Dose reconstruction strategies using prompt-gamma radiation in proton therapy

Beatrice Foglia[1], Chiara Gianoli[1], Takamitsu Masuda[2], Elisabetta De Bernardi[3], Thomas Bortfeld[4], Katia Parodi[1], Marco Pinto[1]

[1]Ludwig-Maximilians-Universität LMU Munich, Experimental Physics - Medical Physics, Garching b. München, DE.
[2]National Institutes for Quantum Science and Technology, Chiba, JP.
[3]University of Milano-Bicocca, School of Medicine and Surgery, Monza, Italy
[4]Massachusetts General Hospital MGH Boston, Radiation Oncology, Boston MA, USA.

INTRODUCTION

To monitor range uncertainties in proton therapy, dose reconstruction is desirable, and it has already been proposed in the literature starting from detected secondary radiation, mostly positron emitters (PE). Prompt-gammas (PG) can be alternatively used: emitted within nanoseconds after nuclear interactions, they can be exploited for real-time adaptation.

MATERIAL AND METHODS

The purpose of this work is to assess the feasibility of three existing approaches for dose reconstruction from PG: the analytical deconvolution method [1], the evolutionary algorithm [2][3][4], and the maximum-likelihood expectation-maximization (MLEM) algorithm [5][6]. These were chosen because of the inherent application of the filtering, introduced first by Parodi and Bortfeld [7] for PET data, then extended to PG radiation by Schumann et al. [2] and by Pinto et al. [8]. Mono- and polyenergetic proton beams irradiation of homogeneous and inhomogeneous phantoms were simulated (using Geant4 [9], v.10.07.p03). 1D laterally integrated depth-dose and depth-PG distributions were considered.

RESULTS

The accuracy of the reconstructed depth-dose profiles was evaluated via comparison with their corresponding ground truth using different metrics, which show an overall match. Regardless of the method, ΔR_{80}, ΔR_{50} and ΔR_{10} metrics (see table 1 caption) were found to be below 1 mm. For the tests performed, the methods are sensitive to properly reconstruct dose when range shifts of different magnitudes are introduced.

CONCLUSIONS

This work verifies the applicability of the investigated dose reconstruction techniques to PG distributions. Extension to 3D distributions is currently in progress, and the application to measured data is foreseen in the near future. The final purpose consists of the comparison of the evaluated strategies as part of their applicability to real-time adaptive particle therapy.

This work is performed as part of the RAPTOR project, funded by the EU's Horizon 2020 MSCA, G.A.No.955956.

1.Remmele2011-Phys.Med.Biol.56
2.Schumann2016-Phys.Med.Biol.61
3.Hofmann2019-Phys.Med.Biol.64
4.Yao2023-Nucl.Sci.Tech.34
5.Masuda2019-Phys.Med.Biol.64
6.Masuda2020-Phys.Med.Biol.65
7.ParodiBortfeld2006-Phys.Med.Biol.51
8.Pinto2020-Phys.Med.Biol.65
9.Agostinelli2003-Nucl.Instrum.MethodsPhys.Res.