also leads to an increase or decrease of the dose deposited at the interfaces between materials
depending on their difference between mass densities. The results of our experiments lead to the same conclusions. These effects have to be taken into account in order to prevent creation of hot spots or a spread of energy distribution in a human body, within computation times compatible with the clinical environment.

Conclusion:

Our model is a good candidate for future Treatment Planning Systems since it allows a faster and efficient way to plan a viable treatment for a patient in presence of strong magnetic fields. A magnetic field modifies the profile of the dose deposition such as it has to be taken into account in calculations to prevent the dramatic changes which occur at interfaces between
media of different density. This work takes place in the framework of POPRA (Programme Optique Physique et Radiothérapie en Aquitaine), which involves several laboratories around problematics on the topic of cancer treatment.

References:

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Mots-Clés: MRI, Guided Radiotherapy, M1 Model