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Extended Abstract

A comparative study of liver cancer treatment methods using thermal ablation versus gold nanoparticle therapy

Ibtihag Yahya

Abstract

One of the most complex problems over the past decades is clinically approved cancer treatment methods because of the conventional methods side effects such as radiation, chemotherapy, and some medication. Correspondingly, in recent years and since 2010, the diagnosis and treatment of cancer have taken a great deal of interest, especially in the field of designing and developments of inorganic nanoparticles because of its unique properties such as thermal heating ability, surface functionalization, surface plasmon, absorption, and scattering properties. This study aims to compare strategies for using thermal therapy versus gold nanoparticles therapy. COMSOL Multiphysics was used to model both techniques by using electric current and bioheat transfer modules for ablation method and heat transfer in solid module for the gold nanoparticles method to treat a cancerous tumor that was discovered in the liver. This study's results of this computational modeling proved that using gold nanoparticles was examine the effectiveness of these particles as a heat source for hyperthermia in liver cancer therapy without affecting the surrounding natural tissue and damage it. This method can overcome the challenges faced by the ablation treatment method, such as hyperthermia and the inability to heat cancer cells locally and thus, limiting the heat within the tumor circumference very complex and difficult which is affecting the surrounding natural tissue and damage it. In conclusion, COMSOL Multiphysics was a very useful platform for modeling the hyperthermia treatment for cancerous cells necrosis over time.

Nowadays, cancer is the most serious health issue leading to the high rates of death worldwide. According to the statistics from the World Health Organization, the number of cancer cases in 2018 increased to 18.1 million new cases and 9.6 million deaths. The leading types of new cancer cases globally are lung, female breast, and colorectal cancers. Therefore, the ability of early cancer detection and treatment is of utmost importance. There are several well-known standard techniques for cancer treatment such as surgery, radiation, and chemotherapy.

However, these methods cannot efficiently fulfill the need in cancer disease treatment due to the several limitations such as the hard-to-reach tumor position, the close location of other possible tumors, the patient's opinion, and health conditions. Moreover, cancer tumors can create protection from numerous chemotherapeutic agents, causing additional obstacles for the treatment. This review paper focuses on thermal ablation therapy to outline the recent advances in cancer treatment by use of radiofrequency, microwave, laser ablation, and photothermal ablation sources supplemented by various nanomaterials. Moreover, the advantages and properties of each nanomaterial, namely magnetic and gold nanoparticles, nanocomposites, nanoshells, nanorods, carbon nanotubes, and other types of nanoparticles are discussed.

Thermal ablation is a technique used in cancer therapy to eliminate damaged cells or tissue by applying external electromagnetic waves and elevated heat. Thermal ablation techniques utilize radiofrequency, microwave frequency, and cryoablation, and is focused on ultrasound (US) and laser light. The advantages of thermal ablation therapy over the conventional methods are the flexibility, low cost, and its minimal invasiveness. However, the choice of a suitable heat delivery route to the tumor is a vital and challenging concern in thermal ablation. Moreover, existing heating methods have difficulties in differentiation between tumors and surrounding healthy tissues, leading to the damage of the neighboring cells.

Therefore, the combination of nanotechnology and thermal therapy has attracted a lot of attention as a

Ibtihag Yahya
Sudan University of Science and Technology, Sudan, E-mail: ibtihag.yahya@sustech.edu

promising method to overcome the relevant limitations of conventional thermal therapies.

Nanotechnology is gaining great attention in the biomedical field due to the possible application in diagnostics and treatment techniques. Nanomaterials, especially nanoparticles-assisted and nanocomposites-assisted thermal therapy, offer many advantages over conventional methods. Due to their magnetic and optical properties, nanomaterials can trigger heat increase in tumor regions by absorbing near-infrared light (NIR), electromagnetic, or radio frequency (RF) waves.

Moreover, surface-functionalized nanomaterials can specifically bind to the cancer cell and allow selective heat destruction of the tumor and also the multitasking possibility of cell separation and imaging. A general procedure for the RF thermal ablation combined with nanomaterials consists of the following stages: the specific and selective attachment of nanoparticles with cancer, validation of binding, and heat administration to the specific area by applying an electromagnetic field. However, in order to have safe tumor destruction, parameters such as the critical heat dose, application of proper magnetic material concentration, and its biodistribution are vital. In addition, the further removal of the nanomaterial from the targeted area should be considered carefully in order to avoid the undesired heating of non-target tissue.

The size and shape of nanoparticles are critical factors that determine their performance: the ability to penetrate the blood vessel, reach the targeted region, affect the rate of macrophage uptake, and finally wash out from the body. For instance, nanoparticles larger than 10 nm will be too large to pull out from the normal capillaries.
In addition, the transport of smaller nanoparticles exhibits relatively higher diffusion rates, which allows them to move laterally in the blood vessel with greater ease. However, larger particles can penetrate the tumor through the gaps between the endothelial cells in leaky tumor vasculature and remain there for a long time. This phenomenon called the enhanced permeability and retention (EPR) effect. Mainly, the EPR effect is beneficial to deliver the nanoparticles loaded with the drug. The larger nanomaterials can permeate and accumulate at the tumor site for a long time, causing the effective treatment and avoiding the side effects that are due to failure to penetrate the normal tissue. The drawback of the EPR effect is the inhomogeneity of interstitial holes, which affects the uniform penetration and distribution of nanoparticles within the tumor.

Nanoparticles of different shapes have a different active fractional area, which results in variability in binding avidity, circulation in the blood, and the ability to bind to wall receptors. Thus, the nanoparticle shape affects the rate of tumor deposition and therapeutic efficacy.

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