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Effect of Manipulating the Radiation Treatment Technique On the Radiotherapy Sessions

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ABSTRACT

The reduction in the number of radiotherapy sessions is a key target in the field of radiotherapy. An essential technique to reach this target is by using nanoparticle substances as absorption factors for the targeted organ in which a given radiation is utilized. Using the nanotechnology approach would improve radiotherapy sessions. Improving the radiotherapy sessions reflects the large number of cancer cell destruction when compared with the destroyed cell number with absence absorption factor. In this work, gold nanoparticles (AuNPs) were applied as an absorption factor for cancerous adipose tissue together using a beam of highly energetic photons whose energy is up to 2 MeV. The resulting data demonstrated that there is an improvement in the radiotherapy sessions when applying gold nanoparticles as an absorption factor. The finding of this study could indicate a clear reduction in the radiotherapy session figures to approach 5 to 3 weeks, based on the photon's energy, instead of applying the routine radiotherapy sessions number which is known to have up to 7 weeks.

Keywords: X-ray beam, adipose tissue, gold nanoparticles, radiation treatment sessions.

1. INTRODUCTION

The therapy based on high penetrating radiation can be considered as a key in the process of adipose tissue cancer treatment [1]. In this type of cancer, high-energy photons are used. The latter is conducted via a specific plan that extends from 5 weeks to 7 weeks, during this period; the patient would receive a dose of radiation that ranges from 50 Gy to 62 Gy. In this regard, the photons that are applied have energy of 2 MeV [2]. Nevertheless, the process of patient radiation therapy is not free of disadvantages. For example, it is known to take a long period; there is a part of the radiation that is going out of the treatment targeted area. Lastly, the patient who is treated might suffer from some symptoms as side effects. This includes exhaustion and fatigue. Therefore, by considering the latter reasons, a necessity should be raised to reduce the number of radiotherapy sessions together with focusing high energy radiation into specific targets [3]. In this regard, researchers are becoming interested in finding the appropriate approach by which radiation therapy can be developed. To illustrate, one of the recently utilized methods that can take part in improving radiotherapy techniques is applying the science of technology as an absorption factor [4]. Knowing that the adipose tissue is a sort of soft tissue, radiologists may face certain difficulties in the determination of the targeted organs with the required accuracy. The utilization of nanoparticles has two key practical benefits, namely identifying the targeted tissues with maximum accuracy, and improving the radiation absorption area of the target. In this regard, the target absorption area (i.e. cross-section) increment indicates the increase in the energy absorption by the target [5].

Nanoparticle-based gold (AuNPs) is characterized by having a high atomic number (e.g. 79), thermally stable, non-toxic, and Ease of manufacture. These features made it a promising material for increasing the impact of radiotherapy [6]. Cancerous tumors are characterized by having large blood vessels when compared with the vessels of healthy, unaffected tissue. Therefore, direct injection of AuNPs will be concentrated inside the cancerous tumor with high quantity. The latter is a very important since gold nanoparticles will lead to an increase in the target (tumor) absorption of the absorbed dose as compared to the same target but without AuNPs[7]. Using the nanoparticles during the radiotherapy sessions coincides with the production of free radicals inside the tumor which therefore damage the cancer cells.

The role of free radicals in this regard is to destroy cancer cells, which would be expected to be much more than doing so without using nanoparticles [8].

The presence of AuNPs can greatly improve the radiation absorption process inside the tumor. This in turn leads to an increase in the destruction of cancer cells in the existence of the cofactor (AuNPs). The cofactor correlates the figure of destroyed cells with the existence of nanoparticles that figure of destroyed cells without the absence of the absorption factor using a similar dose. The destruction of cancer cells occurs with the existence of an absorption factor within the tumor at the same energy dose [9 - 11]. This work is aimed at investigating the possibility of improving the radiotherapy sessions and then producing maximum destruction in malignant cells while minimizing the amount of damage that the normal cells surrounding the tumor might be subjected therefore, therefore minimizing the period of radiation therapy and minimizing its side effects.

