Using Nanoparticles to Treat Cancer

FULBRIGHT | Syracuse University

Abstract

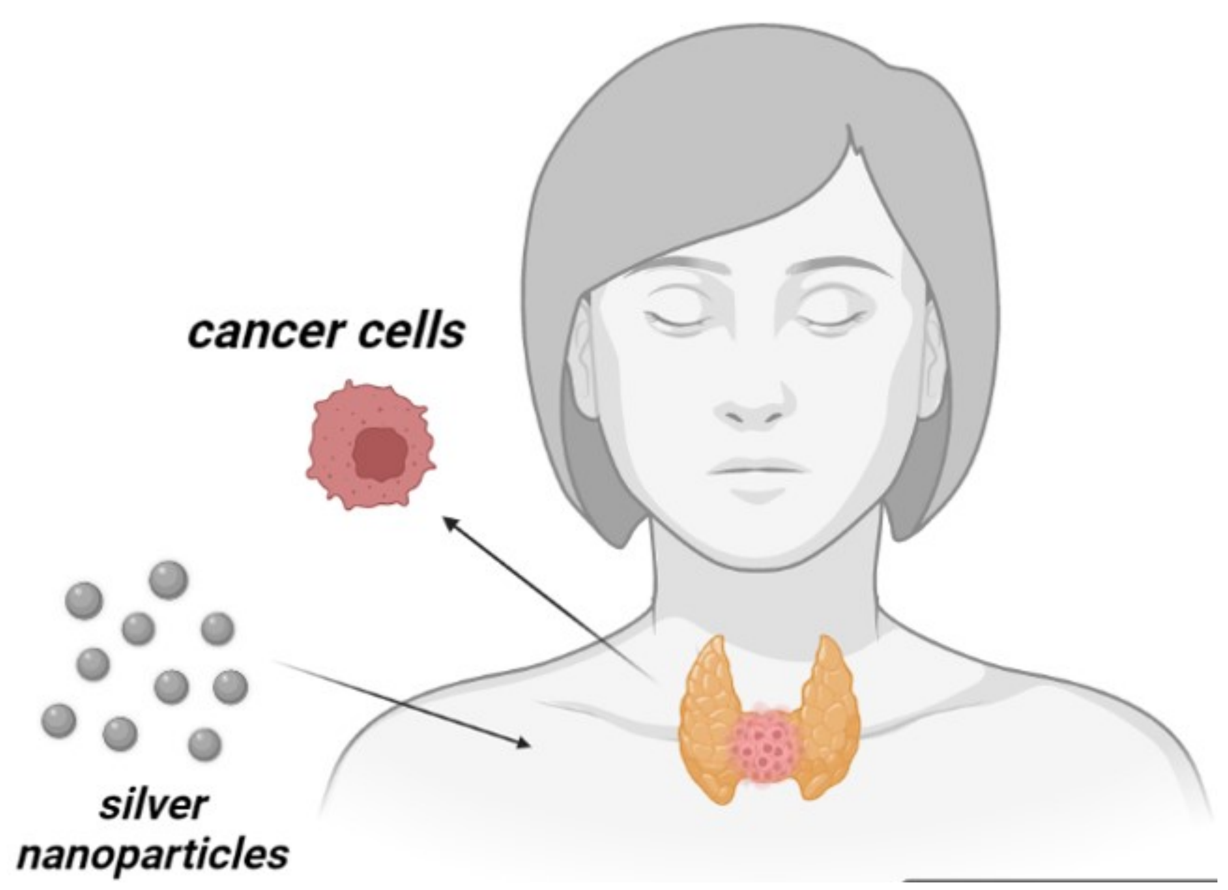
In this paper we briefly discuss methods of cancer treatment, such as surgery, radiation therapy, and chemotherapy for further comparison, with new cancer nanotechnology methods. The paper presents positive and negative aspects of the use of nanoparticles for the cancer treatment . In addition, this article describes a method for selecting a spectrum of irradiation and nanoparticle size for therapy and diagnosis of oncological diseases. Using computer calculations, the research demonstrates that particle size at optimal radiation wavelength affects absorption and scattering coefficients in low-absorbing biological media.

Introduction

Today, the main treatments for cancer are surgery, chemotherapy, and radiation therapy. These therapies are chosen based on the type of cancer, stage, and location. In many cases, doctors consider complex therapies that include all these treatments concurrently. Although technology is advancing from year to year, each of these methods has several drawbacks, such as the inability to address certain types of tumors, a difficult postoperative period when the tumor is large, high toxicity, and damage to organs.

