Nanoparticle Enhanced Radiation Therapy: Theoretical Calculation*

Autumn Paro
Department of Chemical Engineering
Northeastern University
Boston, MA 02115

Radiation therapy is one of the most commonly used cancer treatments. In this treatment, high energy ionizing radiation is delivered to cancer cells. For this to be an effective treatment, beam size and intensity need to be optimized to deliver the highest dose possible to cancer cells, while minimizing damage to the surrounding healthy cells. This is the major limiting factor in radiation therapy since the radiosensitivity of cancer cells is relatively close to that of the surrounding healthy cells. Nanoparticles of heavy elements such as gold have been proposed to increase the radiation dose delivered to cancer cells without increasing its intensity.

Nanoparticles of heavy elements stand as a reliable dose enhancer due to their unique properties. When nanoparticles are subjected to an incident beam of X-ray photons , a variety of interactions can take place based on the energy of the photon. For energies within the diagnostic range, the photoelectric effect dominates. The photoelectric effect is useful in dose enhancement because the secondary electrons (photo-electrons and auger electrons) produced have short ranges in tissues, depositing their energy close to the nanoparticle. This allows for lower energy X-rays to be used while increasing the energy delivered to a cell.

Previous studies have looked at both the theoretical and experimental impact of radiation dose enhancement using gold nanoparticles. Theoretical studies have mostly focused on the effect of particle location, concentration, and size on the enhancement. These studies have also examined how dose enhancement varies with photon energy. One study previously performed in my laboratory looked at how the dose enhancement can be changed based on the nature of the material, whic was limited to gold, platinum, and bismuth. The experimental studies have been performed both in vivo and in vitro, and have focused mainly on gold nanoparticles because of their low toxicity and biocompatibility.

The goal of this project is to study the dose enhancement effects of nanoparticles of various materials, shapes, and compositions both theoretically and experimentally. A Monte Carlo simulation will be carried out to track photoelectrons and auger electrons after leaving the nanoparticles. If the particles enter the cell, then the energy deposited in that area will be scored for each particle individually. To validate the results from simulation, an X-ray fluorescence spectrometer will be used to determine the energy of electrons escaping the nanoparticles under a variety of different X-ray energies.

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