Simulation of silver nanoparticle radio-sensitized tumor and evaluation of dose enhancement in proton therapy

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Abstract

Treatment of radio-sensitized tumor is one of the promising modalities in radiotherapy. Therefore in this study, Monte Carlo simulations are applied to investigate the dose enhancement and the influential factors in proton therapy of silver nanoparticle radio-sensitized tumor. A slab head phantom with a homogenized AgNPs aided tumor was considered to simulate proton therapy in brain tissue. Monte Carlo simulation is performed by MCNPX code to assess dose and its enhancement in a radio-sensitized tumor by AgNPs using proton therapy. Dose and its enhancements are calculated for proton beams with several energies. This work demonstrates that dose enhancement of several percent in and much more dose reduction after the tumor site can be achieved when Ag is used as a sensitizing agent with an SOBP beam. These effects will be improved by increasing Ag concentration.

Keywords: Proton therapy, AgNPs radio-sensitization, modulated dose enhancement, head phantom

Introduction

Radiation therapy is one of the main methods of cancer treatment; low efficiency is the most important problem of this method of treatment. The use of radio-sensitizer in the treatment of tumors is a method that promises new horizons in radiation therapy. Recent studies show the practical applications of this treatment by experimental treatment of animal tumors and irradiation of human cells externally; Recently, the benefits and applications of silver nanoparticles in the treatment of photon activation method have been realized, as well as the safety and necessary tests for its clinical use [1].

Wilson first proposed the use of protons in radiation therapy in 1946. Due to the existence of different parameters and various physical conditions in this treatment method, the use of simulation models is easier, less expensive and, faster than practical methods to predict treatment design optimization solutions [2].

But proton therapy with silver element implants has been less studied. None of the studies have performed simulations on the actual condition of a tumor, so the aim of the present article is to use Monte Carlo simulations to evaluate dose escalation for proton therapy of a silver-activated tumor. Also, simulation of sequence, exact composition and, sequence of different tissues containing tumor activated with silver is the main task of this article [1].

Materials and Methods :

Simulation for the calculation of flux and energy deposition was conducted using MCNPX Code, Version 2.4. A pencil proton beam with a radius of 0.01 cm is vertically irradiated on the surface of the phantom. The tmesh card was used to calculate the sequences as a sequence mesh. A number of 200000 protons were traced to achieve a relative error of less than 0.01.

Head Phantom :

The beam configuration and overall geometry for the phantom head used in this study are described in full in [2]. The lateral dimensions of the phantom were considered in accordance with the maximum values of the brain in the MIRD-ORNL phantom as 17.2 cm × 13.2 cm [2].

In proton therapy, irradiation with a single Bragg peak is not sufficient if the tumor thickness is greater in radiation than the width of a Bragg peak for this reason, we use SOBP, and how to calculate it completely is mentioned in source [2].

Results and discussion

In the combined method of proton therapy with radio-sensitizer AgNPs, the absorption Dose enhancement in the tumor area was investigated, and the effect of radio-sensitizer concentration was investigated. SOBP was irradiated, as shown in Figure 1. This figure shows a uniform increase in dose in the tumor and a valley-like decrease immediately after that. In other words, they minimize unintentional damage to adjacent healthy cells while further damaging tumor cells. Dose enhancement factor indicates that the absorption dose is significantly increased in the tumor area. The curves show this Dose enhancement for the intended concentrations of 50 and 300. The reason for this can be the presence of the radio-sensitizer silver in the tumor

From the Dose enhancement curves, it can be concluded that, first, the absorbed dose always increases significantly in the area impregnated with the AgNPs

