Development of Simulation Model for Calculating Radiation Dose Used to Treat Lung Malignant Cells with The aid of Nanoparticles

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الخلاصة

هذه الدراسة تركز على تحسين كفاءة العلاج الاشعاعي من خلال تحسين معدل التحسس الاشعاعي(SER) . في هذه الدراسة الزيادة في معدل التحسس الاشعاعي تم بواسطة زيادة مقدار الجرعة الممتصة داخل ورم سرطان الرئة دون النسيج الصحي المحيط بالورم نتيجة وجود المواد النانوية لكل من الذهب والكادولينيوم و الفضة والتيتانيوم. وكل مادة نانوية تتفاعل مع اشعة سينية تتراوح طاقتها من (2) الى (20) ميكا الكترون فولت. و هذا بدوره انتج زيادة في معدل التحسس الاشعاعي كالتالي (10.86%) ,(12.15%), (13.03%), (13.59%) عند استخدام التيتانيوم والفضة والكادولينيوم والذهب كمواد النانوية على التوالي.

الكلمات المفتاحية

سرطان الرئة، جسيمات نانوية، العلاج الاشعاعي، معدل تحسين الحساسية.

Abstract

This theoretical study focuses on the enhancement of efficiency for radiotherapy according to increase sensitivity enhancement ratio (SER). The improvement of SER was done by increasing the amount of absorbed dose in lung cancer without the surrounding health tissue due to presence (Gold, Gadolinium, silver and titanium) nanoparticles (NPs) using x-ray with energy rangefrom (2) to (20)MeV. This causes increasing in SER percentages as follows (10.86%),(12.51%), (13.03%) and (13.59%) when using titanium, silver, gadolinium and gold as nanoparticles respectively depending on the type of nanoparticles.

Keywords

Lung cancer, nanoparticles, radiotherapy, sensitivity enhancement ratio.

1. Introduction

The International Agency for Research on Cancer (IARC) and Global Cancer Statistics researchestogether conceder cancer as global disease spread among men and women lead death in late stage [1, 2].

According to World Health Organization - the International Agency for Research on Cancer there are (10.9) millionnew cases, the number of deaths due to cancer is (6.7) million andthere are (24.6) million people still alive with cancer. The most common cancers are lung (1.35) million, breast cancer (1.15) million, Prostate cancer (1.1) million cases, and ovary cancer (204,000)cases [3].

Cancer treatment process consists of a single stage or several stages, depending on the stage reached by the disease, the process of treatment are surgery combine with chemotherapy and radiotherapy [4].

The radiotherapy involves the use of gamma photons orx-rayphotons of high energy which can be produced from linear accelerator these are ionizing radiations lead to death or shrinking for cancer cells. Photon interaction has a high probability of injury to surrounding healthy tissue and thus appears the importance of improved radiotherapy. Improvement of radiation therapy include find a way to make a greater damage in malignant cells with less damage to healthy cells surrounding the tumor [5].

Because human tissues consisting of light elements so photons interact within tissue photoelectric effect phenomenon and Compton scattering. Interaction of electrons and photons within the malignant cells generate free radicals these free radicals leads to the destruction of malignant cells [6, 7].

When the nanoparticles size smaller than human cells, new interactions with surface and inside of the malignant tumor can present, which may improve cancer radiotherapy [8].

The nanoparticlesmaterials havewide utilization in biomedical research. They are used in diagnosing and therapy due to their individual properties like small size, high reaction in the living cells, extensive thermal constancy and nontoxic [9], thus that many of the nanoparticles materials have a high impact on radiotherapy[10].

Many researchers have studied the properties of nanoparticle materials such as gold , gadolinium ,silver and titanium elements , the possibility to apply in medical fields in order to improving therapy [11,12,13,14,15,16,17,18,19,20,21]. One of these studies was focused on the increases the number of destructive cancer cells by increasing the energy of incident radiation with a nanoparticles material [22,23].

