A brief review on the Implementation of Nanoparticle in Medical Treatment

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Nanotechnology is the rapidly developing and innovative field in many areas of human activity. They have wide range of contribution in the medical field. Nanotechnology deals with nano-meter sized objects in the field of material science, nanodevices etc. The nanomaterials are the most advanced in scientific knowledge and in commercial applications due to their size-dependent physical and chemical properties. Nanoparticles have important properties e.g. unique size, shape, biocompatibility, and selectivity. Optical and magnetic effects of nanomaterials are most important for biological applications. Hybrid bionanomaterials can be applied to build novel electronic, optoelectronics and memory devices. This brief review explains to summarise various application of nanoparticles in medical field and biotechnology.

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I. INTRODUCTION

Nanoscience has been identifed as one of the scientific and technological areas of 21st century research as its importance to various domains of human need e.g. computers, biology, electronics, and material design. Nanoparticles[1] are being used to improve or replace todays radiation therapies. Properties such as size, shape, biocompatibility and selectivity allow for nanoparticles to affect the human body differently than traditional therapies. Nanoparticles are practically used to increase image contrast of ultrasound and MRI technology, increase the acoustic reflectivity and ultimately leading to an increase in brightness and creation of a clearer image. The image quality of MRI technology also improve by Nanoparticles. The clarity of the image through the combination of the biocompatible shell and magnetic core is also improved by nanomaterials[2]. The combined effect of these two components help to increase the quality of the image. The application of nanoparticles in medical field is an advance topic of current research and has advantages over cancer therapies. Nanotechnologies have a great use of treating cancer. Magnetic field hyperthermia is very effective by the use of biocompatible superparamagnetic nanoparticles. Oscillations of these particles can help to heat tissues, particularly cancerous tissues by friction. This heating effect damage the cancerous tissues. Cancer is also treated with gold (Au) nanoparticles which are able to select cancerous cells and damage it by laser induced explosion. The nanoparticles the effectiveness of radiation therapy; gold nanoparticles are an effective radiosensitizer, biocompatible and increase number of doses. Free radicals are created due to improve of dose from the energy absorbed by the particles and damage the DNA of cancerous tissues. Nanoparticles have a lot of use in drug delivery[3] because they can be engineered to be sensitive to certain pH values. These particles will remain in a certain conformation protecting the drug till they reach a certain part of the body with a certain pH value. The pH of nanoparticles change conformation shape and release the drug. Nanoparticles have another application to inhibit the bacterial reproduction on surfaces, which creates a cleaner environment and prevents disease. Nanoparticles have been used in orthopedic implants. They increase the biocompatibility of the implants for a longer life span and effectiveness of the implant. Overall, nanoparticles have a wide range of application in medical field because of their unique qualities. Living organisms are built of cells (10m) and protein with typical size 5 nm which are comparable with the dimensions of smallest manmade nanoparticles. This size comparison gives an idea of using nanoparticles as small probe[4]. Understanding of biological processes on the nanoscale level is a strong concept behind development of nano-biotechnology[5]. Composite bionanomaterials can also be applied to build novel electronic, optoelectronics and memory devices.

