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Investigation the effect of Silver nanoparticles on Sensitivity enhancement ratio in Improvement of Adipose Tissue Radiotherapy Using High Energy Photons

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Abstract: Reducing the number of radiotherapy sessions is the primary goal of the radiotherapist domain. One of the most promising ways is to achieve this goal by adding nanoparticles as a contrast agent to the target where radiation is applied. The contribution of the nanoparticles will appear Sensitivity Enhancement Ratio (SER). SER is the ratio between the number of cancer cells destroyed by the presence of the contrast agent and the number of cells destroyed by the absence of the contrast agent for the same dose. Increasing the amount of SER indicates the increase in the number of destroyed cells compared with the number of destroyed cells in the absence of contrast agent. In this research, silver nanoparticles (AgNPs) were used as a contrast agent for adipose tissue cancer together with photons beam whose energy range from (2-15) MeV that applied to the adipose tissue loaded with AgNPs. The results showed an increase in the SER (1.44 with an energy of 15 MeV), which would indicate a reduction in the number of radiotherapy sessions to become from five to three weeks depending on the energy of applied photon where the normal radiotherapy sessions are seven weeks.

Key words: Photon beam, Adipose tissue, Silver nanoparticles, Radiotherapy sessions, Sensitivity Enhancement Ratio.

1-Introduction:

Ionizing radiation therapy plays an important role in the treatment of adipose tissue cancer [1]. In adipose tissue cancer, photons are used in radiation therapy, through a radiation course ranging from five weeks to seven weeks, during this cycle the patient receives a radiation dose ranging from (50- 62 Gy) [2].The therapeutic photons also have an energy ranged from 6 to 20 MeV[2]. During radiation therapy there are several disadvantages, The first is that radiotherapy takes a long time, There is amount of energy coming out of the treatment area Finally, the most important of which is that the patient who is being treated is exposed to symptoms such as exhaustion and fatigue, for these reasons arise necessity to reduce radiotherapy sessions and focusing ionizing radiation in the specific target [3]. So researchers were interested to develop radiation therapy, one of the modern methods used to improve radiotherapy is use the nanoparticles as a contrast agent [4]. The adipose tissue is considered soft tissue so radiologist cannot determine target with high exactness .The addition of nanoparticles has two important advantages specify the target with high exactness and increase the cross section of the target. Increasing the cross section means increasing the absorption of the energy dose applied to the target without side effects [5].

Silver nanoparticles with high atomic number (47), thermal stability, non-toxicity, Easy to manufacture as a nanomaterial considered an ideal material for improving radiotherapy [6]. The blood vessels within the tumor are large in size compared to the blood vessels in the healthy tissue surrounding the tumor. This makes the concentration of AgNPs within the tumor greater than the concentration in healthy tissues [7]. This results in a cancerous tumor that will absorb more radiation than healthy tissue surrounding the tumor comparing with the same tissue without AgNPs which means producing more free radicals within the tumor that destroy the cancer cells. Accumulating free radicals work to destroy cancer cells, the process of cell destruction within the tumor is very large compared to the absence of nanoparticles [8].

The presence of AgNPs leads to arise of an important factor is the sensitivity enhancement ratio (SER). SER is a factor that relates the number of cells destroyed by the presence of nanoparticles with the number of cells destroyed by the absence of nanoparticles at the same dose. The greater the amount of SER factor means the destruction of more cancer cells with the presence of nanoparticles inside tumor at same dose this research has advantage represented by improve the process of absorption dose by increasing SER and production maximum destruction in malignant cells with minimum damage to the healthy cells surrounding the tumor[9]. This leads to reduce the duration of radiation therapy then reduce the side effects of radiation therapy [10,11].

2-Theoretical layout

Photon beam with high energy is best ionizing radiation which used to treat adipose tissue cancer. Ionizing radiation has two roles in radiotherapy: the disorder destroy cancer cells and determine the size of cells that stop cell growth [12].

At the same moment they infect healthy cells that are near to the tumor so that the need arises to cause more damage to the cancerous tumor without the adjacent tissue. The best way to apply this idea is by injecting the silver nanoparticles into tumor with photon beam [13]. Where the AgNPs work to increase the cross section, increase the absorption of photons within the tumor without the healthy tissue adjacent to the cancer cells, this leads to an increase in the cancer cells radio-sensitivity [14,15].