Most of the preparations in oncology are chemotherapy. These medications are injected intravenously, spread through the body, and poison the internal organs. Chemotherapy affects not only cancer cells, but also healthy tissues, which is a serious problem. To solve this problem, specialists decided to develop a new method of drug delivery by using nanoparticles. (See Figure 1: The particles' size does not exceed 100 nanometers.) The specific feature of this delivery method is that nanoparticles do not go beyond the healthy vessel walls; however, they can penetrate tumor tissues through the damaged vessel walls (Zvyagin, 2019).

Figure 1

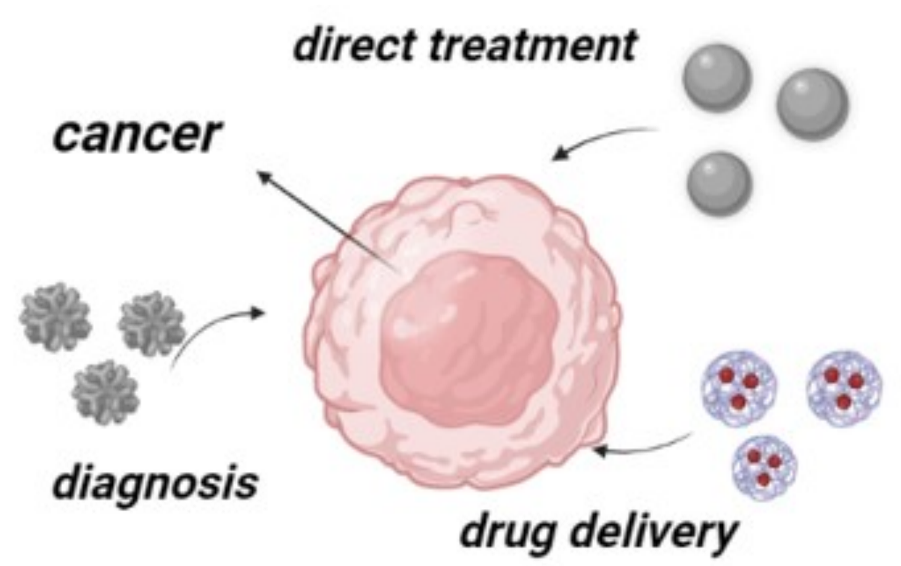


(Akramova R.B., 2022)

One of the drawbacks of this method is the response of the immune system, which quickly removes nanoparticles from the bloodstream. Zvyagin (2019) states that one of the solutions to this issue is to create hybrid nanoparticles that incorporate organic and inorganic material and are able to avoid capture by the immune system cells, therefore accumulating in the tumor and metastases.

In addition to chemotherapy, nanoparticles can be used in the diagnosis and radiation therapy (Letfullin, R.R. George, T.F. 2016). When nanoparticles are injected into the body, they accumulate in the malignancy. To obtain accurate diagnoses, scientists make nanoparticles visible through the contrast method in order to locate them with the diagnostic equipment CT, MRI, ultrasound. (Meshalkin, Bgatova, 2008).

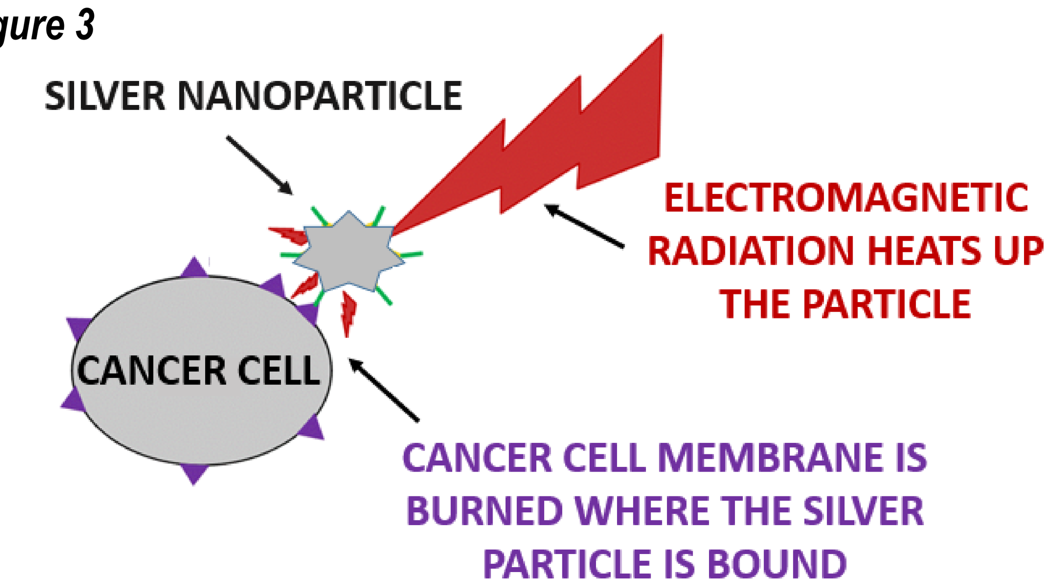
Figure 2



(Akramova R.B. 2022)

Here is an example of cancer therapy based on the use of nanoparticles associated with the heating of metal nanoparticles by infrared laser radiation (Meshalkin, Bgatova, 2008).

