Hydrogen Peroxide (H2O2) production in response to multiple beam irradiation of protons at UHDR


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Does multiple beams delivery preserve the effect of UHDR on the production of the reactive oxygen specie (ROS) H2O2?

Material and methods

- The ARRONAX cyclotron in Nantes delivers protons beam up to 70 MeV, at variable doses rates (0.2 Gy/s to 60 kGy/s) and time structures (milliseconds macro-pulses).
- The experimental set-up for proton radiotherapy [2] with a sample carrier holding designed PEEK radiolysis cells, allows the irradiation of the entire volume of Ultrapure water (Ø = 12 mm, depth = 15 mm) degassed under reconstituted air within the Bragg plateau.
- The concentration of H2O2 is determined by UV-visible spectrophotometry (Ghormley method, [3]).
- Orthochromic OC-1 films [4] were positioned at the cells entrance to ensure targeting and for in vivo dosimetry, as shown in Fig.1. Mean and maximum relative differences between film and online dosimetry are 0.5 % and 1.6 %, respectively.

Figure 1. Left: a photograph of two radiolysis cells in front of the OC-1 films. Right: the depth of the radiolysis cell relative to the Bragg curve of 68 MeV protons, measured with a Markus Advanced (PTW) in water.

- 30 GY were delivered according to beam structures shown in Fig. 2. The impact of the number of the beams was evaluated in the UHDR mode at 8.6 kGy/s, by delivering N times the same pulsed beam every 20 seconds but with a reduced duration of dt/N, with N equal to 1 (1×30 GY), 2 (2×15 GY), 3 (3×10 GY), 5 (5×6 GY) and 10 (10×3 GY).

Figure 2. Beam structures used to deliver 30 GY. For UHDR, dt=3.5 ms.

Results

Preliminary results (n=1) are presented in Fig. 3.

Figure 3. [H2O2] versus number of beams to deliver 30 GY with protons under air.

Conclusion and perspectives

Our study investigated the impact of the number of beams on the concentration of Hydrogen Peroxide (H2O2) after UHDR proton irradiation:

- The decrease of the H2O2 concentration was more significant with a single beam than with multiple beams.
- The delivery of UHDR irradiations with multiple beams allows to obtain a differential effect compared to CONV irradiations but with a lower amplitude.
- In addition to the dose rate, the observed effect also depends on the dose per beam or the total duration of the irradiation.

Subsequent experiments will study the time delay between two beams to deepen this finding. Cross-experiments will be carried out with biological models (zebrafish embryos).

References