Since the human body is made up of a large percentage of the water is about 80%, so water is the main objective of the interaction of ionizing radiation. Interaction of ionizing radiation with the water molecules in vivo interaction produces free radicals. These free radicals are the root of hydrogen and hydrogen hydroxide. The accumulation of free radicals leads to the formation of toxic hydrogen peroxide

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molecule which finally destroy the tumor cell by induced of apoptosis[24]. Therefore, the greater the amount of absorption of ionizing radiation has increased the possibility of formation of toxic molecule and consequently increased the malignant cells destruction[25].

In the last few years ago the researchers injected nanoparticles metal inside cancer cellsas contrast agentsto increase absorbed dose which lead to increase radio sensitivity of cells.Injection of nanoparticles within the cancer cell leads to serious damage at the injection site without thesurrounding health tissue [26].

Nanoparticles with high atomic number effectively can interact with the high energy incident ray and leads to product electron and photonsor positron with high-energy this is called nanoparticle Enhanced x-ray Therapy NEXT[27].

This research aims to enhance lung radiotherapy by increasing SER then reduce the number dose fractions of radiotherapy therefore the side effect of radiotherapy will reduce.

This works to increase SER. SER is a relation between survival cells number after irradiation with and without nanoparticles.

2. Theoretical part:

The radiotherapy includes the use of ionizing radiation like x-ray photons of high energy products from linear accelerator these are ionizing radiations cause either death or shrinking for cancer cells but this interaction has hits to the surrounding health tissue therefore the need arises to find a way to occur more damage in malignant cells with less damage to the healthy cells surrounding the tumor [4]. x-ray interaction within the specified tissue with presence of nano-materials like titanium,silver,gadolinium and gold nano particles lead to an increase in the number of destroyed cancer cells. The high energy x-ray interaction with high atomic number nanomaterials leads to ensure the production of electron and positron inside tumor, who in turn are working to increase the ionization process within tumor [13, 14, 15, 16, 17, 18].

The computer program will apply the following equations:

1-Irradiation equation without and withnanoparticles [28, 29, 30]:

$$N_s = N_i e^{\left(-\left(1+\frac{d}{\alpha/\beta}\right)\right)} \quad \ldots\ldots\ldots(1)$$

Where:

= survival cells number after irradiation. = initial cells number before irradiation [6].

/ is a factor represent radio-sensitivity(Each organ has a constant valuefor lung 3 Gy)[24].

d(Gy): is dose-per-fraction

2- Dose per fraction equation with nanoparticles[31]:

$$d(Gy) = 8.9 * 10^{-3}\left(\frac{\left(\mu/\rho_{Med}\right)+\left(\mu/\rho_{nano}\right)}{\mu/\rho_{air}}\right) * X \quad \ldots\ldots\ldots(2)$$

Where: $\left(\mu_{en}/\rho\right)_{Med}$ is mass energy absorption attenuation coefficient for medium. $\left(\mu_{en}/\rho\right)_{nano}$ is mass energy absorption attenuation coefficient for nanoparticles. $\left(\mu_{en}/\rho\right)_{air}$:is mass energy absorption attenuation coefficient for air.

X: The exposure in roentgen (R) unite calculated theoreticallyby following equation

$$X = 1.8 \times 10^{-8} E(MeV)\left(\frac{\mu_{en}}{\rho}\right)_{air} \emptyset$$ [32].

E:Photon energy in MeV, $\left(\frac{\mu_{en}}{\rho}\right)_{air}$: mass energy absorption attenuation coefficient for air in cm-2 , Ø : flounce in cm-2.

By substituting equation 2 in equation 1 produce final irradiation equation that will be used to get the results:

$$N_s = N_i e^{\left(-\left(1+\frac{8.9*10^{-3}\left(\frac{(\mu/\rho_{Med})+(\mu/\rho_{nano})}{\mu/\rho_{air}}\right)*X}{\alpha/\beta}\right)\right)} \quad ....(3)$$

Lung tissue is composite of light elements. These elements have percentage of mass as follow H(10.3), C(10.5), N(3.1), O(74.9), Na(0.2), P(0.2), S(0.3), C(l0.3) and K(0.2) so it has low cross section [33]. The increase in cross-section of the lung is by injection of nanoparticles inside lung [34,35]. It is known that cancerous tissue has vascular wider than vascular of surrounding healthy tissue tumor malignant[36]. Therefore the nanoparticles which injected inside the tumor will concentrate more than its presence in the healthy tissue and therefore the absorption of ionizing radiation dose inside the tumor will be greater due to the existence of nanoparticles. Interaction of these nanoparticles with high energy x-ray will increase the free radicals. The accumulation of free radicals product decreasing in surviving cancer cells after irradiation.