2. THEORETICAL PART

High-energy photons can be used to treat the cases of cancer of the adipose tissue. The highly energetic photons have two major roles in radiation therapy: they can be able to destroy cancerous cells and define the cells' size that can terminate their growth [12]. The best way to increase the impact of radiation therapy is by inserting the AuNPs into the tumor [13]. The AuNPs' role is to improve the process of tissue absorption for the ionizing radiation (i.e. improves the percentage of absorption of photons energy inside the tumor). This can ensure an increase in the radio sensitivity of the cancer cells [14, 15]. To consider the radiotherapy using a beam of photons together with adipose tissue, the mass-energy absorption coefficient ($^{\mu_{en}}/_{\rho}$) (i.e. total) taking into account the existence of gold nanoparticles inside the body target equal to the sum of two mass-energy absorption coefficients [16]:

$$(\mu_{en}/\rho)_{total}=(\mu_{en}/\rho)_{adipose}+(\mu_{en}/\rho)_{GNPs} \quad (1)$$

Where $(\mu_{en}/\rho)_{total}$: the total mass-energy absorption coefficients, $(\mu_{en}/\rho)_{adipose}$: mass-energy absorption coefficients of adipose tissue, $(\mu_{en}/\rho)_{GNPs}$: mass-energy absorption coefficients of AuNPs.

The absorbed dose (D) for the utilized photon beam can be computed as follows [17]:

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

Where: $\left(^{\mu}/_{\rho}\right)_{target}$ mass-attenuation coefficient for the target, $\left(^{\mu}/_{\rho}\right)_{air}$ mass-attenuation coefficient. for air.

X(R): The exposure.

From the above two Eqs. (1) and (2) the resulting dose fractionation equation with the addition of nanoparticles will be as follows:

$$D(Gy)=..8.9*10^{-3}\left(\frac{\left(^{\mu}/_{\rho\ adipose}\right)+\left(^{\mu}/_{\rho\ GNPs}\right)}{^{\mu}/_{\rho\ air}}\right).*X. \quad (3)$$

$(\mu_{en}/\rho)_{air}$: air mass-energy absorption coefficients.

The irradiation equation for the dose fractionation is as follows [18]:

$$N_s = N_i * Exp\left(-\left(1+\frac{D}{^{\alpha}/_{\beta}}\right)\right) \quad (4)$$

Where: N_s= the number of cells that survive after irradiation. N_i= the initial number of cells prior to irradiation α/β represents the radio-sensitivity coefficient (α/β =2).

Considering the last two Eqs. (3) and (4) the resulting irradiation equation can become as below:

$$N_s = N_i e^{\left(-\left(1+\frac{8.9*10^{-3}\left(\frac{\left(^{\mu}/_{\rho\ adipose}\right)+\left(^{\mu}/_{\rho\ GNPs}\right)}{^{\mu}/_{\rho\ air}}\right)*X}{^{\alpha}/_{\beta}}\right)\right)} \quad (5)$$

3. RESULTS

By utilizing Eq. (5) on adipose tissue with the existence and without the existence of AuNPs, together with using a photon beam with 2 MeV to 10 MeV, the resulting data can be seen in the Table 1 . This table demonstrates a clear decrease in cancer cells that survived. This is specifically clear with applying the AuNPs.

Figures 1 to 4 are statistical analysis using (SPSS) software based on Table 1, which represents the data obtained from the simulation program for radiotherapy using MATLAB computer program. This simulation program was theoretically applied to the fatty tissue in two cases: the case of treatment without the presence of gold nanomaterial and the second case with the presence of gold nanomaterial. The second case was applied more than once depending on the energy of the incident photon, as shown in Table 1.

Table 1: Illustrate the decreasing in the number of surviving adipose tissue cells with increasing energy X-ray with the aid of AuNPs