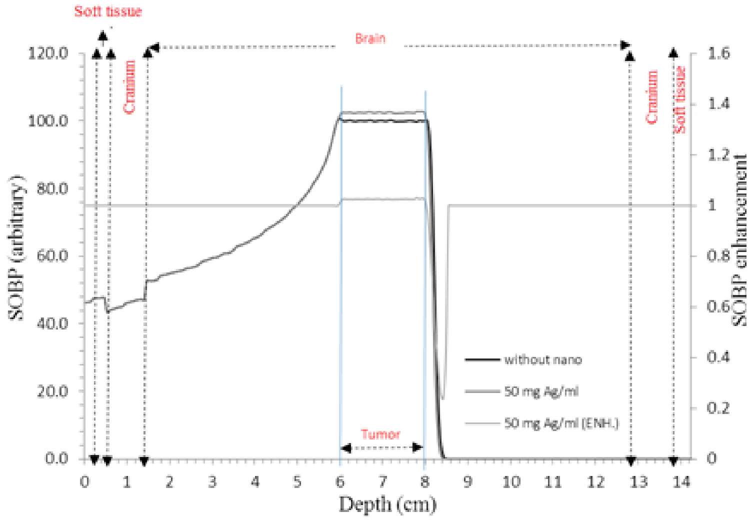
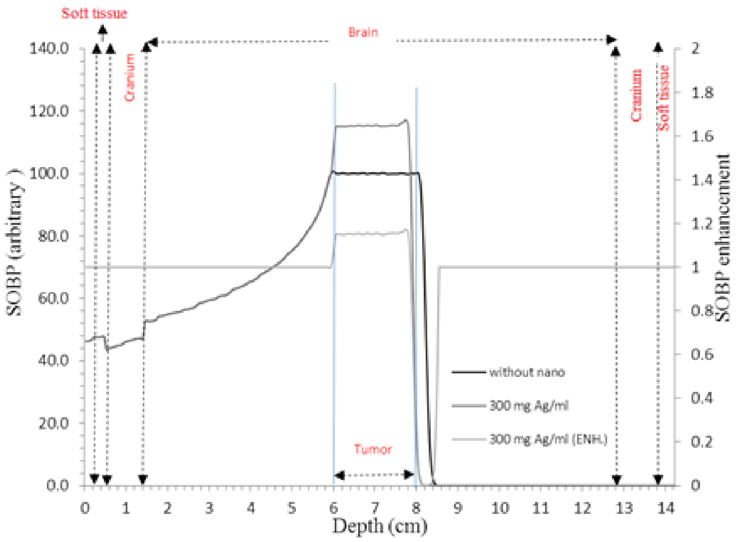


Figure 1. SOBP profile and its enhancement for incident pencil beams (50 mg Ag/ml).

AgNPs and their amount decrease significantly immediately after the tumor. The valley section, like the ENH diagram, shows a decrease in the absorbed dose outside the tumor, the reason is that due to the increased interaction in the tumor area containing nanoparticles, fewer rays have a chance of leaving that area. the Dose enhancement for silver is greater than for gold. [2]

Figure 2. SOBP profile and its enhancement for incident pencil beams (300 mg Ag/ml)

In comparison with Figures 1 and 2, the higher the



concentration of the radio-sensitizer AgNPs in the tissue, the higher the Dose enhancement factor. It means their interaction with the silver aided cells increases which has two influences, dose enhancement in the silver nanoparticle aided tumor. The dose is reduced after that due to the more reduction in proton beam intensity. Decreasing the intensity of the proton beam on top of the nanoparticles has a significant effect on the narrowing of SOBP As shown in Figure 2

. Figure 3 shows changes in the dose obtained relative to the concentration of the radio-sensitized. The results show that these changes follow a linear function with a correlation coefficient of 0.99., even considering an imaginary state of very high concentration, the trend does not deviate from the linear mode, and this can be a good reason to conclude that the trend is linear. In principle, considering the imaginary concentration of 300 also checks the linearity of the process.

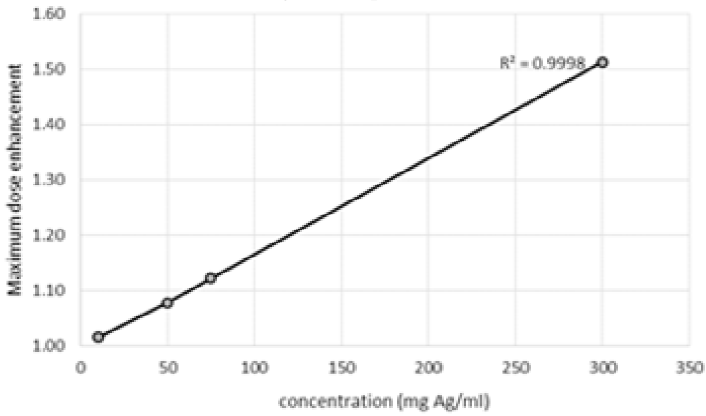


Figure3. Dose enhancement rate calculated for different concentrations of silver

As you know to increase the number of atoms of radio-sensitized in the tissue, the probability of protons interacting with these atoms increases, and the number of nuclear interactions that lead to the production of secondary particles will increase, thus improving the absorption dose in tumor tissue. Changes in the Dose enhancement with respect to the concentration of the active ingredient indicate that these changes follow a linear function.

Conclusion

The deep dose and the spread dose in both cases are the presence and absence of silver activating nanoparticles. Dose enhancement in the tumor due to the presence of nanoparticles confirms the results of previous research in this regard. A dramatic dose reduction immediately after the tumor, which was theoretically predictable, was observed only in this study because previous calculations did not take into account the sequence of materials, compounds, and the actual shape of the brain, and only to nanoscale modeling.

References

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