The mass energy absorption coefficient (μ/ρen) for adding nanoparticles (gadolinium, gold, silver and titanium) get from the National Institute of Standards and Technology NIST2004[37]. Computer simulation used equation of irradiation equation (3) for a lung without and with (gadolinium, gold, silver, titanium) nanoparticles that adding in lung tumor. The X-ray radiation interacts with each kind of nanoparticles with energy ranging from (2) to (20)MeV.

3. Results:

By appling the final irradiation equation equation(3) on lung without and with using-gadolinium nano particles with x-ray photons whose energy range from (2)MeV to(20) MeV we get fig. shows a decrease in the number of surviving cancer cells due to presence of gadoliniumnanoparticles and increasing energy X-rays as showen in fig.(1).

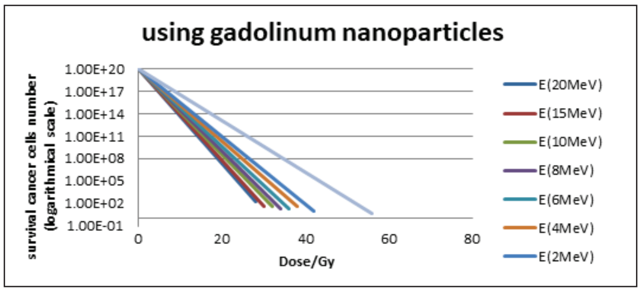

Fig.(1):This figure Shows decreasing in number of surviving cancer cells by utilization gadolinium nanoparticles and incident x-ray radiation with energy (2-20)MeV.

By loading gold nanoparticles inside lung tumor and irradiate by x-ray with energy from (2) MeVto (20) MeVproduct results as shown in fig. (2). This figure shows more decrease in number of surviving cancer cells in other words more destroy in cancer cells.

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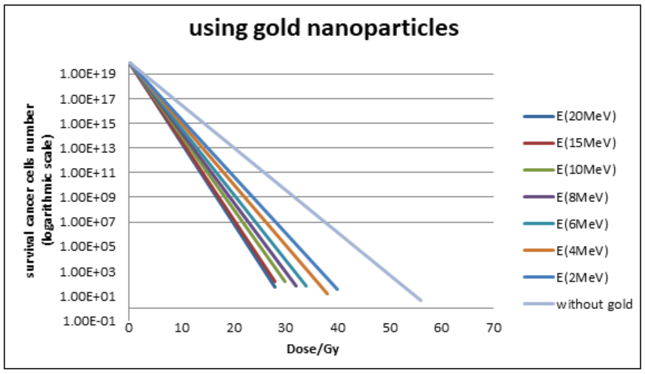

Fig.(2): this figure shows decreasing in number of surviving cancer cellsby utilization gold nanoparticles and incident x-ray radiation with energy (2-20)MeV.

Fig.(3) illustrates interaction results of silver nanoparticles injected into lung with x-ray radiation with energy (2-20)MeV.

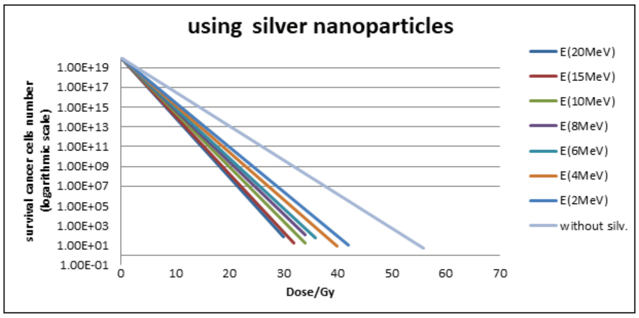

Fig.(3): this figure shows decreasing in number of surviving cancer cells by utilization silver nanoparticles and incident x-ray radiation with energy (2-20)MeV.

