THE USE OF NANOPARTICLES IN THE DIAGNOSIS AND TREATMENT OF CANCER

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Abstract

In this paper we will be exploring the current and potential applications of nanotechnology in medicine, more specifically the use of nanoparticles in imaging, detecting and destroying cancer cells. We will investigate the techniques used in this innovative technology and the problems in the application of these methods. We will look at the advantages and disadvantages of commercializing this treatment, and the controversial ethical issues of this topic. This research has shown that nanotechnology in cancer treatment offers significant advances, and that the use of nanoparticles could completely change medicine.

Introduction

Nanotechnology is a fast developing innovation that enables scientists to accurately manipulate and create functional systems at a molecular scale. It is this ability to control molecules at such an accurate level that is the innovation of nanotechnology.

The application of nanotechnology will undoubtly redefine the processes and equipment used in many commercial industries, such as food, clothing and electronics, as well as scientific areas, including aeronautics, energy supplies and medicine[1]. For medicine, scientists have been researching applications for processes such as imaging, diagnostics and drug delivery; in this essay we will be looking specifically at nanotechnology in cancer treatment.

To give an idea of the scale of nanoparticles, Figure 1.1[2] displays the size of nanodevices. They range between the size of a virus and an antibody (10-10^2 nanometers); this demonstrates the level of precision and accuracy the scientists can achieve by working with nanotechnology.

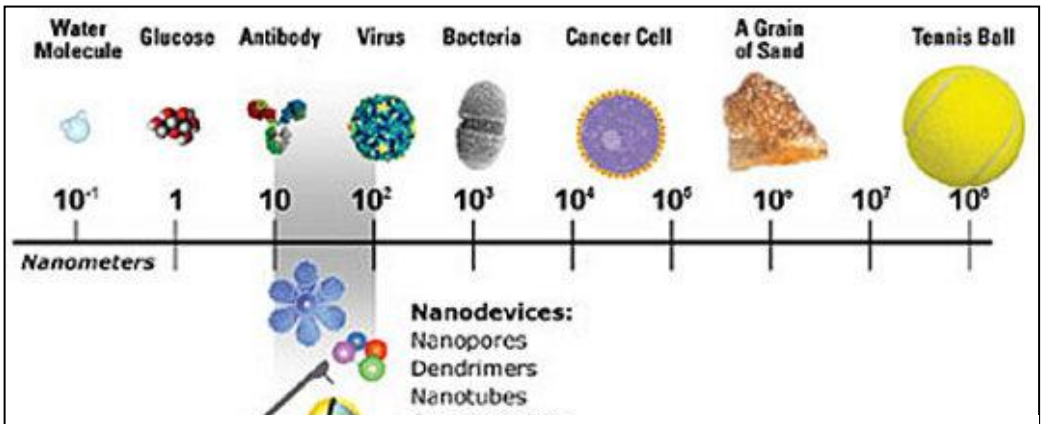

Figure 1.1 Nanometer scale from water molecule to tennis ball

[1] Nanotechnology Application
http://www.understandingnano.com/nanotech-applications.html

[2] Building the Future one Nanoparticle at a time
http://www.theismaili.org/cms/317/Building-the-future-one-nanoparticle-at-a-time

As we researched nanotechnology, we were inspired by Naomi J. Halas, Chair of Electrical and Computer Engineering at Rice University,[3] who has been highly involved in the research and advances in nanotechnology. Though she has published numerous works and investigated various areas of this topic, we were particularly interested in her work involving nanoshells, a type of nanoparticle, to detect and treat cancer. She is currently working on commercialising her cancer therapy, and we were interested to investigate and learn techniques similar to this work.

The uncontrollable division of cells, cancer, affects one in three people during their lifetimes and has recently been a fast advancing area of medicine. It is a difficult illness to deal with both physically and emotionally. We have researched how the application of nanotechnology can help make the treatment of this disease more efficient and comfortable for the patient.

Discussion

From research, to production, to medicine nanoparticles are currently at the centre of interest and are being applied to many modern processes. We will be specifically looking at the imaging, detection and elimination of cancer cells.

