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Improvement of lung cancer radiotherapy using gold nanoparticles and gamma ray photons with high energy.

Najam Abed Askouri
Al- Farabi Institute for High study ,Holy Najaf, Iraq
E-mail:najm.askori@gmail.com

Abstract :

Since the lung tissue has small cross section so that we can introduce an agent to enhance the local cross section. Among nanomaterials gold nanoparticles (GNPs) has significant attention because their physical and biological properties. Like it has high absorb to gamma ray photons when it irradiate by external gamma ray compared to lung tissue so gold nanoparticles are used in local dose enhancement in lung tumor during external radiotherapy. In the present study we estimate the dose enhancement by simulation program for several concentrations of gold nanoparticles (GNPs) interact with high energy photons, by consider entity the gold nanoparticles in lung cancer tumor then irradiate by gamma ray photons with energy 12 Mev. The results showed enhancing in absorbed dose. This enhancement represent by increasing in destroyed cancer cells and it depending on concentration of gold nanoparticles (GNPs) within the lung cancer tumor and gamma ray photons with high energy.

Key Words: Gold nanoparticles (GNPs) , Radiotherapy, Dose enhancement, lung cancer , External gamma photon.

1. INTRODUCTION

lung cancer is the most common cancer in the world, the most common cause of cancer-related death. Between 80% and 90% of all lung cancer cases are non-small cell lung cancer (NSCLC), and most of the others are small cell lung cancer (SCLC). In contrast to other common solid cancers, lung cancer has no well-established methods for early detection, and most cases are diagnosed at an advanced stage. lung cancer has been improvement in treatment options, including surgical techniques, chemotherapy, and radiation therapy, the overall 5-year survival rate for patients with lung cancer remains low, approximately 15%[1].Currently, patients with lung cancer are treated with surgical operation followed by radiotherapy and chemotherapy or by one of these[2].

Radiotherapy aims to deliver a high therapeutic dose of ionizing radiation to the lung tumor without exceeding normal tissue[2]. In radiotherapy lung gland absorbs nearly all of the ionizing radiation . Because of this ionizing radiation can be used to destroy the lung gland cancer .This treatment is often used after lung cancer surgery to destroy any lung cells that may have been left behind surgery. It’s also used to treat some types of lung cancer that spread to lymph nodes and other parts of the body[2].

Gold nanoparticles (GNPs) are used to enhance radiothrapy because their unique properties of small size, high entrance to the living cells, thermal stability over high temperatures and translocation into the cells.Gold nano particles has been used to improve the radiotherapy by enhancing cross section in the lung tissue [3].

The size of GNPs in colloidal suspension is determined mainly by the gold salt concentration and temperature[4]. Radiotherapy combined with Gold nanoparticles is a new way to enhance cancer radiotherapy, in which gold nanoparticles (GNPs) are injected and bound to tumor sites then cancer cells uptake of gold nanoparticles [5,6].

GNPs with high atomic number (Z) enhanced photons absorption have allowed them to emerge as powerful absorbing inside organ . the cross section of the organ with gold nanoparticles have better absorption levels than normal organ[7,8].

When an external gamma photon-ray hits these gold nanoparticles inside lung cancer cells , particles can subsequently generate free radicals that damage lung cancer cells and induce cancer cell apoptosis[9,10].

2. THEORETICAL MODEL:

The linear attenuation coefficient μ depends on the energy E of the incident photons and density of the interacting medium. One of the more important quantities that determines μ is the density of target atoms or electrons in the material . It seems reasonable to expect that μ should be proportional to the "target" atom density in the material, that is

$\mu = N_A \sigma w / A$ ……………………….. (1)

Where μ: linear attenuation coefficient (cm^{-1}), N_A is Avogadro's number , σ: the microscopic cross section and A is mass No., w: is the weight [11].
Dividing both sides by ρ (density g/cm^3)
$\mu/\rho = N_A\,\sigma\,w/\rho\,A$ ………..………… (2)
μ/ρ: mass attenuation coeff. (cm^2/g)
From eq.2 we can write the cross section as follow :

$$\sigma = \frac{(\mu/\rho)\,\rho A}{NA\;\;w} \quad \text{…………….…………. (3)}$$

For photons of high energy (12MeV.) and the attenuator is the gold (Z=79) the pair production(electron and positron) process is prevailing . The equation of irradiation is
$N_d = \phi\, t\, N_i\, \sigma$ …………………………. (4)
N_d: The number of cells destryed cancer cells after irradiation,ϕ: is the flux of particles (particle/ cm^2.sec.), t: is the time of exposure to radiation(second),Ni: is the number of cells cancer per unit volume ($cell/cm^3$) [12].
By substitute eq.3 in eq.4 we get the final irradiation equation as a function of mass absorption coefficient

$$Nd = \phi\; t\; Ni\,\frac{(\mu/\rho)\,\rho A}{NA\;\;w} \quad \text{………………… (5)}$$