Figure 3



(Wei JuAn, 2014)

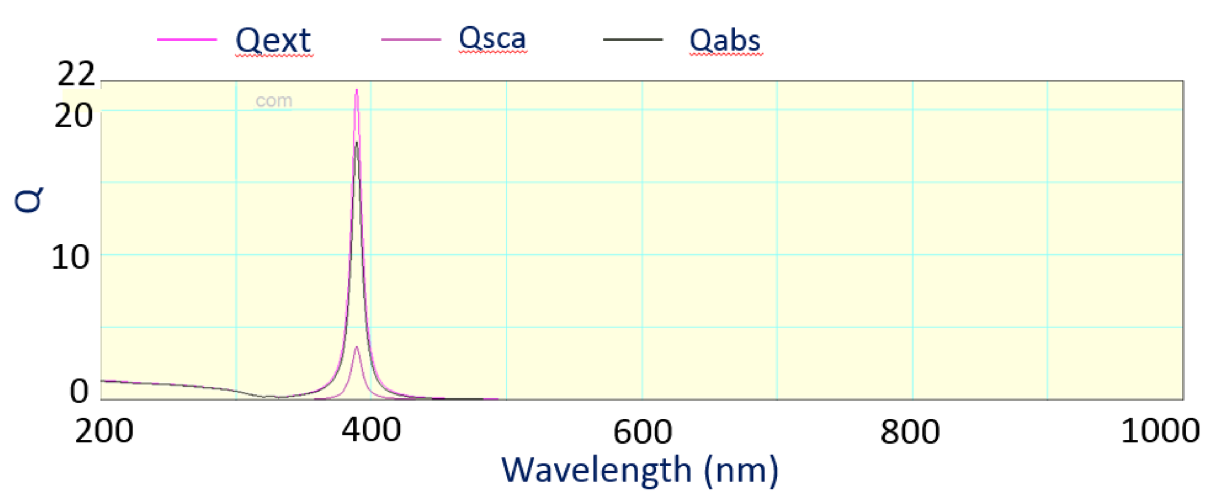
Method

Generally, gold or silver metals are used as bases for nanoparticles. By entering the refractive index (Table 1) of the metal at different wavelengths into a specialized program called "Mie Plot", we select the wavelength at which the absorption coefficient of silver nanoparticles is the highest at a given radius. Then by using this wavelength, we determine the nanoparticle radius that will be most suitable for diagnosis (scattering coefficient higher than the absorption coefficient) and therapy (absorption coefficient higher than the scattering coefficient) (Letfullin, R.R. George, T.F. 2016, p. 213-217).

Data analysis and results

Computer calculations of absorption coefficients Kabs and scattering coefficients Ksca for silver nanoparticles in cytoplasm are shown in Figure 4 and Figure 5. Figure 4 shows the absorption and scattering spectra of silver particles in the range of λ=200-1000 nm, and Figure 5 shows the dependences of Kabs and Ksca on particle size for the optimal wavelength. In Figures 4 and Figure 5 the maximum absorption coefficient Kabs is marked at a wavelength of λ=389 nm and a silver particle radius of 10 nm. For silver nanoparticles with a radius greater than 4.3 nm at λ=389 nm, the scattering of light can be recognized. The scattering coefficient Ksca increases with the size of the nanoparticles and becomes equal to the absorption coefficient at a particle radius of 17.1 nm. When the particle size is equal to or greater than 17.1 nm, the scattering coefficient becomes greater than the absorption coefficient.

