

NANOTECHNOLOGY IN THE  
TREATMENT OF  
CANCER

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PASS WITH MERIT

RESEARCH PAPER  
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## ABSTRACT

Nanotechnology, from Greek word for dwarf, is the study of materials ranging in the area of 1-100 nm. Interestingly, although nanotechnology may be perceived as a brand-new development, it has in fact been around for many years; for example, in pottery. The Lycurgus chalice, which used silver and gold nanoparticles, dates back to the fourth century, AD. Nanotechnology is still being researched and is an evolving aspect of science with potential to completely revolutionise medicine as we know it. The nanoparticles offer different properties to the atoms in bulk, making nanoscience a fascinating area and giving research teams the opportunity to research particles with different properties to materials which are currently being used in medicine. It is for this reason that there are different universities and companies investing time and money into nanotechnology, and is also the reason why billions of Euros are being invested into nanotechnology across Europe. In fact, it is so important that the UK government had planned to spend £45 million on its research 2003-9 (1). This paper discusses the use of nanotechnology in cancer treatment.

## INTRODUCTION

There have been many developments in nanotechnology which could benefit medicine immensely. Such developments include the nanoparticles ability to detect specific cells and therefore behave as 'guided missiles'. It is not yet fully understood why nanoparticles are able to detect specific cells, but this is currently an area of research. The very small size of the nanoparticles also allows them to enter the bloodstream and areas that larger particles perhaps could not easily gain access to. Also, due to the tiny size of nanoparticles, their surface area to volume ratio is significantly altered, which is the reason for their altered properties. New properties and uses of nanotechnology are continuously being discovered, making nanomedicine a fascinating area of research, and the unique properties of nanoparticles offer a chance to completely revolutionize medicine, and more specifically to this paper, cancer treatment, as we know it.

Research is currently being undergone in many different areas of medicine, such as research into materials for cancer including nanoparticles for joint replacement, and also other areas such as cell and bone repair and regeneration. Nanotechnology's range of applications offers huge hopes for the world of medicine. This paper specifically evaluates its uses in cancer treatment.

One in three people will develop cancer at one stage during their life (2). Cancer is in fact so serious and so common that it has become known all around the world, 'cancer is a word, not a sentence,' John Diamond, British broadcaster and journalist, conveys this message exactly.

It is a multifactorial disorder with both environmental and genetic causes as some may have a genetic pre-disposition to cancer, making it more likely that they will develop it, although it is mainly affected by environmental factors such as smoking, obesity and diet; only 5-10% of cancer cases are due to genetic causes alone (3)

Cancer also has a great impact in the medical world, with time of doctors, money and

hospital beds being required for cancer patients. However, thanks to nanotechnology, this could all change due to nanotechnology's great potential for cancer treatment which could reduce these costs so that the money can be spent on other areas of medicine.

Furthermore, research into nanotechnology could have great benefits to the general economy also. As nanotechnology seems to become more promising, the research into nanotechnology continues to expand and more jobs become available in this area. It is so important worldwide, in fact, that the US National Institute of Health is funding nanomedicine research has plans to create four nanomedicine centres. As more and more uses for nanotechnology are discovered, it has the potential to create many jobs in other areas and industries also, with nanotechnology having an estimated total market of \$1 trillion by 2015 (4). The nanotechnology research into cancer treatment is very important, '...cancer deaths in America have been declining for more than a decade. Much of that success is due to early detection and better treatments...' Larry Craig shows the importance of good cancer treatment in saving the lives of many. Nanotechnology offers just that; a chance to save millions of people.

## DISCUSSION

Nanomedicine is a huge area of research around the world today. The size of the nanoparticles and their altered surface area to volume ratios means that the particles have altered properties, and this makes nanomedicine truly fascinating for research in all areas of medicine, including cancer treatment. Not only could the nanoparticles offer new forms of cancer treatment, without the severe side-effects of current treatment, but the new treatments could also be used alongside the current treatments, to increase the chances of the patient's survival. Some of the aspects of nanotechnology cancer research are described and explained below.

### Current Treatment of Cancer

Current treatments of cancer include surgery. Surgery is usually the most effective treatment, providing that the cancer has not spread to other parts of the body. Radiotherapy can also be offered before or after the surgery; radiotherapy is basically killing the cancer cells with radiation. However, this also kills healthy cells, which can lead to unfortunate side-effects.

Perhaps the most commonly talked about treatment for cancer is chemotherapy. This is basically a course of drugs; there are different types of chemotherapy drugs depending on the patient and the type of cancer they have. Usually, two drugs will be given together, known as 'combination therapy'. Unfortunately, like radiation, chemotherapy has unfortunate side



Figure 1: Chemotherapy drugs are a current treatment for cancer, but they often have unpleasant side-effects.

-effects also.

