AbstractID: 10545 Title: Characterization of the spatial and energy distribution of electrons emitted from a gold nanoparticle irradiated by x-rays using Monte Carlo simulations

Purpose: Through Monte Carlo simulations, we investigate the spatial and energy characteristics of electrons formed from interactions of keV photon beams irradiating a gold nanoparticle to understand their role in enhancing cell kill.
Methods and Materials: The GEANT4 toolkit was used for Monte Carlo simulation. A gold nanoparticle sphere with a 100 nm diameter was irradiated by x-rays with energies of 35 to 6000 keV inside a tracking volume of water. For each electron emitted from the irradiated gold nanoparticle, the following parameters were tracked: i) the physics process that created the electron, ii) energy distribution of the electron, iii) range, and iv) deflection angle. The same simulations were performed by replacing the gold nanoparticle with water.
Results: The energy distribution of the secondary electrons when the gold nanoparticle is irradiated by a monoenergetic photon beam with various energies is calculated. The number of interactions for 35 keV photons is about 157 times more than that for 660 keV, and 683 times more than the 6000 keV beam. When the gold nanoparticle is absent, the probability of creating an electron becomes much lower. Specifically, the ratio of total interactions with and without gold is 812, 137, 10, 7, and 2 for energies 35, 73.3, 660, 1200 and 6000 keV respectively. Furthermore, irradiating the gold nanoparticle at a higher photon energy increases the range over which the election can travel, and decreases the deflection angle. This represents a change in volume over which the electrons can deposit dose.
Conclusions: We conclude that for a cell of typical size, a low energy (35 keV) photon beam generates a large number of secondary electrons when a gold nanoparticle is present compared to without, and will have sufficient range to cause damage in the cell in which the nanoparticle is uptaken.