Last fig.(4) shows interaction of titanium nanoparticles with x-ray has energy range(2-20)MeV.

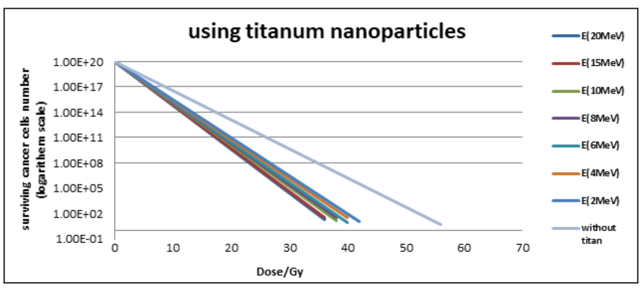

Fig.(4):This figure shows decreasing in number of surviving cancer cells by utilization titanium nanoparticles and incident x-ray radiation with energy (2-20)MeV .

4. Discussion

Fig.(1) shows that when irradiation equation (3)applied on lung malignant cells without and with gadolinium nanoparticles there is an increase in the number of cancer cells destroyed and a decreasing in number of surviving lung cancer cells as a result of the presence of gadolinium nanoparticles.

Also without and with gold, nanoparticles there were increasing in number of destroyed-malignant cells and decreasing malignant cells survivor as shown in fig.(2). Each of fig.(3) and (4) shows reduces in number of surviving lung cancer cells due to presence silver and titanium nanoparticles respectively.

These interesting results were achieved due to the existence of each of nanoparticles incancer tissue in high concentration. Nanoparticles (NPs) have the ability to increase dose deposited from high energy X-ray inside cancer tissue because of their high mass energy absorption coefficient Comparing with health tissue mass energy absorption coefficient which in turn caused breaks in DNA by generating free radicals that damage malignant cells.

By comparing the results of the number of surviving cancer cells with and without existence of nanoparticles its clear can be observed the improvement in sensitivity enhancement ratio(SER) , the results show that the SER was (10.86%) for titanium nanoparticles,(12.51%) for silver nanoparticles,(13.03%) for gadolinium nanoparticles and (13.59%) for gold nanoparticles. The largest amount of improvement was for gold nanoparticles because a gold nanoparticle has a larger absorption coefficient mass attenuation coefficient then gadolinium nanoparticles, silver nanoparticles and titanium nanoparticles respectivelyas shown in fig.(5).

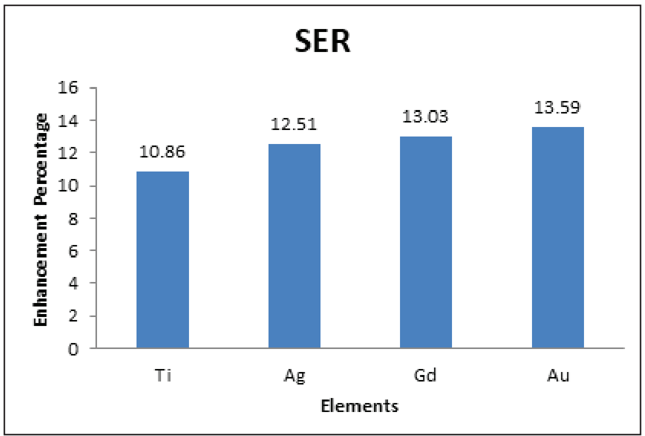

Fig.(5):this figure shows the sensitivity enhancement ratio (SER) in lung with gold nanoparticles(Au), gadolinium nanoparticles(Gd), silver nanoparticles(Ag) and titanium nanoparticles(Ti).

5. Conclusions

Theinteraction of high energy X-ray with gold, gadolinium , silver or titanium nanoparticlescan be improve the lung cancerous tumor radiotherapy by increasing in the number of destroyed malignant cells and decreasing in the number of surviving malignant cells.

The results show that the SER was(13.59%) with gold nanoparticles, (13.03%) with gadolinium nanoparticles,(12.51%)with silver nanoparticles and(10.86%)with titanium nanoparticles respectively.

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