Problems with current treatment are the severe side effects including hair loss, difficulty when breathing, vomiting and diarrhoea. There are also no 'guarantees' with current treatments as there is no certainty that the cancer will be cured, nor is there any certainty that the cancer will not return. Nanotechnology brings the possibility of improving the current treatment which due to the severe side-effects can bring distress, which in some cases, is during the last moments of the person's life; it is for this reason that new treatments for cancer are really needed. It is also for this reason that The National Cancer Institute relies on nanotechnology for a cure in the future, 'nanotechnology will change the very foundations of cancer diagnosis, treatment and prevention'. The following treatments could vastly change the way in which a cancer patient is treated, and could also be used alongside current treatments to improve the patient's chances of survival.

### Brain Tumour Drug Delivery

One very severe form of cancer is brain tumours. Nanotechnology drug delivery is currently being researched as drug delivery for brain tumours and could provide a more efficient treatment for this very severe cancer.

Dr Maciej S. Lesniak, director of neuro-oncology research in the University of Chicago Brain Tumour Centre, has been investigating nanotechnology and its potential for brain tumours. One area within his research is the potential of light-based nanoplatforms. These nanoplatforms have the potential to *specifically* kill brain tumour cells. As Dr Lesniak explains, it is the combination of the properties of nanoparticles with the identification properties of bio molecules which can achieve this possibility of treatment that will only harm only cancerous cells, whilst sparing the healthy cells; a problem with current cancer therapies, which is why nanomedicine is so important for cancer treatment.

An interesting advancement within this area is TiO<sub>2</sub> nanoparticles, which are currently known for their properties of deactivating microorganisms. However, in an advanced twist, the nanoparticles seem to actually be able to show cytotoxicity to *certain cancer cells*. This is a great leap in cancer treatment as it combats the major fault of current cancer treatment, which harms healthy cells. To investigate this, Dr Lesniak and his team used a polyfunctional linker to link a cancerous cell (more specifically, a glioma cell) to the nanoparticle being researched (the TiO<sub>2</sub> nanoparticle). The properties of the TiO<sub>2</sub> nanoparticles are unusual and unexpected; nanoparticles show different properties to the materials in bulk, due to their different surface area to volume ratios.

This treatment has the potential to cure brain tumours by selectively killing the tumour cells in the brain using the nanoparticles (which would most likely be injected directly into the blood stream), curing the cancer whilst leaving the healthy cells unharmed. This is particularly important with brain tumours, as the brain cells must be spared. Another advantage of drug delivery is that it is more financially viable as

there is less wastage; only the amount of drugs that is needed is used. Moreover, I feel that these developments offer an alternative to the very risk brain operations for brain tumours, or at least increase the chances of survival for brain tumour patients, as the drug delivery can be used before and after surgery.

### Cancer Nanovaccines

Vaccinations for cancer are currently being developed. Recently, there have been huge leaps in the development of vaccinations as a form of cancer treatment. For example, the HPV vaccine which provides immunity against the HPV virus is in current use for cervical cancer, is administered to girls aged 11-14 through their schools.

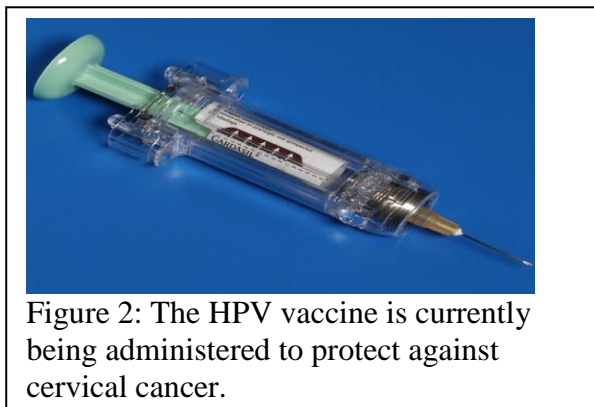


Figure 2: The HPV vaccine is currently being administered to protect against cervical cancer.

There are two types of cancer vaccines currently being developed. The first type, prophylactic vaccines, triggers humoral and cellular immunity and is administered into *healthy* individuals in order to prevent them from getting cancer. The HPV vaccine is an example of a prophylactic vaccine.

For those who already have cancer, there is a second type of cancer vaccination; therapeutic vaccines. Cancer patients often have weakened immune systems, which can be caused by their chemotherapy drugs or radiation treatment. Unlike the prophylactic vaccines, therapeutic vaccines need a rapid cytotoxic T-cell response, because cancer cells divide very quickly and therefore tumors can grow at a very fast rate, and thus require a fast immune response. However, it is proving difficult to successfully provide a fast immune response, and it is for this reason that many scientists believe that nanotechnology may help to do this.

As previously mentioned, nanoparticles can be directed, like ‘guided missiles’ to specific sites. Therefore, they could improve the efficiency of the vaccines by being directed to the specific cancer cells. The nanoparticles can also encourage activated T-cells to come to the site of the tumor; the nanovaccine would cause the cancer cells to release chemo attractants, which causes the T-cells to migrate to the cancer cells down a concentration gradient. In this way, the nanovaccine is far more effective in triggering an immune response. The nanovaccines can also trigger *complement activation*, a part of the innate immune system which eventually leads to cell lysis, triggering the death of the cancer cells. This is done by the cancer cells releasing distress signals.

