Optimization of photon beam energy in the treatment of thyroid cancer in the presence of gold and silver nanoparticles

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Abstract:
Today, the use of nanoparticles in radiotherapy is recommended and Increases survival and reduces local attack as well as DNA damage of cancer cells. ,in this study, to investigate the effect of radiation sensitivity, parameters such as radiation energy and type of nanoparticles in the thyroid tissue simulated in MCNPX code were investigated. The results show that in the presence of nanoparticles the absorption dose within the tumor increases. The highest dose improvement coefficient was obtained in the presence of gold nanoparticles in energies of 64 to 66 keV with a value of 158% and in the presence of silver nanoparticles in energies of 68 keV with a value of 192%. At optimum energy, silver nanoparticles are more effective than gold nanoparticles in terms of dose increase. It was also observed that megavolt beams in comparison with kilovolt beams cannot be suitable activating beams because at energies of 2 to 6 megavolts we did not see a significant increase in the dose of nanoparticles and this increase was reported to be about 4 to 8 percent.

Keywords: MCNPX code, gold and silver nanoparticles, radiotherapy

Introduction:

In the interaction between X-rays and metal nanoparticles, photoelectrons and secondary electrons are formed. These electrons, with biological tissue, produce free radicals that can directly break DNA strands or indirectly cause Planned cell death. In other words, nanoparticles can be considered as an additional source of free radicals. Therefore, it is expected that in the presence of nanoparticles, the benefit of radiation therapy will increase due to the increased destructive effect on cancer cells (due to the increase of cell toxicity factors).

In this study, thyroid, tumor and source tissue simulations were performed using MCNPX code, which is a computer code for Monte Carlo radiation transfer. The optimum energy of photon beams in the presence of gold and silver nanoparticles was investigated.

Method:

In this study, we tried to predict suitable conditions for treatment using external beam radiotherapy by simulating a phantom derived from phantom (ORNL-MIRD), Phantom was designed using AutoCAD software and the resulting files were transferred from AutoCAD to SuperMC software version 3.2.0. In this simulation, the tumor was placed in a cube inside the thyroid phantom (made of water) and the gold and silver nanoparticles were distributed spherically and uniformly inside the tumor volume using repetitive structures. The SuperMC converter feature was used to create the MCNP input file. For the kV and MV modes, single-energy photon beams in the range of 20 to 90 kV and 2, 4, 5 and 6 MV were used, respectively. The source was a flat surface, the distance from the surface for kV and MV, respectively, was considered 25 and 100 cm.

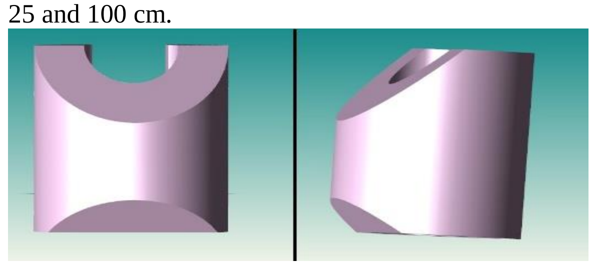

Figure 1 - View of the simulated phantom in Super MC software

Results

In this study, using tally f6, the energy released in the tumor was calculated per unit MeV per gram and two million particles were tracked, with an error of about one percent. Multiple single energies (20 to 90 kV) were used to obtain the optimal energy that maximizes the dose improvement (dose ratio in the tumor area in the presence and without the presence of nanoparticles). According to Figure 2, The general results of the implementation of 108 programs show: the rate of increase of the absorption dose coefficient in the presence of gold nanoparticles for energies less than 44 keV is more than silver nanoparticles. At 44 keV, Dose improvement coefficient is the same for gold and silver nanoparticles and was 114%. For energies higher than 44 keV, an increase in the absorption dose improvement coefficient created in the presence of silver nanoparticles for energies greater than 44 keV was more than gold nanoparticles. (Witness the behavior of gold and silver nanoparticles from 44 KeV upwards)

