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UNDERSTANDING THE TRANSITION TO FLASH: THE NEXT REVOLUTION IN THE TREATMENT OF CANCER

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During the last years, ultrahigh dose irradiation (>=40 Gy/s), also known as FLASH-RT, has emerged as a revolutionary technique with the potential to change the current radiotherapy paradigm. Compared to conventional dose rate radiotherapy (CONV-RT), it spares normal tissue while keeping an equivalent or superior tumoricidal effect. In vitro and in vivo studies have shown that oxygen plays a key role in the FLASH effect. However, although several hypotheses have been proposed, the exact mechanism behind this process is still far to be well understood. Since experimental data is scarce, simulations of the radiolysis of water in oxygenated conditions at ultra-high dose irradiation can shed some light on this issue.

In this work, we present a new simulation framework aiming to study dose rate effects in the production of radical species in water and biological media. The physical stage is simulated using the Monte Carlo track structure code TOPAS-nBio whereas the chemical stage is based on a nonlinear reaction-diffusion model implemented in GPU. This approach allows to consider the oxygen and other substances explicitly without compromising the global computational time of the simulation. To cover the biological stage simulations are extended over a longer period (~10^2 s) assuming a homogeneous distribution of radicals.
We found a good agreement between our simulations and the previous experimental data and calculations available in the literature. The results obtained in organic matter media support the theory of enhanced radical recombination rather than transient radiolytic oxygen consumption as the main driver to the FLASH effect. Finally, the influence of other key beam parameters for inducing the FLASH have been tested in the simulations and the variation of the NTCP is presented for different intrapulse dose rate and pulse frequency configurations, which are relevant in the clinical scenario.

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