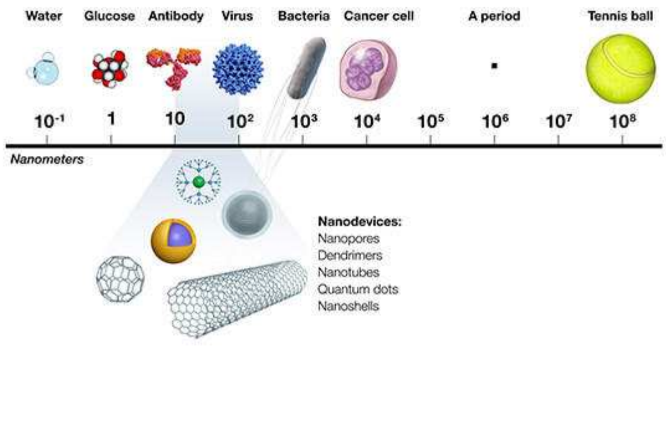

FIG. 1: Size composition of nanoparticle

II. IMPLEMENTATION OF NANOPARTICLE

A. Magnetic Field Hyperthermia: Cancer Treatment with AC Magnetic Field

There are many different treatments for cancer. Hyperthermia is one of the most useful treatments being studied. Hyperthermia is the heating of certain organ or tissues to temperature between 41°C and 46°C and it causes damage to the cells. But there is a drawback with hyperthermia, it is difficult to target specific cells, for example cancer cells, without using a targeting agent. Magnetic particles are used with magnetic fields at specific sites by hyperthermia process. In this technique nanoparticles penetrate much more power from AC magnetic field and create a magnetic core as well to develop a magnetic moment. Once a magnetic field is applied the nanoparticle lines up along the field direction. However, if the magnetic field is changed the particle will rotate to realign with the new field lines. The fields are constantly changing as they are with AC magnetic field[6]. As a result particles will constantly be rotating from one orientation to another. This oscillation creates a transfer of energy that causes friction and produce heat resulting in hyperthermia in the tissue where the magnetic nanoparticles are present. However, if the tumor cells grow between treatments their daughter cells will have some of these nanoparticles inside of them. This represents that future applications of AC magnetic fields will affect the daughter cells. Magnetic field hyperthermia is advanced technology because with the magnetic nanoparticles it is more specific to cancer cells and more damaging occurs.

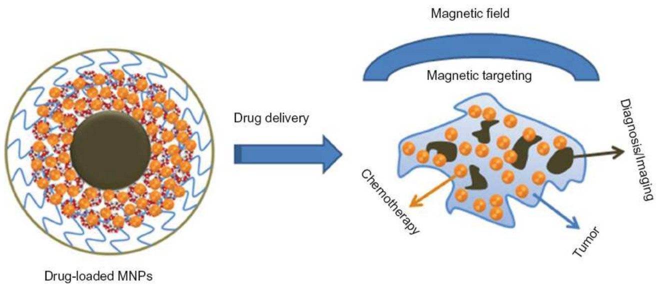

FIG. 2: Cancer Treatment with AC Magnetic Field

B. Laser-Induced Explosion of Gold Nanoparticles for Treatment of Cancer

Researchers are constantly looking for Cancer treatment. Cancer cells along with bacteria, viruses and DNA can be damaged by nanophoto-thermolysis process with lasers and gold nanoparticles. This is a favorable process because if one damage cell is left, it can cause the cancer to regrow. Gold nanoparticles are irradiated by short laser pulses, as a result their temperature rises very quickly and reach a thresholds limiting value. Finally micro bubble formation, acoustic and shock waves are generated. These bubbles can then burst and shockwaves spread inside the abnormal cell. The force from the shock wave can damage the cell membrane. This technique also allows healthy tissue to be spared inside body and replace the tissue damaged by cancer. This technique depends on laser wavelength, pulse duration, particle size and particle shape etc. All of these factors are very important in creating localized damage of the cancer cells and sparing healthy tissue. The gold nanoparticles are respectable radiosensitizers[7] because they absorb 10 to 150 times more energy per unit mass than soft tissues. When the particles absorb more energy, more damage is caused to the tumor cells. Thus free radicals are created near DNA in the tumor cells. These causes the majority of DNA damage observed in this system which inhibits cellular reproduction and growth.

C. Energy Dependence of Gold Nanoparticles to damage Tumors

The radiotherapy is to deliver a lethal dose to tumor volumes while at the same time avoiding exposure to healthy tissues[8]. Nanoparticles are being used to increase radiosensitization, which is when the cells become more 5 susceptible to radiation damage. Gold nanoparticles (GNPs) are used as a radiosensitizer, as these particles are biocompatible, high mass energy absorption coefficient and their ability to increase dose deposited. The particles are used within the human body and they should not harm healthy tissue as biocompatibility is an important issue. These particles accumulate in tumor cells, which make them useful therapeutic agents for the treatment of tumors. The gold nanoparticles absorb 10 to 150 time more energy per unit mass than soft tissue. Radicals are created when gold nanoparticles absorb the energy from radiation, which causes electrons to become excited and to create the free radicals Gold nanoparticles are considered as radiosensitizers because they are selective to tumor cells.