Imaging Cancer

Imaging is a key part in the diagnosis of cancer. With imaging, doctors can recognise and pinpoint problems within the body; we have researched how nanoparticles have been used to locate and image cancer cells.

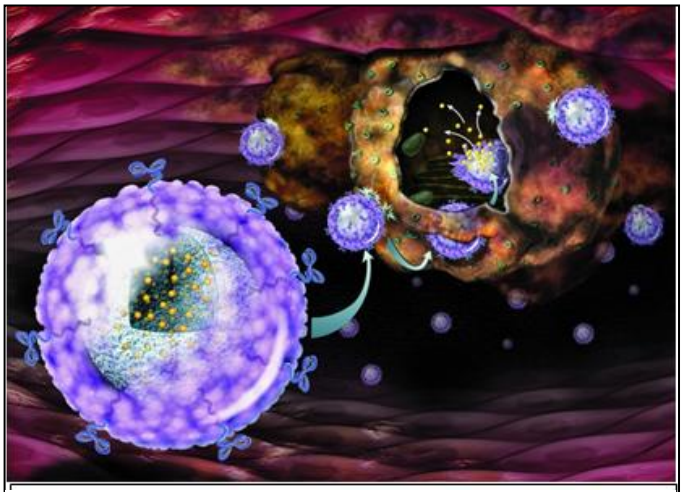

Figure 1.2 Nanoparticles carrying and releasing drugs

Research carried out at Washington University School of Medicine in St Louis US,[4] has successfully demonstrated a nanoparticles imaging technique to investigate the formation of young capillaries in the body. These capillaries are necessary for the

[3] Nanotech Scientists
http://www.nanotechcompanies.us/scientists.htm

[4] Nanoparticle Imaging Technique Could Detect Early Cancer
http://nanotechweb.org/cws/article/tech/16452

formation of tumors. Such technology in the future will allow scientists to detect very early cancers as well. The university managed to develop a means of taking early stage images of cancer using a non-invasive method before it could have possibly been detected by any other technique.

An MRI scan using 200nm-long nanoparticles as labels was first carried out to locate the capillaries in question. 80 000 atoms of gadolinium were primed into the nanoparticles; this element can be seen on the MRI scan. The nanoparticles also have a marker protein on their surface so that they lock on to cells with avb3 on their surface. The nanoparticles therefore lock onto these cells while the gadolinium reveals their location by showing up as a bright spot on a magnetic resonance image. The scientists believe nanoparticles are the best carriers for gadolinium as they contain many more of these atoms and so result in a brighter image formed. The incredible thing scientists believe is that these nanoparticles can be primed with anything you want - the targeting agent can be added to let scientists select where the particles travel; an imaging agent, such as gadolinium, can be added; or a drug, such as plaque-stabilizing medications or anticancer agents can be added. This offers a number of useful uses of nanoparticles. In Figure 1.2,[5] the nanoparticles can be seen efficiently transporting and releasing drugs in the appropriate area. Later we will discuss how we would like to incorporate this technique, along with another, to destroy cancer cells.

Preliminary results from the research done at Washington University, hint that scientists can engineer the nanoparticles to image plaques just as they are beginning to form. Furthermore, combining previously acquired knowledge with the research would suggest that this technique can distinguish between stable plaques and plaques which are about to rupture and thereby cause a heart attack or stroke in patients.

