DOI Number: 10.37506/v14/i1/2020/ijfmt/192943

The Effect of Doubled Concentration of Nanoparticles with Gamma-Rays Energy as Simulation Radiotherapy in Lung Cancer

Shihab Ahmed Jasim[1], Nihad A. Saleh[2]

[1]Department of Physics, College of Science/ Kufa University, Iraq

Abstract

Background: Nanoparticles are considered main mediatorss to improve the efficacy of radiotherapy. By their nano size, they can penetrate the cellular environment and concentrate inside it. Nanoparticles own high cross-section and energy mass attenuation coefficient which means that they have high energy absorption. This study focused on decreasing the irradiation dose required to kill malignant cells by direct injection of NPs inside tumor cells in order to increase the amount of absorbed dose by adding a doubled increased concentration of (zinc and tellurium) NPs in tumor cells with minimum injury to the surrounding healthy tissue and increasing the number of destroyed cancer cells. **Method:** The theoretical basis for conducting current study was that to increase organ tolerance for radiation dose absorption, the injected particles inside the tumor should have high radiation dose absorption inside tumor. **Results:** There was increasing apoptosis of cancer cells and decreasing malignant cells survivor in low dose in comparison with high dose without NPs. The number of dead cancerous cells was increasing with doubling increase of NPs which depends on cross-section that is usually depending on high mass energy absorption coefficient and type and amount of energy. **Conclusion:** Zinc and tellurium nanoparticles can potentiate the effect of radiotherapy on lung tumor cells through increasing number of destroyed malignant cells which depended on atomic number and cross-section.

Keywords: *lung cancer, high energy gamma ray, absorbed dose, Zn NPs, Te NPs.*

Introduction

According to World Health Organization, the International Agency for Research on Cancer, the number of cancer death is 6.7 million and there are 24.6 million people are still successful with cancer. The highest public cancers are lung (1.35 million) [1].

The radiobiology and radiation injury to the lungs has been described by several authors. The lung is the most radiosensitive organ in the thorax, because lung tissue has a lower density than other soft tissue. A nominal 8Gy corresponds to doses 8-15% higher to lung tissue using cobalt-60 gamma rays. Hence, 8Gy becomes 8.6-9.2 Gy (cobalt-60). The earliest signs of radiation injury in the lungs are oedema and changes in blood circulation followed by pneumonitis and pronounced respiratory insufficiency, which appears after a latent period of 1-3 months after doses greater than about 8Gy [2].

The effect of radiation therapy on cancer occurs when applying high energy rays using the technology of nanoparticles [3]. The radiotherapy does not always give the required efficiency to treat tumor cells, because radiation sensitivity of tumor cells is limited, therefore; it appears necessary to increase the concentration of radiation within the ionizing zone and increase the Sensitivity Enhancement Ratio (SER), because of difficult treatment in the area and the limited tolerance dose of the organ [4].

The effective dose of radiation involves use of high energy rays and the concentration of ionizing radiation in the tumor within the dose. Sometimes, this method has limited effect on the treatment process [5].

The Direct injection technique of nanoparticles (NPs), such as ZnNPs and TeNPs in the tumor has some practical advantages such as to focuses the radiation within the desired area and increase the absorbed dose in the tumor and to avoid surrounding healthy tissue from exposure to unnecessary radiation [6].

Radiotherapy involves the use high Gamma-energy (ionizing radiations) that lead to death or shrinkage of cancer cells, but this interaction causes injury to the enveloping healthy soft tissue. To create greater damage for malignant cells with fewer damage to healthy cells nearby the malignant tumor, we need to increase the organ tolerance for radiation dose absorption inside the tumor by injecting particles that have high radiation dose absorption inside tumor [7]. The choice of such material is for several reasons; it is easy manufactured as nano materials, possesses thermal stability, do not interact with organ tissue and do not have toxic effects [8].

The interaction of electrons and photons within malignant cells creates free radicals that lead to the damage of malignant cells [9, 10].

Thus, the greater quantity of absorption of ionizing radiation has better formation of toxic molecules and so increased malignant cells damage. The injection inside cancer cells works on directing specific cellular components within the tumor tissue leading to severe damage at the injection site without affecting nearby health soft tissue [11,12].

The interaction between ionizing radiation with water inside the cell results in formation of free radicals. The accumulation of free radicals leads to formation of toxic molecules. These toxic molecules work cause destruction of cancer cells. Since the production of free radicals within the tumor is larger than in healthy tissue surrounds the tumor, the destruction inside tumor is larger [13].