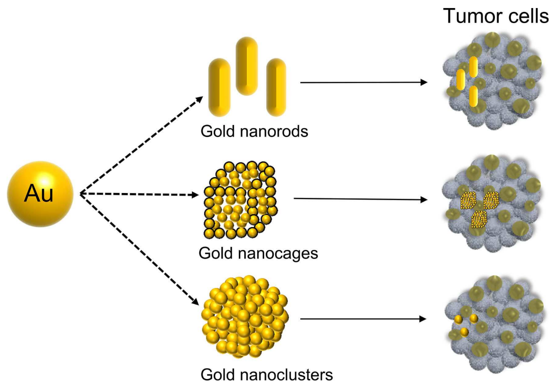

FIG. 3: Gold nanoparticle applied on tumors

D. Nanoparticles as Image Enhancing Agents for Ultrasonography

Ultrasonography uses sound waves to create an image of body organs. These sound waves are transmitted through the body, bounce off of tissues and return to a receiver acts like SODAR (Sound Detection and Ranging). This receiver measures the time it takes for the sound wave to reflect and return to the original place, covered a distance and is transformed it into an electrical signal, which is then converted into an image by the computer. Unfortunately, with ultrasonography the image may not be of the best quality. Nanoparticles have been found to help increase the contrast of the image produced by the ultrasonography particularly when imaging tumor cells. These nanoparticles used are called perfluorocarbon emulsion nanoparticles (PFC) and are about 250 nm in diameter. These particles, due to their size, can be deposited at targeted sites and help increase the acoustic reflectivity[9] because tumor vasculature exhibits an enhanced permeability and retention effect. The acoustic reflectivity caused by the retention of the nanoparticles helps to create a better image of the tumor and a better diagnosis. By preforming these experiments on a living animal model, their results suggest it could have an application in humans. The increase in image quality from ultrasonography, due to nanoparticles, can help in many branches of medicine because ultrasonography can be considered more economical than other noninvasive imaging technologies and can help with diagnosis.

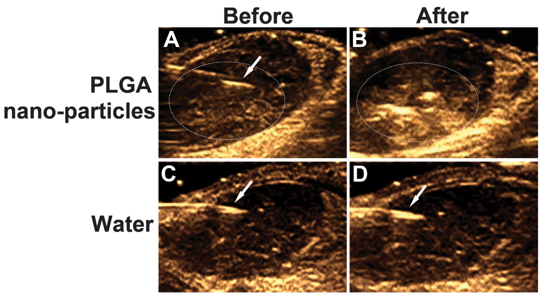

FIG. 4: Implemetation of nanoparticle for imaging ultrasonography

E. Magnetic Resonance Imaging (MRI) by Iron Oxide Nanoparticles

Magnetic Resonance Imaging (MRI), is a widely used technique to observe the noninvasive part of human body. The images that MRIs produce can sometimes leave out important informations. Proper contrasts are very important to see the full image that can sometimes be lost with MRI technology. The MRI contrast agents are generally categorized according to their effects on longitudinal (T1) and transversal (T2) relaxations[10] and is referred to as relaxivity (r1, r2). The area of T1 relaxation takes place appears bright whereas T2 relaxation results in the dark contrast in the MRI imaging. T1 relaxation contrast is most important because it will create bright spots in the image that could otherwise not have been seen. . If these spots cannot be seen a diagnosis could be incorrect. According to Kim et al. (2011), uniform and extremely small-sized iron oxide nanoparticles are successful as T1 contrast agents for MRI. The size and shape of iron oxide nanoparticles are important because they affect certain properties. These nanoparticles have a biocompatible shell with a magnetic core. The larger the particle the larger the magnetic core within the nanoparticles. These nanoparticles also move and rotate within the fields that they create, which increase T1 effects. Iron oxide nanoparticles have a greater half-life than traditional gadolinium based contrast agents. . Iron oxide nanoparticles provide good T1 contrast agent for steady-state imaging. The longer half-life allows for MRI to be used to track pooling blood in blood vessel. This is essential because it shows that MRI can be used as a more accurate diagnostic tool for problems pertaining to the circulatory system. Overall, iron oxide nanoparticles are successful as a contrast agent because their unique size and half-life allows for improved detail in magnetic resonance images.