For photon beam and adipose tissue total mass energy absorption coefficient ($^{\mu_{en}}/_{\rho}$) with presence silver nanoparticles as contras agent inside target equal sum of two mass energy absorption coefficients [16]:

$$(\mu_{en}/\rho)_{total}=(\mu_{en}/\rho)_{adipose}+(\mu_{en}/\rho)_{AgNPs} \text{ ....(1)}$$

Where μen linear energy absorption coefficient, ρ the density , $(\mu_{en}/\rho)_{total}$: total mass energy absorption coefficients, $(\mu_{en}/\rho)_{adipose}$: mass energy absorption coefficients of adipose tissue, $(\mu_{en}/\rho)_{AgNPs}$: mass energy absorption coefficients of AgNPs.
The absorbed dose (D) in unit Gray (Gy) for photon beam [17] :

$$\mathbf{D\ (Gy)=8.9*10^{-3}}\left(\frac{\left(\mu/\rho_{\ target}\right)}{\mu/\rho_{\ air}}\right)*\mathbf{X} \text{ ....(2)}$$

Where: $\left(\mu/\rho\right)_{target}$ mass attenuation coefficient for target, $\left(\mu/\rho\right)_{air}$:mass attenuation coefficient for air. X(R) : The exposure. From two equations (1 ,2) results dosage fractionation equation with nanoparticales as follow:

$$\mathbf{D(Gy)=8.9*10^{-3}}\left(\frac{\left(\mu/\rho_{\ adipose}\right)+\left(\mu/\rho_{\ AgNPs}\right)}{\mu/\rho_{\ air}}\right)*\mathbf{X} \text{ ....(3)}$$

$(\mu_{en}/\rho)_{air}$: air mass energy absorption coefficients, Irradiation equation of dosage fractionation [18]

$$\mathbf{N_s=N_i*Exp(-(1+\frac{D}{\alpha/\beta}))} \text{ ....(4)}$$

Where:N_s= survival cells number after irradiation. N_i= initial cells number before irradiation. α/ β is a factor represent radio-sensitivity takes from references (α/ β =2) [18]. From last two equations (3,4) we get the final irradiation equation:

$$\mathbf{N_s=N_i e}^{\left(-\left(1+\frac{8.9*10^{-3}\left(\frac{\left(\mu/\rho_{\ adipose}\right)+\left(\mu/\rho_{\ AgNPs}\right)}{\mu/\rho_{\ air}}\right)*X}{\alpha/\beta}\right)\right)} \text{ ....(5)}$$

3-Results:

By applying equation (5) on adipose tissue with and without silver nanoparticles, and photon beam has range from 6 MeV to 15 MeV product results show in table (1). Table shows reduction in surviving cancer cells with AgNPs less than irradiates without AgNPs**,** this reduction proportion with energy.

Table 1: Illustrate the decreasing in the number of surviving malignant cells with increasing energy photon beam with the aid of AgNPs.

Dose (Gy)	Number of surviving malignant cells with the aid of AgNPs and high energy photon						
	Without AgNPs	E=2(MeV)	E=4(MeV)	E=6(MeV)	E=8(MeV)	E=10(MeV)	E=15(MeV)
0	1.00×10^{20}	1.00×10^{20}	1.00×10^{20}	1.00×10^{20}	1.00×10^{20}	1.00×10^{20}	1.00×10^{20}
2	2.03×10^{19}	1.25×10^{19}	1.11×10^{19}	9.75×10^{18}	8.72×10^{18}	7.96×10^{18}	6.86×10^{18}
4	4.12×10^{18}	1.56×10^{18}	1.23×10^{18}	9.50×10^{17}	7.60×10^{17}	6.34×10^{17}	4.71×10^{17}
6	8.37×10^{17}	1.95×10^{17}	1.37×10^{17}	9.26×10^{16}	6.63×10^{16}	5.05×10^{16}	3.23×10^{16}
8	1.70×10^{17}	2.43×10^{16}	1.53×10^{16}	9.02×10^{15}	5.78×10^{15}	4.02×10^{15}	2.22×10^{15}
10	3.45×10^{16}	3.04×10^{15}	1.69×10^{15}	8.79×10^{14}	5.04×10^{14}	3.20×10^{14}	1.52×10^{14}
12	7.01×10^{15}	3.79×10^{14}	1.88×10^{14}	8.35×10^{13}	4.4×10^{13}	2.55×10^{13}	1.05×10^{13}
14	1.42×10^{15}	4.73×10^{13}	2.09×10^{13}	8.35×10^{12}	3.83×10^{12}	2.03×10^{12}	7.17×10^{11}
16	2.89×10^{14}	5.91×10^{12}	2.33×10^{12}	8.14×10^{11}	3.34×10^{11}	1.61×10^{11}	4.92×10^{10}
18	3.86×10^{13}	7.38×10^{11}	2.58×10^{11}	7.93×10^{10}	2.92×10^{10}	1.29×10^{10}	3.38×10^{9}
20	1.19×10^{13}	9.21×10^{10}	2.87×10^{10}	7.93×10^{9}	2.54×10^{9}	1.02×10^{9}	2.32×10^{8}
22	2.42×10^{12}	1.15×10^{10}	3.19×10^{9}	7.73×10^{8}	2.22×10^{8}	81458362	15920474
24	4.91×10^{11}	1.44×10^{9}	3.55×10^{8}	73401977	19334752	6485296	1092691
26	9.97×10^{10}	1.79×10^{8}	39418370	7153470	1686036	516326	74996
28	2.02×10^{10}	22395231	4380479	697149	147026	41107	5147
30	4.11×10^{9}	2796374	486793	67941	12821	3272	353
32	8.34×10^{8}	349168	54096	6621	1118	260	24
34	1.69×10^{8}	43598	6011	645	97	20	1
36	3.44×10^{7}	5443	668	62	9	1	0
38	6.98×10^{6}	679	74	6	1	0	0
40	1.42×10^{6}	84	8	1	0	0	0
42	2.88×10^{5}	10	1	0	0	0	0
44	5.85×10^{4}	1	0	0	0	0	0
46	1.19×10^{4}	0	0	0	0	0	0
48	2.41×10^{3}	0	0	0	0	0	0
50	489	0	0	0	0	0	0
52	99	0	0	0	0	0	0
54	20	0	0	0	0	0	0
56	4	0	0	0	0	0	0
58	1	0	0	0	0	0	0
60	0	0	0	0	0	0	0
SER	----	0.89	1.03	1.17	1.27	1.34	1.44