Dose (Gy)	**Without AuNPs**	**Number of surviving malignant cells with the aid of AuNPs and high energy X-ray**				
		E=2(MeV)	E=4(MeV)	E=6(MeV)	E=8(MeV)	E=10(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}
2	2.01×10^{19}	1.16×10^{19}	9.8910^{18}	8.2010^{18}	7.0410^{18}	6.2410^{18}
4	4.04×10^{18}	1.35×10^{18}	9.77×10^{17}	6.73×10^{17}	4.96×10^{17}	3.89×10^{17}
6	8.11×10^{17}	1.57×10^{17}	9.66×10^{16}	5.52×10^{16}	3.49×10^{16}	2.43×10^{16}
8	1.63×10^{17}	1.82×10^{16}	9.55×10^{15}	4.52×10^{15}	2.46×10^{15}	1.51×10^{15}
10	3.27×10^{16}	2.12×10^{15}	9.45×10^{14}	3.71034×10^{14}	1.73121×10^{14}	9.44911×10^{13}
12	6.58×10^{15}	2.45839×10^{14}	9.33963×10^{13}	3.04296×10^{13}	1.21905×10^{13}	5.8948×10^{12}
14	1.32×10^{15}	2.85601×10^{13}	9.23388×10^{12}	2.49562×10^{12}	8.584×10^{11}	3.67746×10^{11}
16	2.65447×10^{14}	3.31794×10^{12}	9.12934×10^{11}	2.04673×10^{11}	60444925913	22941706134
18	5.33305×10^{13}	3.85458×10^{11}	90259775333	16785879492	4256276476	1431211860
20	1.07145×10^{13}	44780187693	8923786363	1376660269	299709018	89285747
22	2.15264×10^{12}	5202289310	882275219	112904033	21104243	5570066
24	4.32482×10^{11}	604370268	87228619	9259598	1486071	347487
26	86889054424	70212054	8624102	759407	104642	21677
28	17456709474	8156808	852646	62281	7368	1352
30	3507193256	947608	84299	5107	519	84
32	704623316	110087	8334	419	36	5
34	141564488	12789	824	34	2	0
36	28441443	1485	81	3	0	0
38	5710000	172	8	0	0	0
40	1150000	20	0	0	0	0
42	231000	2	0	0	0	0
44	46300	0	0	0	0	0
46	9310	0	0	0	0	0
48	1870	0	0	0	0	0

50	376	0	0	0	0	0
52	75	0	0	0	0	0
54	15	0	0	0	0	0
56	3	0	0	0	0	0
58	0.6	0	0	0	0	0
60	0	0	0	0	0	0

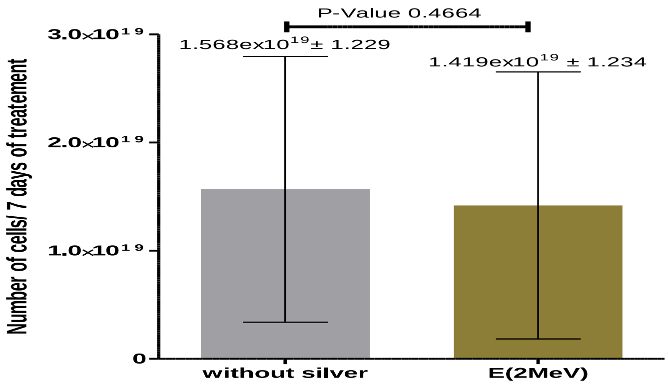
4. DISCUSSION

Having considered the fact that the blood supply via cancerous tumor is higher than that of health tissue blood supply, it must be, then, expected that the AuNPs be greatly concentrated among the tumor area much more than the surrounding cells being healthy. The X-ray radiations from the linear accelerator obtained with an energy that varied from 1 MeV to 15 MeV. It should be noted that the radiation interaction with human tissues within the radiotherapy domain is Compton scattering [19]. In order to increase the amount of radiation absorbed dose, a material with a high cross section is utilized inside the targeted tumor. The role of this high cross-sectional material can lead into the followings: the first is to increase the absorbed dose inside the target; the second one is to convert the type of interaction from Compton interaction into pair production [20-21].

The latter point means that the ionization process will be increased within the targeted tumor. This therefore results in increasing the amount of killing for the cancer cells. Hence, destroying the large amount cancer cells can be achieved using less number of sessions when compared those sessions without using AuNPs[22-23-24].

this would, in turn, increase the percentage of radiation received by the tumor specifically the ionizing site. This is due to the target site of the cancer being injected already with AuNP nanoparticles that had high absorption characteristics for the energy. This, in turn, raises the figure of the damaged cell (malignant) in comparison to a similar cancerous target by applying the same energy, but without using nano-particles as an absorption factor [25]. To sum up, the radiotherapy sessions figure that is expected to be decreased is at a limit of thirty to fifty percent based on the presence of absorption factor and energy used by a given photon.