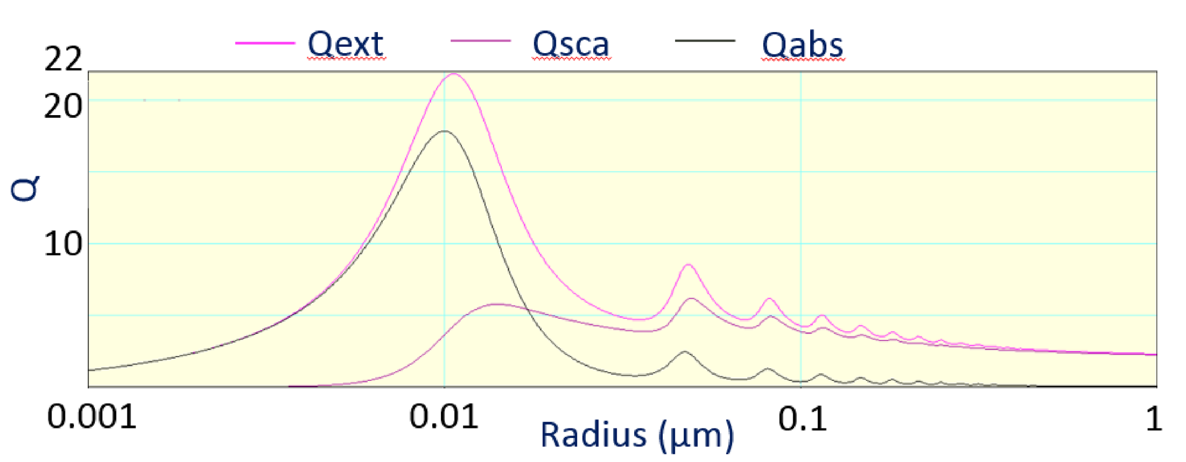
Figure 4
Absorption and scattering spectrum



Note. Computer calculations of the absorption, K_{abs} and scattering, K_{sca} coefficients for silver nanoparticles in a cytoplasm in range λ=200-100nm

For particles with a radius in the 1-17 nm range, the laser heating efficiency is greater, since the absorption coefficient Kabs is much larger than the scattering coefficient Ksca. Thus, a suitable size of silver nanoparticles for cancer therapy by laser heating of nanoparticles at the localization of cancer cells is 1-17 nm, where Kabs>1 and Kabs>Ksca. The maximum effect of silver particles laser heating in cytoplasmic environment is obtained for particles with a radius of 10 nm at a wavelength of λ=389 nm (Kabs=17.77).

Figure 5
Absorption and scattering as a function of particle size



Note. Computer calculations of the K_{abs} and K_{sca} coefficients for silver nanoparticles in a cytoplasm: illustrates the dependences of K_{abs} and K_{sca} on particle size for the optimal wavelength

Table 1

λ(nm)	Refractive index,N	K_{abs}, max	λ_{max}, nm	r_{max},nm
400 (Cytoplasm)	1.35	17.77	389	10
500	1.36			
600	1.365			
700	1.367			

Mie Theory Maximum Light-Absorption Factor (K_{abs}), Wavelength(λ_{max}), and Radius(r_{max}) for Silver in Media of Different Refractive Indexes.

Conclusion

With the help of a detection system and re-radiation by nanoparticles, it may be possible to diagnose cancer early, detect and remove remaining malignant tissue after surgery. Nanoparticles can also be used in cancer therapy, improving the accuracy of the treatment.

Currently, specialists are facing multiple challenges that need to be addressed in order to normalize the use of this method.

Almost no data is available on how nanoparticles will be incorporated into biochemical processes in the human body, what is their further pathway, the residence time in the human body, the place of accumulation, the effects on cellular and tissue functions, their access to blood circulation, and information on unintended reactions in vivo (Zvyagin, 2019).

The disadvantages of nanoparticle experiments are costly and approvals of medical authorities are complicated. However, nanotechnology methods can be a good alternative for the classic use of chemotherapy and radiotherapy, and an advanced diagnosis tool for oncology surgeries.

References

Akramova, R.B.(2022) created by BioRender https://app.biorender.com/

Letfullin, R.R. George, T.F. (2016). Computational nanomedicine and nanotectology. Springer International Publisher, Switzerland. 687 p.

Letfullin, R.R. George, T. F. (2016). Computational nanomedicine and nanotectology. Springer International Publisher, Switzerland. p 213-217

Meshalkin, Y.P., Bgatova, N.P. (2008). Prospects and problems of using inorganic nanoparticles in oncology (review). Journal of Siberian Federal University. Biology 3 (2008 1) 248-268. https://cyberleninka.ru/article/n/perspektivy-i-problemy-ispolzovaniya-neorganicheskih-nanochastits-v-onkologii-obzor/viewer

Zvyagin, A. (2019, July 15). How are nanoparticles used in medicine? PostScience. https://postnauka.ru/faq/100927

Wei JuAn(2014, January 21) *Nanobodies for photothermal therapy.* Wikipedia. https://commons.wikimedia.org/wiki File:Nanobodies_for_photothermal_therapy.gif

Author:
Rukhsora Akramova
Syracuse University ELI

Advisors:
Carmen J. Falasco
Nina Rosenfeld