3.THEORETICAL CALCULATION:

The mass attenuation coefficient for gold when interact with photon energy 12 MeV is 0.04355 cm^2/g , the mass number 196.966, the gold density 19.32 g/cm^3 [13].The mass number for lung (A) 33.04967 and lung density 1.05 g/cm^3 [14]. Mass attenuation coefficient for lung 0.199 cm2/g [15]. Fractionation by external photons ray assumed to create a suitable therapeutic [16] .

Computer simulation program was used equation of irradiation (eq. 5) for a lung with Gold nanoparticles (GNPs) in concentrations (0.001, 0.01, 0.002, 0.02, 0.003, 0.03, 0.004, 0.04, 0.005, 0.05)grams, each concentration interact with photons in energy 12MeV. The flux was 10^{18} ($photon/cm^2.s$) and time of irradiation is 1200 sec. The results are tabulated in tables 1and 2 and these table are agreement with fractionation in radiotherapy .

4-DISCUSSION

From the results in table 1 and 2 we note that when the gold nanoparticles in small weight i.e. in small size , there are increasing in number of destroyed lung cancer cells this result due to entity of gold nano-particles in lung cancer cells with high concentration.

Gold nanoparticles (GNPs) have biocompatibility and ability to increase dose deposited because of their high mass absorption coefficient. which in turn caused breaks in DNA by generating free radicals that damage cancer cells .

Maximum damage noted in concentrations(0.001-0.05) grams respectively because these nanoparticles formed in nanosize to become capable to enter inside the cancer cells and make maximum damage by accumulation free radicals inside lung cancer cells then generate peroxide hydrogen molecule .

Figure 1 indicate the gold nanoparticles in concentration 0.001 gram make the maximum destroyed in lung cancer cell, because it capable to entrance to the cancer cells and make the maximum damage .

5-CONCLUSION

We conclude entity gold nanoparticles as a colloidal solution inside lung cancer cells enhancing the lung cancer radiotherapy . Our results showed that gold nanoparticles (GNPs) with photons of high energy (12MeV) significantly enhancing the radiotherapy . Where we note increase in number of destroyed cancer cells i.e. destroy large number from cancer cells in minimum dose that given to patient.

There are two benefits from using gold nanoparticles with external high energy photons:

1- GNPs can be enhanced the local cross section radiotherapy by increase absorbed dose of ionizing radiation to the lung tumor without exceeding normal tissue.
2- GNPs were used to enhance lung cancer apoptosis by radiotherapy.

we find enhancement in external radiotherapy and this result in agreement with literatures in the world[6-9,17-23].

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Table -1 : Destroyed of lung cancer cells by dose fractionation concentration of gold nanoparticles (0.001-0.003)g.

Dose (Gy)	Number of destroyed cancer cells by dose fractionation at concentrations:				
	W=0.001 g.	W=0.01 g.	W=0.002	W=0.02 g.	W=0.003 g.
2	232746051387	23274778709	116373121218	11637484879	77582147506
4	117913103695	11791398303	58956600242	5895747546	39304433949
6	59736781527	5973722701	29868415281	2986885868	19912293971
8	30263668374	3026389406	15131846608	1513207124	10087906410
10	15332088540	1533220287	7666050562	766616436	5110704768
12	7767496527	776755445	3883751451	388380910	2589169860
14	3935145700	393517504	1967574465	196760367	1311717437
16	1993611665	199362653	996806650	99682144	664538338
18	1009997538	101000507	504999183	50500668	336666411
20	511681911	51168572	255841165	25584496	170560923
22	259226749	25922868	129613481	12961540	86409061
24	131328675	13132965	65664391	6566536	43776298
26	66533337	6653383	33266696	3326719	22177816
28	33706919	3370717	16853473	1685372	11235658
30	17076497	1707662	8538255	853838	5692175
32	8651243	865130	4325625	432568	2883752
34	4382867	438289	2191435	219146	1460958
36	2220434	222045	1110218	111023	740146
38	1124910	112491	562455	56246	374970
40	569898	56990	284949	28495	189966
42	288720	28872	144360	14436	96240
44	146270	14627	73135	7313	48756
46	74103	7410	37051	3705	24701
48	37541	3754	18770	1877	12513
50	19019	1901	9509	950	6339
52	9635	963	4817	481	3211
54	4881	488	2440	244	1627
56	2473	247	1236	123	824
58	1252	125	626	62	417
60	634	63	317	31	211
62	321	32	160	16	107
Status	F	F	F	F	F

Note:1- W: represent the concentration of gold nanoparticles in gram.
2- F. :Fractionation

Table -2 Destroyed of lung cancer cells by dose fractionation concentration of gold nanoparticles (0.03-0.05)g.

