Title: Simulation and validation of plasmid DNA irradiation by electrons using Geant4-DNA

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Background: In radiotherapy and radiobiology studies, damage to the DNA molecule is of high interest since it directly impacts the cell's function, replication and mortality. Plasmids are an interesting target to study radio-induced effects on DNA. In this work, we simulate pBR322 plasmid DNA (4361 pb) and its irradiation by electron beams to estimate the direct and indirect damages. We compare the results with experimental data.

Material and Methods: A geometry of plasmid is implemented following the approach of Lampe et al. [1]. This geometry can be used with Geant4-DNA [2]. A total of 10^4 plasmid loops are placed with random 3D orientations within a 6.5 μm radius sphere to reproduce the experimental density. The material used is liquid water for all structures and they are irradiated with a monoenergetic electron beam. Several energies were tested with the option2 and a recently extended version of option4 Geant4-DNA physics models [3]. The chemical stage was activated and simulated using the IRT method. Direct damages were registered when energy depositions in the sugar and phosphate group were > 8.22 eV and indirect damages were registered when the hydroxyl radical encounters sugar or phosphate group with a 0.65 interaction probability within an interaction radius of 9 nm, beyond which the radicals are killed. These damages are considered to induce single strand breaks (SSB) and when two SSBs on opposite strands are located within 10 base pairs, a double strand break is induced (DSB). The damage results have been compared with existing experimental data [4].

Preliminary results: Preliminary results of 5.5 MeV electrons in dry plasmids where only direct effects are considered were 0.35 ± 0.02 $Gy^{-1}Mbp^{-1}$ for simulated SSB yield, compared to 0.42 ± 0.07 $Gy^{-1}Mbp^{-1}$ for the experiment. The simulated DSB yield was 0.02 ± 0.005 $Gy^{-1}Mbp^{-1}$ compared to the 0.012 ± 0.059 $Gy^{-1}Mbp^{-1}$ experimental value. Simulations for wet plasmids include the indirect effects resulting in 1.66 ± 0.042 $Gy^{-1}Mbp^{-1}$ SSD and 0.12 ± 0.01 $Gy^{-1}Mbp^{-1}$ DSB yields. The experiment on the other hand did not have any scavengers and resulted in 25.19 ± 0.8 $Gy^{-1}Mbp^{-1}$ for SSB and 0.87 ± 0.08 $Gy^{-1}Mbp^{-1}$ for DSB.

[1] N. Lampe *et al.*Physica Medica 48 (2018)135-145
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