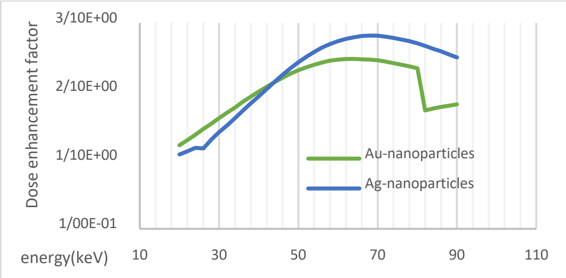

Figure 2 - Dose improvement coefficient in the presence of spherical nanoparticles of gold and silver with a radius of 70 nm for a density of 50 mg / g at different energies

in the presence of gold nanoparticles, the absorption dose reaches the maximum increase (5.56×10^{-12} Gy) at 20 keV energy and the lowest increase at 82 keV energy (2.28 $\times10^{-12}$ Gy). In the absence of nanoparticles, the absorption dose reaches the highest increase (4.42×10^{-12} Gy) at 20 keV energy and the lowest increase (.12$\times10^{-12}$Gy) at 64 keV energy. The rate of absorption dose improvement coefficient in the energies of 62 to 64 keV reaches the highest increase (1.58%) and in the energy of 20 keV reaches the lowest increase (32%). In the presence of silver nanoparticles, the absorption dose reaches the maximum increase (4.99×10^{-12} Gy) at the energy of 20 keV and the lowest increase (3.12×10^{-12} Gy) at the energy of 46 to 50 keV. And in the absence of nanoparticles the absorption dose at energy 20keV to the maximum Increase (4.42×10^{-12} Gy) and at 64 keV energy reaches the lowest increase (1.12×10^{-12} Gy). And the rate of absorption dose improvement coefficient in 68 keV energy reaches the highest increase (1.92%) and in 20 KeV energy reaches the lowest increase (18%). To investigate whether nanoparticles can be effective in the presence of megavolt beams or not? The source was located along the y-axis at a distance of 100 cm from the surface. In MeV beams in the presence of gold nanoparticles the absorption dose at 6MeV energy increased to the highest (7.53×10^{-11} Gy) and at 2 MeV energy to the lowest increase (3.41 $\times10^{-11}$ Gy) and also in the presence of silver nanoparticles absorbed dose at 6MeV energy increased to the highest (7.40×10^{-11} Gy) and at 2 MeV energy decreased to the lowest (3.39 $\times10^{-11}$ Gy) In the absence of nanoparticles, the absorption dose at 6MeV energy reaches the highest increase (6.95×10^{-11} Gy) and at 2MeV energy reaches the lowest increase (3.26×10^{-11} Gy). And reaches the lowest increase (4%) in 2MeV energy, and reaches the highest increase (7%) in the presence of silver nanoparticles at 6 MeV energy and the lowest increase (4%) in 2MeV energy.

Conclusion:

The energy that can produce the highest radiation sensitivity in the presence of nanoparticles is called the optimal energy. This energy was obtained for 62-64 »keV gold nanoparticles, which is approximately 16.7 to 18.7 keV less than the k edge energy of the gold element. And was obtained for 68 keV silver nanoparticles, which is approximately 42.4 keV more than the k edge energy of the silver element. According to Figure 2: The presence of silver nanoparticles at energies above 44 keV is more effective than gold nanoparticles. The presence of gold nanoparticles at energies below 44 keV creates greater radiation sensitivity.

Megavolt beams cannot be suitable activating beams compared to kilovolt beams. This is because irradiation in the kilovolt range causes high-potential photoelectric absorption, with low-range secondary electrons leaving their energy in the tumor area and injecting relatively large doses into the tumor. Based on the basics of physics, in the interaction of ionizing beams with materials with high atomic number (gold and silver nanoparticles) at high energies (2 to 6 electron volts), the compton phenomenon and pair production are dominant and are effective in increasing the dose coefficient. Megavolt beams cannot be suitable activating beams compared to kilovolt beams. This is because irradiation in the kilovolt range causes photoelectric absorption to occur with high probability, and low-range secondary electrons leave their energy in the tumor area, causing relatively high doses to enter the tumor. Although according to Figure 2, nanoparticles are effective on the dose improvement coefficient, at lower and higher energies of 44 kV, gold and silver nanoparticles change behavior, but according to the text at high energies, the nanoparticle type will not have a significant effect on increasing the dose improvement coefficient, and the percentage difference between the two nanoparticle types was calculated from 0 to 1%.

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