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Using gold nanoparticles with high energy gamma photons (12MeV)to treat brain cancer

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Abstract:

This paper deals with one of the interesting topic in medical application where Gold nanoparticles (GNPs) are good choice due to characterize ability of synthesis as colloidal solution as well as did not interact with healthy tissue, less toxicity, ease of detection and thermal stability. The brain cancer can be treatment by high energy photons of gamma ray about (12 MeV) and gold nanoparticles while preserving the brain and prevents the risk of recurrence of brain cancer. This occur in a minimum dose given for patient i.e. enhancing the radiotherapy that is used in brain cancer treatment by depending on pair production phenomena. Our results showed that GNPs have significantly enhancing the radiotherapy for brain cancer treatment with high energy of gamma photons (12MeV).

استعمال جسيمات الذهب النانوية مع فوتونات كاما ذات طاقة عالية(12MeV) لمعالجة سرطان الدماغ

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الخلاصة:

اختيار جسيمات الذهب النانوية في التطبيقات الطبية هو اختيار جيد بسبب القدرة على تصنيعها كمحلول غروي , لا يتفاعل مع النسيج الحيوي, لا يتأكسد فلا ينتج آثار سمية في النسيج الحي ومستقرة حراريا أيضا من مميزاته انه عنصر ثقيل نسبة إلى عناصر النسيج الحيوي لذا سهولة الكشف عنه داخل النسيج الحيوي وضمان حدوث ظاهرة إنتاج الزوج الالكتروني عند تفاعل الذهب مع فوتونات كاما ذات الطاقة العالية 12 ميكاالكترون فولت. في هذا البحث سنركز على كيفية علاج سرطان الدماغ بواسطة فوتونات أشعة كاما ذات الطاقة العالية (12 ميكاالكترون فولت) عند تفاعلها مع جسيمات الذهب النانوية مع البقاء على خلايا الدماغ , أيضا منع خطورة إعادة المرض بعد العلاج يتم هذا بأقل جرعة من الإشعاع تعطى للمريض . بعبارة أخرى تحسين العلاج بالإشعاع المستخدم في علاج سرطان الدماغ بالاعتماد على ظاهرة إنتاج الزوج الالكتروني . النتائج التي تم الحصول عليها أظهرت ان تفاعل جسيمات الذهب النانوية مع فوتونات اشعة كاما ذات طاقة عالية (12 MeV) ينتج عنها تحسن ملحوظ لعلاج سرطان الدماغ بواسطة الإشعاع .

Key Word: gold nanoparticles, gamma photons, Brain cancer, pair production

كلمات مفتاحية : جسيمات الذهب النانوية , فوتونات كاما ,سرطان الدماغ , إنتاج الزوج .

1-Introduction:

Brain tumors include all tumors in the central spinal canal or inside the human skull (cranium). They are created by an abnormal and uncontrolled cell division, most of them in the brain itself, but also in lymphatic tissue, in blood vessels, in the cranial nerves, in the brain envelopes (meninges), skull, pituitary gland, or pineal gland. Within the brain itself, the involved cells may be neurons or glial cells (which include erythrocytes, oligonucleotide, and dependably cells). Brain tumors might spread from cancers primarily located in other organs (metastatic tumors) [1]. Currently, patients with brain cancer was treated by radiotherapy and chemotherapy [2]. GNPs are considered in therapeutics due to their unique properties of small size, high reactivity to the living cells, stability over high temperatures and translocation into the cells [3]. GNPs are the colloidal suspension of gold particles of nanometer sizes [4]. The size of GNPs is determined mainly by the gold salt concentration, temperature and rate of addition of reactants resulting in size range of 10–25 nm. However, the size range of 1–100 nm or more can also be achieved by varying the gold salt concentration and temperature [5]. A new way to treat cancer is therapy combined with metallic nanoparticles where GNPs are injected and bound to tumor sites. The particles can be subsequently generated freely radicals that damage cancer cells and induce cell apoptosis when an external photon-ray source hits on these nanoparticles. Results have shown improvement in the treatment effects on brain cancer cells with little or no increase in harm to normal surrounding tissues. In a translation study, GNPs were used to enhance brain cancer apoptosis by radiotherapy [6].