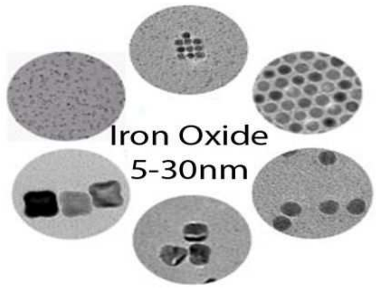

FIG. 5: Iron oxide Nanoparticle used in MRI

F. Effects of Silver Nanoparticles against Bacterial Cells

Antibacterial properties present in silver nanoparticles and it inhibit the reproduction of bacteria which is a microbe. These nanoparticles are nontoxic to humans in low concentrations. The silver nanoparticles can inactivate proteins, blocking respiration and electron transfer, and subsequently destroy the bacteria. These inactive bacteria does not reproduce and will result in a sanitized surface. The nanoparticles are able to interact with the microbes because the cell wall peptidoglycans contain negatively charged molecules that will interact electrostatically with the silver ions[11]. The silver nanoparticles have a positive charge and attracted to the negatively charged molecules within the cell wall and causes damage to the cell by interruption of its natural processes. The antibacterial properties of the silver nanoparticles depend on the size of the particles; the smaller the particles the greater the effect, which allows for greater interaction with the bacteria. Nanoparticles and silver ions interact with sulfur-containing compounds found in bacterial membrane protein and with phosphorous-containing compounds, such as DNA. The interaction these nanoparticle with the DNA can also cause a decrease in microbe reproduction and allow the antimicrobial effects.

FIG. 6: silver nanoparticles used against bacterial cells

G. Orthopaedic Implants

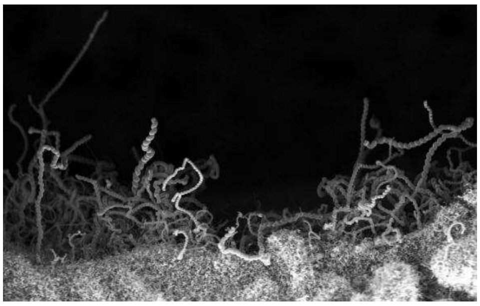

FIG. 7: Bone growing nanomaterial improve Orthopaedic Implants

Nowadays the orthopedic implants are used in many surgical procedures. The main purpose of an orthopedic implant is to replace or support a damaged bone or joint in human body. These implants are used to help patients achieve a better quality of life. The use of carbon nanotubes in orthopedic implants is very effective. Carbon nanotubes, about 0.7-100 nm in length, depending on if they are single wall or multiwall, can be used to improve the lifespan of an orthopedic implant. These nanotubes are made up of carbon atoms. The resemblance of the carbon nanotubes and the collagen fibers of regular bone tissue allow for improved bone regeneration and adherence to the implant, which in turn creates a more stable implant. These coatings and composites may lead to the production of nanotubes as wear debris[12], which may trigger an immune response. With any immune response there could be a number of side effects that could limit the effectiveness of these implants. Overall, the use of carbon nanotubes in orthopedic implants is still being researched, and ideas are being tested due to the many positive outcomes that could be occur with their application in bone and tissue engineering.

III. DISCUSSION

In this review I discuss only a few examples of possible use of nanoparticles in medical field. These nanoparticles have in common is that they need be to biocompatible. Some of these particles e.g. gold or silver nanoparticles are naturally biocompatible while others, such as the magnetic particles, need a special shell to become biocompatible. Some nanoparticles used to improve ultrasound, were later recognized by the immune system and removed from the body. To have a positive effect, the nanoparticles have to be created with a specific purpose. One of these specific purposes is to be used as a therapy to target cancer cell. Some of these nanoparticles, such as the ones used in magnetic hyperthermia, radiosensitization, selective pH drug delivery and laser induced explosion, are able to target cancerous tissue through specific method. Nanoparticles, such as the ones used in laser-induced explosion, can be engineered to have markers or monoclonal antibodies attached to them specific for a type of cancer cell. Overall, nanoparticles can be used in various medical advances because of their unique qualities and applications.

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