Spatial fractionation of the dose in charged particle therapy: dosimetry evaluations

W. González1,2, C. Guardiola1,2, C. Peucelle3, I. Martínez-Rovira1,3 and Y Prezado1,3
1. Laboratoire d’Imagerie et Modélisation en Neurologie et Gérontologie, CNRS-INSERM, Orsay, France
2. Centre Antoine Lacassagne-Institut Mediterranéen de Protonthérapie, INSTV CEA Nice, Nice, France
3. UAB- Universitat Autònoma de Barcelona, Barcelona, Spain

Introduction

The dose tolerances of normal tissues continue being the main limitation in radiotherapy. As a strategy to overcome it, we propose to ally inherent physical advantages of heavy ions (up to Fe) with the normal tissue preservation observed when irradiated with submillimetric spatially fractionated beams (minibeam radiation therapy, MBRT) [1,2]. This would allow the use of higher and potentially curative doses in the treatment of radioresistant tumors.

Material and methods (Monte Carlo (GATE/Geant4) codes were used to do dosimetric evaluations in hadron-MBRT)

Minibeam generation: magnetic collimation assumed.

Dosimetry evaluations were assessed to the optimum irradiation configuration in terms of ion species, beam widths and center-to-center distances (ctc).

Dose distributions and dose averaged linear energy transfer (LET) were recorded in water phantom.

The contribution of secondary fragments, Peak-to-Valley-Dose-Ratio (PVDR) and Peak-to-Valley-dose averaged LET-Ratio (PVLR) assessed.

Full proton beam line of the Orsay Proton Therapy Center simulated and benchmarked with experimental data.

Complete dosimetric dataset acquired to guide the preclinical studies.

Experimental

Descriptive statistics

Results

Comparison of depth dose distributions of protons and oxygen minibeam. Due to the reduced scattering for higher ions, the characteristic shape of the depth dose curve is maintained.

In normal tissues, LET values remains below 100 keV/μm threshold where biological effects starts being significant, except for iron.

Conclusions

Heavy ions MBRT could offer some advantages with respect to proton MBRT, in particular, the possibility of using thinner beams.

A possible drawback of heavy ions MBRT is influence by the fragmentation, but large ctc (3500 μm) would lead to valley doses composed of lighter nuclear fragments and lower dose averaged LET which minimizes the possible biological effects of heavier ions in the valleys in normal tissues.

Ne stands out as the one leading to the best balance between high PVDR and PVLR in normal tissues.

References


Acknowledgments

The authors acknowledge the calculation time granted at Centre de Calcul de Lyon (IN2P3) and at Grand Equipement National de Calcul Intensif (in particular at the supercomputer Curie of CEA). We warmly thank the access to Castilla y León Supercomputing Center (Calendula) awarded by the Red Española de Supercomputación. We also acknowledge PRACE for allowing us access to resource MareNostrum Barcelona Supercomputing Center based in Spain.