The biological effect of ionizing radiation depends on absorbed dose, the energy of gamma rays radiation and organs irradiated. When photons enters to the body they lose energy and are finally absorbed, but also they give rise to new photons by multiple scattering. The magnitude of this new effective photon can be estimated by buildup factor) which depends on atomic number of absorbing medium, energy of gamma rays and the penetration depth in addition to the shape of the radiation source and the medium [14].

The tables of mass attenuation coefficients and the mass energy absorption coefficients for 40 elements and 45 mixtures and compounds over energy range from 1keV to 20MeV. These tables, although widely used, should now be replaced by the Hubbell and Seltzer tabulation for all elements (Z=1-92) and 48 additional substances for diametric interest. The mass attenuation coefficient, a number of related parameters can be derived, such as mass energy absorption coefficient, total interaction cross-section, molar extinction coefficient, effective atomic number and the effective electron density [15].

The vascularity of malignant tissue is higher than surrounding healthy tissue so that when NPs are injected, they diffuse to the malignant tissue more than healthy tissue so that the absorption of ionizing radiation dose inside tumor become greater due to the presence of NPs.

This study focused on decreasing the irradiation dose required to kill malignant cells by direct injection of NPs inside tumor cells in order to increase the amount of absorbed dose by adding a doubled increased concentration of (zinc and tellurium) NPs in tumor cells with minimum injury to the surrounding healthy tissue and increasing the number of destroyed cancer cells.

Methodology

The theoretical basis for conducting current study was that to increase organ tolerance for radiation dose absorption, the injected particles inside the tumor should have high radiation dose absorption inside tumor [16,17].

The ionizing either causes destruction or shrinkage of cancer cells, but it may cause damage to surrounding health tissue, therefore; radiologist needs to find a way to produce maximum destruction in malignant cells with minimum damage to healthy cells surrounding the tumor[18].

Nanoparticles with high energy radiation interaction lead to ensure the production of electron and positron inside tumor which increase the ionization process inside tumor then lead to increase production of free radicals and toxic molecules. As a sconsequence, accumulation of reaction products leads to cancer cells death [19,20].

The total cross-section for lung with presence of nanoparticles as contrast agent inside lung equals sum of two cross-sections [21]:

Where: Number of survival cells after irradiation. : Number of initial cells before irradiation and ( ) relative effectiveness [26].

The total cross-section for lung with presence of nanoparticles as contrast agent inside lung equals sum of two cross-sections [21]:

$$\boldsymbol{\sigma}_{total} = \boldsymbol{\sigma}_{lung} + \boldsymbol{\sigma}_{Nps} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where $\boldsymbol{\sigma}_{total}$, $\boldsymbol{\sigma}_{lung}$ and $\boldsymbol{\sigma}_{Nps}$ equals to lung and nanoparticles cross-sections.

The correlation between cross-section ($\boldsymbol{\sigma}$) and mass energy absorption coefficient ($\boldsymbol{\mu}_{en}/\boldsymbol{\rho}$) can be explained in the following equation [22]:

$$\boldsymbol{\mu}_{en}/\boldsymbol{\rho} = \sum_i w_i \left(\frac{N_A.\boldsymbol{\sigma}}{A}\right)_i \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where N_A: Avogadro's number, A: Mass number and w: The fraction by weight of the organ with added nanomaterial per volume (μg/ml).

We can modify the equations as follows:

$$(\boldsymbol{\mu}_{en}/\boldsymbol{\rho})_{total} = (\boldsymbol{\mu}_{en}/\boldsymbol{\rho})_{lung} + (\boldsymbol{\mu}_{en}/\boldsymbol{\rho})_{NPs} \ldots\ldots\ldots\ldots\ldots (3)$$

Where $(\boldsymbol{\mu}_{en}/\boldsymbol{\rho})_{total}$, $(\boldsymbol{\mu}_{en}/\boldsymbol{\rho})_{lung}$ and $(\boldsymbol{\mu}_{en}/\boldsymbol{\rho})_{NPs}$: Total Lung and Nanoparticles mass energy absorption coefficient.

The exposure rate constant(Γ) relates activity of a point isotropic radiation source to the exposure rate in air at a given distance [23]:

$$X = \Gamma \frac{A}{d^2} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Where A is the source activity, (d) is distance from the source.

The equation (7) modification for a lung without and with nanoparticles that adding by direct injection technique with double increase concentrations. Each NP material interacts with extent of radiation falling energy ranging from 1 to 20Mev adding nanoparticles (zinc and tellurium) get from the National Institute of Standards and Technology (NIST2004) [27].