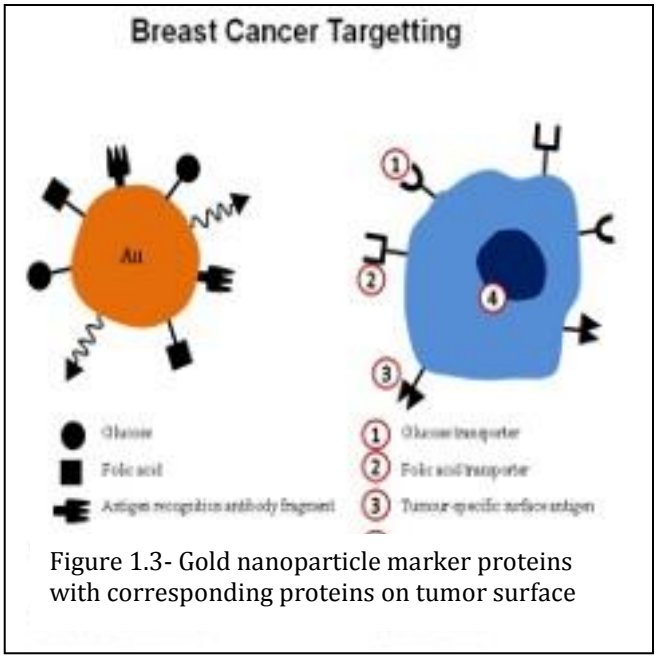

Figure 1.3- Gold nanoparticle marker proteins with corresponding proteins on tumor surface

Treating Cancer

Nanoparticles can also be applied in the detection and destruction of cancer cells. In particular gold nanoparticles have been the centre of much research because of their great potential in treating cancer more efficiently than current methods.

One of the main problems with

[5] Shefin , Novel biodegradable nanoparticles for drug delivery, January 6, 2010 http://biomedme.com/general/novel-biodegradable-nanoparticles-for-drug-delivery_5276.html

current cancer-treating drugs is that the toxin damages both the cancerous and normal cells. At present it is difficult to accurately target the cancer cells, and this means there can be severe side-effects of chemotherapy for the patient. By comparison, nanotechnology offers a major development in isolating cancer cells and specifically treating them without harming healthy cells. This targeted therapy promises to be more efficient, with fewer side-effects and improved results These nanoparticles have been developed to possess two key features necessary in detecting and destroying cancer cells.

Firstly, the particles are engineered so that their surface can effectively detect and bind with cancer cells. This means the gold nanoparticles can accurately track the cancerous cells and therefore minimize the damage to normal cells. Gold nanoparticles, as seen in Figure 1.3,[6] have antibodies on the surface, which are used to specifically target the cancerous cells. The antibodies bind with the protein Epidermal Growth Factor Receptor (EGFR)[7] which is over-expressed in the cancerous cells. This means only these cells receive the thermal treatment and the normal cells are unaffected.

The second feature is an ability to destroy the cancerous cells. This is where the design of the particles is essential; the shape of the nanoparticles is constructed to maximize the heat energy they generate when reacted with a laser, and thermally destroy the cancer cells effectively. Scientists have found that gold nanoparticles can convert laser pulses into heat energy;[8] it is this thermal energy can be used to destroy cancer cells. Since the heat is only generated when the radiation is emitted and absorbed, the treatment can be accurately monitored.

Our hypothesis is that we could give the patient the current cancer treating drugs that are carried by nanoparticles and opened by heat energy. Then administer the gold nanoparticles to the patient, and aim the lasers at the targeted cancerous area. As a result, only the cancer receives the medicine and other normal cells would be unharmed; this means there would be fewer side-effects and therefore the patient would have a more comfortable treatment.

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[6] Gold Nanoparticles (GNP) Can Target Tumors and Deliver Therapy
http://www.mdx.ac.uk/research/areas/biomedical/Oncology/Research/GoldNanoparticle.aspx

[7] Nanoparticles for Cancer Detection and Destruction
http://www.appropedia.org/Nanoparticles_for_cancer_detection_and_destruction

[8] Numerical investigation of heating of a gold nanoparticle and the surrounding microenvironment by nanosecond laser pulses for nanomedicine applications
http://iopscience.iop.org/0031-9155/54/18/013

Advantages

The growing evolution of nanotechnology has opened up doors to scientists demonstrating a vast array of advantageous uses nanotechnology has to offer in the area of medicine. A perfect example is the new concept of using nanorods to detect cancer; this has proved to have numerous positive outcomes compared to flow cytometry, in which fluorescent markers bind to cancer cells. The price of diagnosis compared to that of the method of flow cytometry could be cut by two-thirds just by using nanorods. Where flow cytometry demands a larger sample size, nanorods only require a fraction of the number of cells, meaning that nanorods are capable of helping to determine an earlier diagnosis. Even more so, nanorods have been proven to be far less invasive compared to some other methods due to the fact nanorods use blood samples and do not require a biopsy. However, it must be taken into consideration that some forms of cancer are not expressed in blood samples and in such cases other methods would be necessary to detect cancer. The added advantage of this is that scientists can use conventional microscopes and light sources to view the samples versus other methods that utilize expensive microscopes or lasers contributes to the overall cost savings of nanorods.

