Radiobiological effectiveness difference of proton arc beams versus conventional proton and photon beams

Alejandro Carabe^{1,*}, Ilias V Karagounis¹, Kiet Huynh¹, Alejandro Bertolet¹, Amit Maity¹, Eric Abel³, Roger Dale²

¹ Department of Radiation Oncology, Hospital of the University of Pennsylvania, Philadelphia, PA, USA.
² Department of Surgery and Cancer, Imperial College London, London, UK
³ Varian Medical Systems, Inc. Palo Alto, CA, USA
*E-mail: a.carabe@uphs.upenn.edu

INTRODUCTION AND OBJECTIVES

Single energy proton arc (SE-PAT) therapy allows simultaneous dose and Linear Energy Transfer (LET) painting of the target. As the biological effectiveness of particle beams increase with LET, it is expected that SE-PAT is more effective than conventional proton (IMPT) or photon (IMRT) delivery techniques. Cells of different radiosensitivity were exposed to SE-PAT and IMPT under the same experimental condition and dose distribution to evaluate the difference in biological effectiveness between these techniques.

METHODS

H1299, H460 and V79 cells were exposed within a cylindrical uniform phantom using SE-PAT and IMPT in order to perform clonogenic and immunofluorescence assays. The SE-PAT consisted of 13 fields spread over 180° every 15°, where each field had a single layer of Bragg peaks of 10.1cm in range. The IMPT plan consisted of 3 fields with each field covering the target in full (Figure 1). The phantom was a cylinder of solid water, with 20cm in diameter and a drilled holder of 6cm in diameter to insert Petri dishes (Figure 2, left).

Figure 1: Dose (left) and LET (right) distributions and lateral profiles. The cells counted in the clonogenic and immunofluorescence assays were in the homogeneous dose part of the Petri dishes, which are marked in the blue and grey shaded areas on the lateral profiles of dose and LET

Figure 2: Phantom setup description (left) and dose and LET volume histograms (right)

The dose coverage of the target with both techniques was the same, but the LET distribution differed, with a higher LET concentrated in the target for SE-PAT (Figure 2, right). Clonogenic and immunofluorescence assays were performed in order to characterize the biological response of cells to SE-PAT versus IMPT.

RESULTS

Figure 3: Left, survival curves for each proton technique. Photon (6MV) survival

Figure 4: Repair kinetics curves obtained from immunofluorescence assays. SE-PAT always produce a larger fraction of unrepaired damage

CONCLUSIONS

At clinically relevant doses, the RBE of SE-PAT versus IMPT is 1.26 for H1299, 1.24 for H460 and 1.19 for V79, respectively. The remaining fraction of unrepaired damage after SE-PAT is always higher than with IMPT. Both, the clonogenic and the repair kinetic curves for IMPT are similar to the photon curves. These result indicate the possible therapeutic window increase by using SE-PAT with proton beams. For the relatively small difference of LET between IMPT and SE-PAT, the differences in cell survival and unrepaired fractions are substantial. These results need to be validated in non-homogeneous phantoms with non-central targets and as well as in-vivo.

ACKNOWLEDGMENTS

This project was supported by Varian Medical Systems, Inc. Palo Alto, CA.