2-Theoretical Models:

2-A: Equation derivation

Photons may undergo various possible interactions with atoms of an attenuator (photo electric effect, Compton scattering and pair production); the probability (cross-section) for each interaction depends on the energy hν of the incident photon and on the atomic number Z of the matter(attenuator) . When the energy of photon 6MeV and the attenuator is the gold (Z=79) the pair production(electron and positron) process is prevailing these electrons and positrons generate free radicals then cause damage to DNA of cancer cells. [7]

The linear attenuation coefficient (μ) relate with probability for pair production interaction (cross section σ) by the following relation:[8]

$$\mu = N_A \sigma w / A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where μ: linear attenuation coefficient (cm^{-1}), N_A is Avogadro's number (6.022 1367 * 10^{23} atoms/mol), σ: the microscopic cross section for reaction (cm^2) and A is mass No., w: is the weight (gram) [9]. Dividing both sides by ρ (density g/cm^3)

$$\mu/\rho = N_A \sigma w/ \rho A \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

μ/ ρ: mass attenuation coeff. (cm^2/g)

From eq.2 we can write the cross section as follow :

$$\sigma = \frac{(\mu/\rho)\,\rho A}{NA\ w} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

For photons of high energy (6MeV.) and the attenuator is the gold (Z=79) the pair production(electron and positron) process is prevailing . The equation of irradiation is given by

$$N_d = \phi\, t\, N_i\, \sigma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

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) [10]. By substitute eq.3 in eq.4 we get the final eq. for irradiation

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

2-B: Theoretical Calculation and results :

The mass attenuation coefficient for gold and brain can be calculated through the photon energy and number of atoms from the National Institute of Standards and Technology (NIST2004) [11, 12] and encyclopedia of medical devices and instrumentation [13]. Fractionation was assumed to create a suitable therapeutic [14]. We consider computer simulation program for equation of irradiation eq. (5) for a brain with (GNPs) in concentrations (0.005,0.015,0.025, 0.035, 0.045, 0.055, 0.065, 0.075, 0.085, 0.095, 0.15, 0.25, 0.35, 0.45, 0.55) grams. Each concentration interact with photons in energy 12MeV. The flux is 10^{18} (photon/cm^2.s) and time of irradiation is 1200 sec. The results are tabulated in tables 1,2,3,4 and these table are in agreement with fractionation in radiotherapy [6,15-19].

Table 1 : Destroyed of brain cancer cells by dose fractionation concentration of gold nanoparticles (0.005-0.045)gm. W: denotes the concentration of gold nanoparticles in gram, S.Sh.: Single shot, and F.:Fractionation

Dose (Gy)	Number of destroyed cancer cells by dose fractionation at concentrations:				
	W=0.005 gm.	W=0.015 gm.	W=0.025 gm	W=0.035 gm.	W=0.045 gm.
2	46550300870	15517517324	9310960268	6651007563	5173255821
4	23583173252	7861437899	4717090653	3369513423	2620859286
6	11947636217	3982737995	2389758262	1707052744	1327771839
8	6052875483	2017722730	1210692134	864821920	672671771
10	3066489550	1022212613	613357203	438133477	340786947
12	1553535702	517870276	310737179	221965862	172648456
14	787047579	262361879	157424734	112451677	87466641
16	398731674	132916985	79754044	56969930	44312086
18	202004240	67338002	40404754	28861934	22449255
20	102338779	34114576	20469734	14621946	11373174
22	51846564	17283023	10370315	7407726	5761843
24	26266350	8755873	5253777	3752880	2919047
26	13306979	4435874	2661653	1901272	1478839
28	6741541	2247289	1348438	963217	749205
30	3415379	1138514	683141	487982	379560
32	1730289	576791	346091	247220	192291
34	876593	292212	175335	125245	97418
36	444097	148039	88828	63451	49353
38	224987	74999	45001	32145	25003
40	113982	37995	22798	16285	12667
42	57745	19249	11550	8250	6417
44	29254	9752	5851	4179	3251
46	14820	4940	2964	2117	1647
48	7508	2502	1501	1072	834
50	3803	1268	760	543	422
52	1927	642	385	275	214
54	976	325	195	139	108
56	494	164	98	70	54
58	250	83	50	35	27
60	126	42	25	18	14
62	64	21	12	9	7
Status	S.Sh.	S.Sh.	S.Sh.	S.Sh.	S.Sh.