Results and Discussion

The irradiation equations applied on lung malignant tumor with usage of Zinc and Tellurium nanoparticles were shown in Figures (1), there was increasing apoptosis of cancer cells and decreasing malignant cells survivor in low dose in comparison with high dose without NPs. The number of dead cancerous cells was increasing with doubling increase of NPs which depends on cross-section that is usually depending on high mass energy absorption coefficient and type and amount of energy.

We noticed that at dose of 5Gy there was an increase in number of living cancer cells because of lowering the cross-section and decrease mass energy absorption coefficient in comparison with the non-injectable cells by NPs. The increasing concentration of NPs gives a possible decrease of irradiation dose with same number of killed malignant cells.

Figures (2) and (3) showed that the number of living cells was less with the use of Tellurium (Z=52) which has high cross-section with high atomic number in comparison to Zinc (Z=30) at dose of 4Gy. Thus, led to an increase in the number of destroyed cells and decreasing in the number of surviving cancer cells.

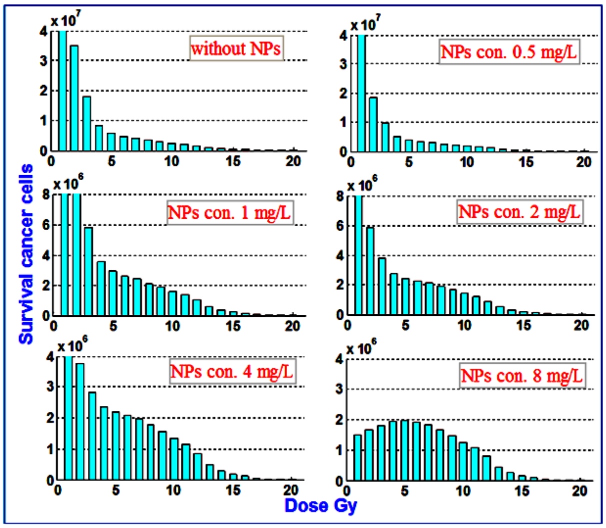

Figure 1: Survival cancer cells of the lung malignant tumor with a doubled increased concentration of ZnO NPs (μg/mL) against irradiation dose (0.1-20) Gy

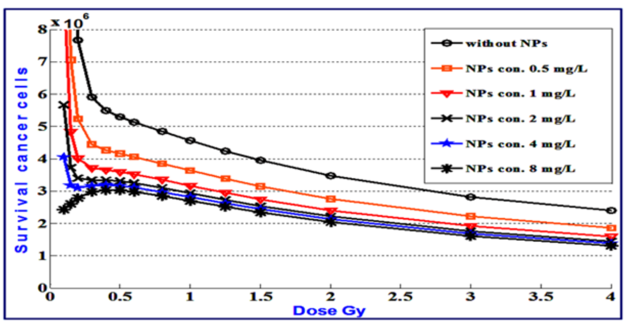

Figure 2: Survival cancer cells of the lung malignant tumor without and a doubled increased concentration of ZnO NPs (μg/mL) against irradiation dose (0.1-4)Gy.

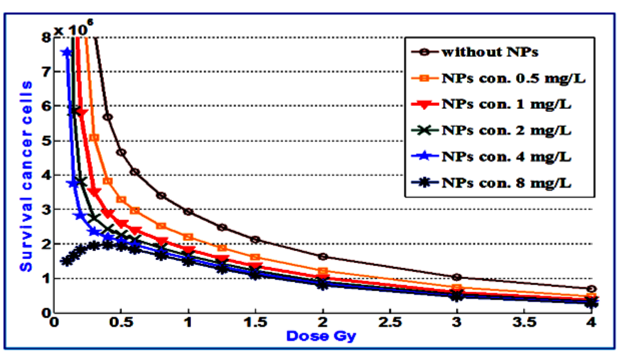

Figure 3: Survival cancer cells of the lung malignant tumor without and a doubled increased concentration of TeO2 NPs (μg/mL) against irradiation dose (0.1-4)Gy.

Conclusions

Zinc and tellurium nanoparticles can potentiate the effect of radiotherapy on lung tumor cells through increasing number of destroyed malignant cells which depended on atomic number and cross-section.

Therefore, the interaction of Gamma-rays will be concentrated into the tumor without affecting healthy tissue that surrounds the tumor. This means that the absorption of radiation dose will be concentrated into the tumor without the surrounding healthy tissue. High energy Gamma-ray helps increase free radicals that produce interaction with water molecules inside cells.

Ethical Clearance: The research Ethical Committee at scientific research by ethical approval of both environmental and health and higher education and scientific research ministries in Iraq.

Conflict of Interest: The authors declare that they have no conflict of interest.

Funding: Self-funding.

