

Photothermal Therapy as an Alternative Treatment for the Clinical Management of Cancer

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Abstract: Alternative medicine can commonly be thought of as the use of homeopathy, acupuncture, or herbalism. Despite this stereotype, uncharted scientific research could be considered alternative medicine. In recent years, new oncology research has arisen in the form of synthesized organic nanomaterials for photothermal ablation of cancer cells. This relatively new process has numerous benefits but has remained untapped by medical professionals thus far. Considering that the benefits of photothermal ablation far outweigh the benefits of current cancer treatment options, the practice should receive more encouragement and recognition from the scientific community.

Introduction

Photothermal therapy (PTT) is best defined as “a hyperthermia therapeutic approach that employs photoabsorbing agents to burn cancer cells by heat generated from optical energy”¹. In other words, nanoparticles that have an affinity for cancerous cells are injected into and circulated throughout the body. The chemical agents are led to the source (the tumor) through the use of laser guided light sources, specifically near-infrared technology². The injected nanoparticles are taken up by the tumor and begin generating heat, causing ablation of the cancer cells². The two agents most commonly used in recent years are gold-based nanostructures and carbon nanotubes, but organic agents (such as polyaniline) are being developed as well^{2/3}.

Advantages of Photothermal Therapy

Photothermal therapy has the potential to be more safe and effective in the treatment of cancer than current cancer treatment options. For example, the use of near-infrared light (lasers) and nanoparticles takes away the need for radiation or chemotherapy. This dramatically reduces the toxicity that the patient is exposed to because the only regions of the body receiving any toxic effects are the targeted tissues, which are the cancerous tumors. The current treatment options- chemotherapy and radiation therapy- submit the entire body of the patient to toxic hammering. Chemotherapy and radiation have a wide range of adverse effects such as pain, weakness, hair loss, “chemo brain,” peripheral neuropathy, and loss of fertility⁴.

The use of near-infrared light and nanoparticles also removes the need for surgery, meaning a shorter

recovery time for the patient and fewer possible complications. Though surgery continues to be an evolving practice despite the many years of use, and the surgical field continues to advance with regard to technology, basic problems still exist for surgeons, such as how to properly puncture the skin without harming organs beneath. The avoidance of nerve cells in the patient is also problematic for surgeons, especially in the removal of tumors. For example, many men who receive surgery for removal of prostate cancer, a surgery considered low risk, leave the surgical room with erectile dysfunction and incontinence⁵. This is a result of surgeons harming tiny nerve cells within the prostate because they are not visible to the naked eye⁵. The use of nanoparticles and infrared light for photothermal therapy would eliminate the need for surgery in cancer patients because the technique is minimally invasive and does not require intrusion of the skin other than injection of the nanoparticles by needle.

Recent research performed in mice has provided further evidence of the benefits of *in vivo* cancer treatment through nanoparticles for photothermal ablation of cancerous cells. In 2012, the Functional Nano & Soft Materials Laboratory performed *in vivo* phototherapy in mice tumor models¹. The scientists developed the a polymer, poly-(3,4-ethylenedioxythiophene):poly(4-styrenesulfonate) (PEDOT:PSS), that has high conductivity and near-infrared (NIR) absorbance levels¹. The PEDOT:PSS was then coated in polyethylene glycol (PEG), creating PEDOT:PSS-PEG nanoparticles that are very stable in physiological environments and have long lasting half-life circulation within the blood¹. Blood tests and histological reviews of the mice

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found that there was no toxicity of the PEDOT:PSS-PEG caused by the forty-day treatment dosage¹.

Other studies involving mice have also generated positive feedback for the use of photothermal therapy. In the case of Nanospectra Biosciences Inc., murine colon carcinoma tumors were grown in healthy mice to determine the effectiveness of nanoshell assisted photothermal therapy (NAPT)⁶. The experimental mice had PEGylated nanoshells (a class of gold nanoparticles) intravenously injected and circulating within their system for six hours before using a diode laser of near infrared light (NIR) with wavelengths measured at 808 nm to attract the nanoparticles to the tumors⁶. The experiment resulted in the treated mice living healthy, tumor-free lives for more than 90 days⁶. The control mice and mice that received only laser treatment without nanoparticles (“sham-treatment” mice) were euthanized once the tumors grew to a predetermined size 6-19 days later⁶. This information about the control mice and “sham-treatment” mice helps to understand two highly important points: 1) the cancer could not have been removed or cured without treatment and 2) the successful treatment of cancer with nanoparticles was not singularly the result of the laser.

There are some opposing claims that have accompanied the rapid advancement of photothermal nanoparticle technology. For one, there are concerns about the unknown levels of toxicity that could remain in the patient’s system when using inorganic nanoparticles^{1,7}. There is a limited amount of knowledge about the extended effects of toxicity for many of the inorganic molecules that are being used for biomedical purposes⁸. This issue, however, has been partially resolved through the generation of organic nanoparticles. The prime illustration of how this problem has been addressed is the example of mice that received the organic PEDOT:PSS-PEG previously referenced. Though the long-term biological degradation is still under investigation, these mice had no significant levels of toxicity within their systems post-treatment when the researchers followed their forty-day protocol¹. More organic compounds could be revealed and developed with the encouragement and advancement of research of photothermal therapy.

Another problem presented is the ability of the nanoparticle and laser combination to generate enough heat after being engulfed by the tumor⁹. In previous research attempts, heat conversion efficiency has been fairly low. While the tissue should not be heated too much, there should be enough of an increase in temperature to provide successful ablation of the cancer cells. However, in a recent study there was an increased efficiency of heat conversion when aqueous Cu₉S₅NCs was exposed to tumors with a 980 nm laser containing a power

density of 0.51 W/cm², elevating the temperature by 15.1° C in 7 minutes, which is a heat conversion efficiency of 25.7%¹⁰.

Overall, there is an extensive amount of unexplored opportunities for advancement in the field of photothermal therapy. New organic materials that could improve upon the already successful technology being developed are waiting to be discovered. The current technology of chemotherapy and radiation therapy is simply not sufficient for oncology patients. The hazardous effects for patients using current technology are far more detrimental than the prospective technology of photothermal therapy. Though the long-term biological degradation of nanoparticles remains under investigation, the current results of today’s oncology practices are clearly causing hazardous biological outcomes in patients. Increasing the progress of research in the field of photothermal therapy is dependent upon the encouragement of the medical and pharmaceutical communities. Photothermal therapy has the capability to move out of the alternative medicine realm and completely replace chemotherapy and radiation as the go-to treatment if enough time and research are invested in its development.

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