Dose (Gy)	Number of destroyed cancer cells by dose fractionation at concentrations:				
	W=0.03 g.	W=0.004 g.	W=0.04g	W=0.005 g.	W=0.05 g.
2	7758386936	58186656134	5818837964	46549366368	4655108408
4	3930530627	29478348515	2947922167	23582699817	2358357004
6	1991273590	14934232158	1493467451	11947396368	1194783723
8	1008813030	7565935725	756615983	6052753971	605297732
10	511081819	3833031574	383314511	3066427990	306654114
12	258922732	1941878913	194193643	1553504514	155356184
14	131174655	983788847	98381798	787031779	78706082
16	66455308	498404143	49841890	398723670	39873838
18	33667388	252500006	25250748	202000185	20200763
20	17056470	127920792	12792458	102336725	10234050
22	8641097	64806846	6480876	51845523	5184743
24	4377727	32832249	3283322	26265823	2626679
26	2217830	16633375	1663386	13306712	1330720
28	1123590	8426750	842700	6741406	674165
30	569230	4269135	426926	3415311	341543
32	288381	2162816	216288	1730254	173031
34	146099	1095719	109575	876576	87660
36	74016	555110	55512	444088	44410
38	37497	281228	28123	224982	22499
40	18997	142474	14247	113980	11398
42	9624	72180	7218	57744	5774
44	4875	36567	3656	29254	2925
46	2470	18525	1852	14820	1482
48	1251	9385	938	7508	750
50	633	4754	475	3803	380
52	321	2408	240	1927	192
54	162	1220	122	976	97
56	82	618	61	494	49
58	41	313	31	250	25
60	21	158	15	126	12
62	10	80	8	64	6
Status	F	F	F	F	F

Note:1- W: represent the concentration of gold nanoparticles in gram.
2- F. :Fractionation

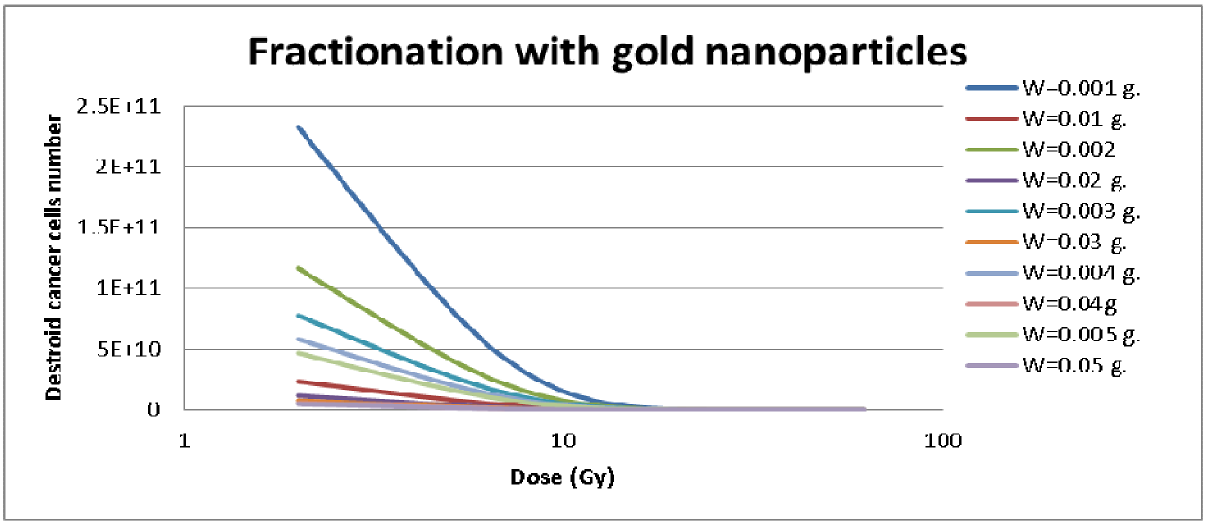

Fig.1: Gold nanoparticles concentrations (0.001-0.05) g. interact with photon in energy 12 MeV .