Table-2 Destroyed of brain cancer cells by dose fractionation concentration of gold nanoparticles (0.055-0.095)gm. W: denotes the concentration of gold nanoparticles in gram, S.Sh.: Single shot, and F.:Fractionation

Dose (Gy)	Number of destroyed cancer cells by dose fractionation at concentrations:				
	W=0.055gm.	W=0.065gm.	W=0.075gm	W=0.085gm.	W=0.095gm.
2	4232868690	3581831396	3104403713	2739312245	2451082123
4	2144443189	1814616636	1572743661	1387782120	1241759844
6	1086411351	919315616	796778657	703073999	629096633
8	550394447	465740909	403661604	356189232	318711041
10	278839177	235952256	204501826	180451516	161464428
12	141264664	119537421	103604099	91419803	81800622
14	71567078	60559688	52487596	46314825	41441585
16	36257098	30680567	26591108	23463877	20995011
18	18368461	15543296	13471507	11887198	10636429
20	9305774	7874498	6824894	6022256	5388595
22	4714463	3989354	3457607	3050977	2729954
24	2388427	2021074	1751682	1545677	1383041
26	1210017	1023910	887432	783066	700672
28	613015	518730	449588	396714	354972
30	310564	262797	227769	200982	179835
32	157337	133137	115391	101821	91107
34	79709	67449	58459	51584	46156
36	40382	34171	29616	26133	23383
38	20458	17311	15004	13239	11846
40	10364	8770	7601	6707	6001
42	5250	4443	3850	3398	3040
44	2660	2251	1950	1721	1540
46	1347	1140	988	872	780
48	682	577	500	441	395
50	345	292	253	223	200
52	175	148	128	113	101
54	88	75	65	57	51
56	44	38	32	29	26
58	22	19	16	14	13
60	11	9	8	7	6
62	5	5	4	3	3
Status	S.Sh.	S.Sh.	S.Sh.	S.Sh.	S.Sh.

Table 3 : Destroyed of brain cancer cells by dose fractionation concentration of gold nanoparticles (0.15-0.55)gm. W: denotes the concentration of gold nanoparticles in gram, S.Sh.: Single shot, and F.:Fractionation

Dose (Gy)	Number of destroyed cancer cells by dose fractionation at concentrations:				
	W=0.15 gm.	W=0.25 gm	W=0.35 gm.	W=0.45 gm.	W=0.55 gm.
2	1552764632	932109037	666113767	518338612	424299854
4	786656942	472222273	337464550	262599147	214957514
6	398533771	239235826	170965274	133037189	108901128
8	201903979	121200933	86613912	67398900	55171161
10	102287985	61402452	43880079	34145427	27950647
12	51820831	31107525	22230393	17298653	14160273
14	26253313	15759600	11262295	8763791	7173834
16	13300374	7984081	5705670	4439885	3634386
18	6738195	4044871	2890589	2249321	1841242
20	3413684	2049200	1464421	1139544	932804
22	1729430	1038159	741900	577312	472574
24	876158	525949	375859	292476	239414
26	443876	266454	190416	148173	121291
28	224875	134990	96468	75067	61448
30	113925	68388	48872	38030	31130
32	57716	34646	24759	19266	15771
34	29240	17552	12543	9760	7990
36	14813	8892	6354	4945	4047
38	7504	4505	3219	2505	2050
40	3802	2282	1631	1269	1038
42	1926	1156	826	642	526
44	975	585	418	325	266
46	494	296	212	165	135
48	250	150	107	83	68
50	126	76	54	42	34
52	64	38	27	21	17
54	32	19	13	10	8
56	16	9	7	5	4
58	8	5	3	2	2
60	4	2	1.8	1	1
62	2	1	0.9	0.7	0.5
Status	S.Sh.	F	F	F	F