4-Discussion:

Due to the fact that the vascularity of cancer tumor is being larger than that of healthy tissue, then AgNPs is expected to be highly concentrated within tumor more than healthy tissue [7]. Therefore lead to increasing the amount of absorbed dose by the tumor especially ionizing zone since the target is already injected with nanoparticle whose mass energy absorption coefficient is high. This would consequently improve the number of destroyed malignant cell compared with the same target at similar energy but without nano-particles [19]. Overall, the number of the radiotherapy sessions can be reduced at a range of 30 to 50 % depending on the photon energy.

The energy of photon can be considered as another factor which may help in improving of the radio-sensitivity ratio due to its marked contribution in increasing the amount of free radicals yield where this increment can lead to increase the number of destroyed cancer cells. In this research, it was found that the SER was 0.89 with AgNPs at energy 2MeV. In next highest obtained SER values were 1.03 at 4MeV, 1.17 at 6 MeV, 1.27 at 8 MeV, 1.34 at 10 MeV and 1.44 at 15 MeV as can be demonstrated in figure 1. It is clear improving the SER depends, to high extent, on energy of the photons and consequently on the cross section and beam energy.

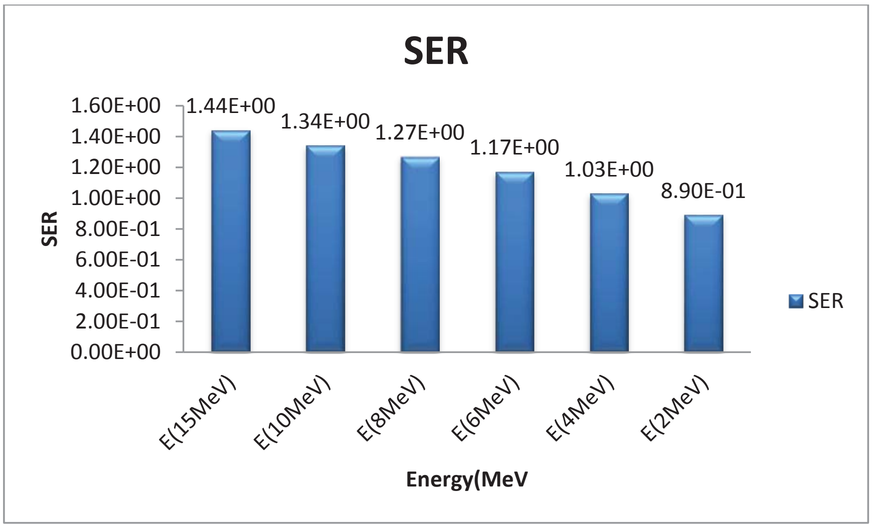

Figure 1: Sensitivity Enhancement Ratio (SER) by usage AgNPs.

5-Conclusion:

Combining AgNPs with high energy photon beam is useful for radiotherapy treatment planning and dose reception then lead to reduce number of radiotherapy sessions to become from 20 to 15 sessions instead of 30 sessions, this reduction depending on beam energy. AgNPs are important in photon dose therapy due to they characterized high accuracy, high efficiency, low cost and are available with high purity.

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