AbstractID: 9092 Title: Resonant X-ray Irradiation of High-Z Nanoparticles for Cancer Theranostics

Purpose:

Broadband X-ray sources employed in current cancer therapy are indiscriminant of tissue composition. We demonstrate significant dose enhancement by high-Z (HZ) sensitizing agents at resonant energies below the K-edge. This is of particular interest in cancer theranostics using agents such as gold nanoparticles embedded in malignant tissue.

Method and Materials:

Relativistic R-matrix calculations were performed for radiative transitions and photoionization for many HZ elements from Fe to U. Accurate cross section data and monochromatic attenuation coefficients were computed in energy ranges where the large k-α resonance complexes occur. Scaling laws up to HZ species such as Pt, Au, and U are studied. Depth dose curves based on photon transport in a numerical model containing muscle, bone, and tumor with 1mg/cc concentration of gold nanoparticles were calculated using the new resonant atomic data and compared with those calculated using standard evaluated data.

Results:

Giant resonance complexes were identified in all HZ species at energies below the respective K edge. For example, the resonant attenuation coefficient for k-α transitions in Fe and Au are more than 1000 times higher than at their K edge. The average absorption efficiency in cm^2/g of Au at ~68 keV is 7400, compared to 3.3 at the Au K-edge, and only about 0.2 for C, N, O and 0.24 for Ca. The gold resonance complexes lie in the range 67-80 keV, below the K-edge. The calculations reveal preferential dose deposition ratio of 3 to 4 between the gold nanoparticle-bearing tumor and soft tissue (including surface) or bone.

Conclusions:

Opportunities exist to specifically target HZ-bearing tumors while sparing normal tissue at monochromatic or narrowband X-ray sources tuned to resonant energies. We identify and discuss potential sources for the generation of sufficiently intense K-alpha resonant radiation, such as laser produced plasma devices and electron-beam ion traps.