References

1. Ferlay J, Soerjomataram I, Dikshit R, Eser S, C. Mathers, M. Rebelo,D.M.Parkin, D. Forman and F. Bray ,"Cancer incidence and mortality worldwide". International Journal of Cancer 2015.
2. United Nations Scientific Committee on the Effects of Atomic Radiation, "sources effects and risks of ionizing radiation", New York; 1988.
3. Barrett A, Dobbs J, Morris S and Roques T."Practical Radiotherapy Planning", Ann Barrett, Jane Dobbs, Stephen Morris and Tom Roques U.K; 2009.
4. Podgorsak EB. "Radiation oncology physics, International Atomic Energy Agency (IAEA)",Vienna.(2005).
5. Hansen EK and Roach M. "Handbook of Evidence-Based Radiation Oncology", Springer Science - Business Media U.S.A; 2010.
6. Mayles P, Nahum A and Rosenwald J. "Handbook of radiotherapy physics theory and practice", Taylor and Francis Group U.S.A; 2007.
7. Hansen EK, Roach M. "Handbook of Evidence-Based Radiation Oncology", Springer Science, Business Media, LLC; 2010.
8. Lechtman E, Chattopadhyay N, Cai Z, Mashouf S, Reilly R, Pignol JP, "Implications on clinical scenario of gold nanoparticle radio sensitization in regards to photon energy, nanoparticle size, concentration and location". Physics in Medicine and Biology, Phys Med Biol 2011.
9. Bruce GH, Thomas AB, Perez CA. Perez and Brady's, "Principles and Practice of Radiation Oncology", 5th Edition; 2008 .

10. Logothetidis S,"Nanomedicine and Nanobiotechnology", Springer-Verlag Berlin Heidelberg (2012).

11. D.Kwatra, A.Venugopal1, S.Anant,"Nanoparticles in radiation therapy: a summary of various approaches to enhance radiosensitization in cancer". Translational Cancer Research 2013.

12. Carter JD, Cheng NN, Qu Y, et al, "Nanoscale energy deposition by X-ray absorbing nanostructures". J Phys Chem B 2007.

13. Townley HE, Kim J, Dobson PJ. "In vivo demonstration of enhanced radiotherapy using rare earth doped titanium nanoparticles". Nanoscale 2012.

14. Manohara SR, Hanagodimath SM, Gerward L. " Energy absorption buildup factors of human organs and tissues at energies and penetration depths relevant for radiotherapy and diagnostics". Journal of Applied Clinical Medical Physics 2011.

15. Singh K, Singh H, Sharma V, Nathuram R, Khanna A, Kumar R, Bhatti S.S., Sahota H.S,." Gamma-Ray Attenuation Coefficients in Bismuth Borate Glasses". Nuclear Instruments and Methods in Physics 2002.

16. Jain RK, Stylianopoulos T. " Delivering nanomedicine to solid tumors". Clinical Oncology 2010;7: 653-664.

17. Hainfeld JF, Slatkin DN, Smilowitz HM. The use of gold nanoparticles to enhance radiotherapy in mice. Physics in Medicine and Biology 2004; 49(18): N309-N315.

18. Jameson C., Lunn RM, Jeter S, Sabella A. " Report on Carcinogens Background Document for X Radiation & Gamma Radiation and Neutrons ", U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, Research Triangle Park, NC; 2003. 27709.

19. Robar JL, Riccio SA, Martin M.. " Tumour dose enhancement using modified megavoltage photon beams and contrast media", Phys Med Biol. (2002),47:2433–49 20. Jain R.K. and Stylianopoulos T.," Delivering nanomedicine to solid tumors". Clinical Oncology 2010.

21. Mayles P,Nahum A, Crosenwald J. " Handbook of Radiation Physics", Taylor and Francis Group(2007).

22. Hubbell J., "Review of photon interaction cross section data in the medical and biological context ". Phy Med Bio 1999; 44: R1-R22.

23. Stabin MG. "Radiation protection and dosimetry: an introduction to health physics", New York, Springer; 2007.

24. Halperin EC, Perez CA, Brady LW. " Perez and Brady's Principles and Practice of Radiation Oncology", 6th Edition, Lippincott Williams and Wilkins; 2013.

25. Chapman JD, Nahum AE. " Radiotherapy Treatment Planning", by Taylor and Francis Group; 2015.

26. Steel GG, Mayles P, Nahum A. J-C. Rosenwald."Handbook of radiotherapy physics Theory and practice", New York, London: Taylor and Francis; 2007.

27. Hubbell KJH, Seltzer SM. " Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients", National Institute of Standards and Technology [NIST]; 2004.