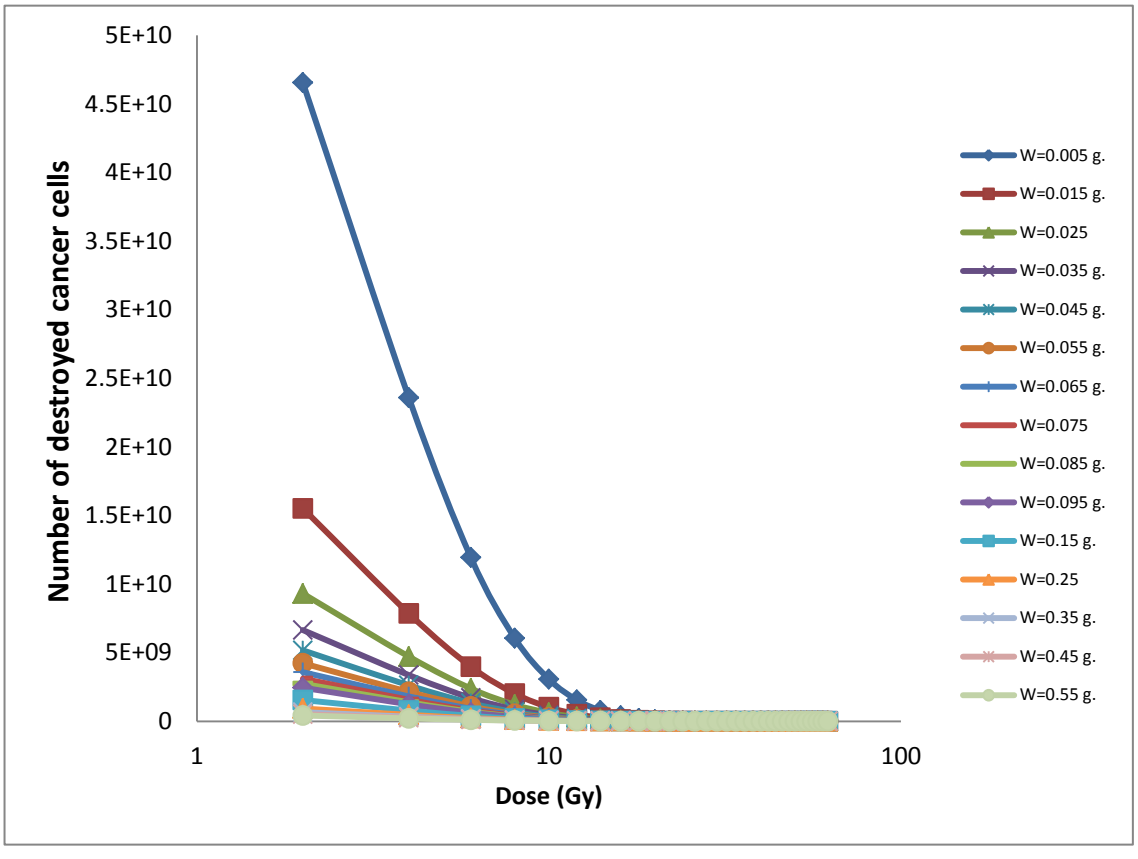

Fig.1: Gold nanoparticles concentrations (0.005-0.55) g. interact with photon in energy 12 MeV.

3-Discussion

We apply equation 5 with gold nanoparticles by Fortran program and input the number of parameters for brain cancer cells, the flux of incident photons and time of irradiation 1200 second. We can see increasing in number of destroyed cancer cells this result due to existence of gold nano-particles in cancer cells with high concentration. The results obtained in table 1 A and B. In particular, due to high mass energy absorption coefficient of GNPs which lead to have biocompatibility and ability to increase dose deposited that it turns to break in DNA by generating free radicals that damage cancer cells. Our results showed improvement in the treatment effects on cancer cells. Maximum damage noted in weights (0.05; 0.015) grams, respectively, because the nanoparticles have a formed in size to become capable to enter inside the cancer cells and make maximum damage in single shot (S.Sh.).

4-Conclusions

We have developed a method for enhancing the treatment of brain cancer by using gold nano-particles as a colloidal to achieve targeted delivery at the brain cancer cells. Our results showed that gold nano-particles (GNPs) with photons of high energy (12MeV.) have significant enhancing of the radiotherapy. Indeed, we showed that the number of destroyed cancer cells are increase (i.e. destroy large number from cancer cells in minimum dose that given to patient). Our results can be arranged in two benefits from using gold nano-particles with high energy photons:
1) GNPs can be enhanced the treatment by radiation. Thus, lower doses of radiation can be used to avoid the risk of side effects.
2) Local damage to normal tissue surrounding the cancer is decreased because the concentrations of gold nanoparticles increase in cancer cells.

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