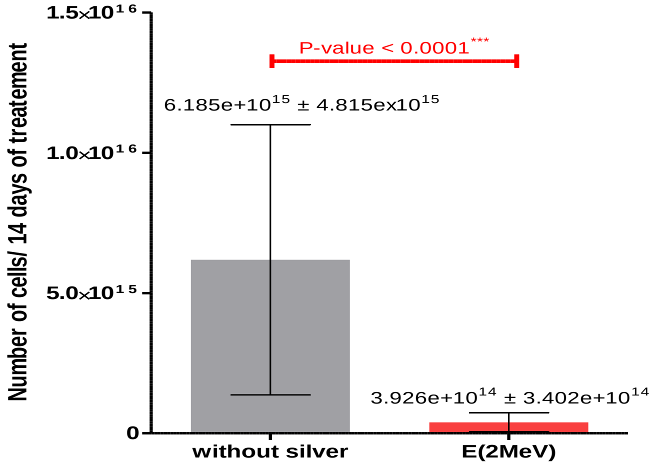
The energy of X-ray used can be taken into account as is another parameter that can help in manipulating the radio sensitivity ratio due to its considerable impact on the increase of the amount of free radicals generated. This increase can result in an increment in the figure of cancer cell destruction. According to the resulting data, and after making the statistical analysis of SPSS, it can be argued that there was a clear and significant reduction (P-value <0.05) in the figure of the irradiated cancer cells. This was very marked with those cancer cells that took the AuNPs when compared with those that did not have the AuNPs. From Fig. 1,



Without AuNPs *With AuNPs*

Fig. 1. Comparison between first-week sessions with and without AuNPs.

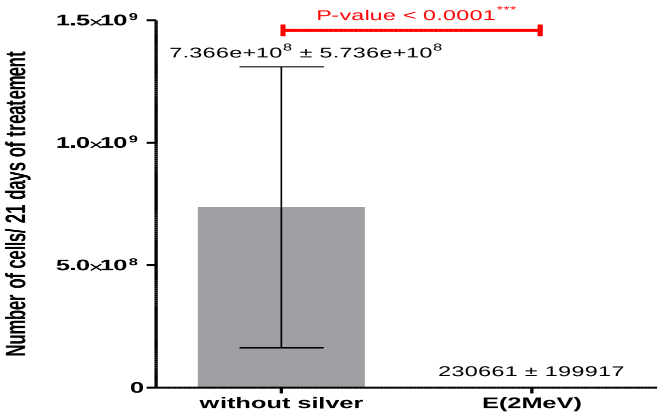
it can be found that the P-value for the first week of irradiation was not significant in terms of radiotherapy impact (i.e. P-value = 0.4). The second-week effect of the radiotherapy session using nanoparticles demonstrates that the irradiation had a clear destruction in the cancer cells (P-value = 0.0001) as can be illustrated in Fig. 2.



Without AuNPs *With AuNPs*

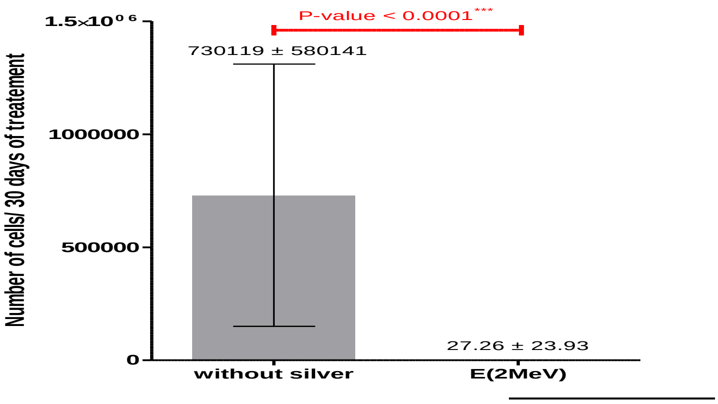
Fig. 2. Comparison between second-week sessions with and without AuNPs.

The latter improvement was seen to be continued even in the later week sessions of the irradiation which indicate the efficiency of the considered strategy in enhancing the patient healthcare in the radiotherapy department (see Figs. 3 and 4).



Without AuNPs *With AuNPs*

Fig. 3. Comparison between third-week sessions with and without AuNPs.



Without AuNPs *With AuNPs*

Fig. 4. Comparison between fourth-week sessions with and without AuNPs.

Overall, the radiotherapy sessions figure was reduced to about one to two weeks by using the gold nanoparticles.

5. CONCLUSION

The combination of the AuNPs with high energy photon beam in treating the cancer of the adipose tissue is a highly promising approach in radiotherapy treatment planning. The latter can then lead to minimizing the radiotherapy sessions figure to become 5 instead of 10 sessions. This reduction is thought to be based on the inclusion of the nanoparticle technique.

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