Disadvantages

Yet in recent times growing numbers of scientists have begun to shine a light on the possible concerns that nanoparticles bear and their negative health effects. Nanoparticles are famous for their small size. Due to this, it is possible for nanoparticles to penetrate almost any membrane in the body. Where this is advantageous for cancer treatment, it is a major drawback because of the potential harm to healthy cells and DNA – causing more cancer cells.

Careful consideration must also be taken concerning the disposal techniques for nanoparticles used in manufacturing or other processes. It is important that special disposal methods are practiced to stop damaging particles from ending up in the water supply or in the general environment, where they would be impossible to track.

Another potential disadvantage derived from nanoparticles is concerns over the idea of mass poisoning.[9] As nanotechnology can be found in almost every food product in the market place, it is a probable idea that the future health effect of this has the potential to be on a large scale. If the coatings contain toxic nanoparticles which are capable of transgressing the blood-brain barrier, they then run the risk of creating mass poisoning.

The dangers of manipulating the structure of material on a nano level without fully comprehending the potential impact on the nanoscale kick starts the hazard

[9] The Potential Disadvantages of Nanotechnology
http://nanogloss.com/nanotechnology/the-potential-disadvantages-of-nanotechnology/

of developing a brand new world of materials that have atoms that cannot fit together and work properly.

Finally, a vast array of potential weaponry could be manufactured using nanoparticles due to their tiny molecular size that is un-detectable.[10] The possibility that they could easily penetrate our body and release poisonous substances being carried inside them and kill us almost instantly cannot be ignored. Furthermore, their minute, lightweight feature makes it possible for such toxins to spread at an alarming rate in large public areas before even being detected. The unknown of whether other countries will, or have already produced such weaponry is an extremely distressing thought.

Scientists know we can create materials with nanotechnology but the true test is whether we can all stop to understand the impact the advancements in this evolving field will have on the nanoscale and beyond.

Ethical Issues

Although nanotechnology offers many positive scientific advances, the ethical issues involved must be considered. Recent ethical issues raised suggest that the continued introduction of nanoparticles would lead to an engineered human race which would in time become hyper-intelligent and far stronger than the current average human. This issue could then be developed further to the suggestion that advanced scientific technology would only be open to those who can afford it. Subsequently this would mean a hierarchy of the human race would emerge, leaving the people we are now as the underclass citizens.

With the use of nanotechnology we are using particles that are so small and can pass through almost all membranes. We must consider the fact that this is something we can neither see nor control, at the moment. Another problem is that the implications of nanotechnology are revolutionary - but the consequences could be severe. Jobs will be under threat as an explosion of new technology is developed. Are we willing to delve further into the unknown depths of nanotechnology with the risk of the repercussions?

Conclusion

In this essay we have looked at a number of issues concerning nanotechnology-applications of nanoparticles in the imaging, detection and elimination of cancer cells; the advantages and disadvantages of nanotechnology; and the ethical issues of using nanotechnology in medicine. We have focused on combining the methods of energy releasing gold nanoparticles, with nanoparticles that release drugs when thermally induced. We recognize that there could be problems with this, for example, the nanoparticles are so small, that they can cross almost any

[10] Nano Weapon
http://www.hk-phy.org/atomic_world/social/social01_e.html

membrane, and would be extremely difficult to trace. However we hope that the nanoparticles can be developed so that they only attach to the cancer cells and any unbound nanoparticles will be engineered to exit, rather than remain in the body. We hope that the work of scientists such as Naomi J. Halas will continue to improve nanotechnology in medicine and that the advances in this area of medicine will fulfill the potential that this technology has to offer.

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