In current, regular vaccines, adjuvants are added; these maximize the effect of the vaccine, but nonetheless keep the level of foreign antigen at a minimum dosage. Interestingly, nanovaccines seem to have this property in them, which is a major reason why many scientists have high hopes for the use of nanomedicine in vaccinations.

These nanovaccines are of incredible importance for cancer treatment and cure. With current treatments, there are many side-effects, and the patient has to go to the

hospital on many occasions to receive the treatment. However, the ideal for nanovaccines would be that one nanovaccine, or a short course of nanovaccines, would be enough to provide immunity from cancer, or to treat cancer patients. Therefore, nanovaccines would provide a very 'easy' treatment for cancer, so that the patient does not have to go to the hospital on a regular basis to receive cancer treatment.

### Nanomedicine Heat Therapy

Another potential cancer treatment under development is using heat therapy. Similar to radiotherapy in the way that it is for treatment of tumours, this treatment uses nanoparticles so that the treatment is targeted to cancer cells only.

Currently, AuroShell® nanoparticles are being investigated for this use. The

AuroShell® particles have optical properties, and are used alongside a source of infrared waves, allowing the nanoparticles to destroy the cancerous cells. The purpose of the nanoparticles is that the AuroShell® nanoparticles are able to transform the infrared radiation from the source, and transform it into heat radiation, which kills the cancerous cells. Like radiation therapy, a laser optic probe is also used, and this basically ensures that the infrared radiation is directed at the tumour and allows the treatment to be through the skin, from outside of the body. Therefore, this new heat treatment is very similar to the current method of radiation therapy, but the nanoparticles alter the treatment in that they cause minimal damage to the healthy tissue. The preclinical studies have proven successful, and the potential treatment is looking promising.

The size of the nanoparticles means that they can simply be injected into the body into a vein and travel through the bloodstream until they reach the site of the point; they recognise this cell as the nanoparticles gather at the point where the tumour is. The purpose of the nanoparticles is then to concentrate the infrared rays, so that the cancer cells are killed.

The particles themselves have an external shell made of gold with a silica core. The gold is used for its biocompatibility, which basically means that it is an inert, harmless substance that will not cause a bad reaction when in the body; it will not cause any sort of immune response in the body. The geometric structure of the conducting shell surrounding a non-conducting core is used because this allows a shift in the optical properties, which is best for the nanoparticles' function of aiming directly to cancer cells, while avoiding healthy cells.



Figure 3: Nanomedicine heat therapy is quite similar to the current radiation therapy.



Figure 4:  
IV Bag of AuroShells®



Figure 5:  
Individual AuroShell® Particle

The technology is proving very promising so far. In fact, Nanospectra Biosciences, Inc, has pilot trialed the new therapy on humans for head and neck cancers.

The current developments are fascinating and really do offer the possibility of completely revolutionising cancer treatment. However, it is well known that prevention is better than cure, and it should also be noted that nanotechnology does also offer advancements in regards to early detection of cancer, which significantly affects the chances of survival. This area is proving promising; scientists are able to detect certain proteins which can be found in the blood of patients with certain cancers. There are different methods of doing this, such as quantum dots, superparamagnetic nanoparticles and various other possible advancements. In fact, with nanovaccines, vaccines that offer immunity to cancer would be ideal.

There have been many advancements and research into nanomedicine. Below is a table summing up current products in nanotechnology being developed and researched for cancer treatment.

### Ethical Issues

In the treatment of cancer using nanotechnology, there are different ethical issues that need to be considered.

The clearest point is that the non-invasive nanotechnology cancer treatment

can increase chances of survival without the unpleasant side-effects of current treatments. For these reasons, research into nanomedicine for cancer treatment may be considered morally right.

For every moral issue, the intentions behind the acts must be considered. If the doctors and research teams involved with nanomedicine for cancer were working in order to save lives and help others, then their intentions would be considered morally good. However, if the motives behind the research were to earn money and fame, then the intentions behind the acts would not be morally good.

It is also important to consider that, if all goes well and nanotechnology treatments are available, who will have access to the treatments. Factors such as whether you can afford the treatment, or the area in which you live, can affect who has access to the treatment. One well-known example is with the 'Herceptin' drug for women with breast cancer. However, this drug is very expensive; doctors at the Norfolk and Norwich University calculated a cost of £1.9 million per year if the drug were to be administered to cancer patients. For this reason, the drug is an example of a 'postcode lottery'; only people in areas which can afford the drug are given it. Many feel that this is incredibly unfair and that everyone has an equal right to life, therefore it is imperative that everyone has equal access to life-saving treatment, regardless of whether they can afford it, where they live, or other such factors. This is emphasised also in religious teachings, for example Christians feel that everyone is equal in the eyes of God, therefore giving treatment to only certain people is morally wrong.

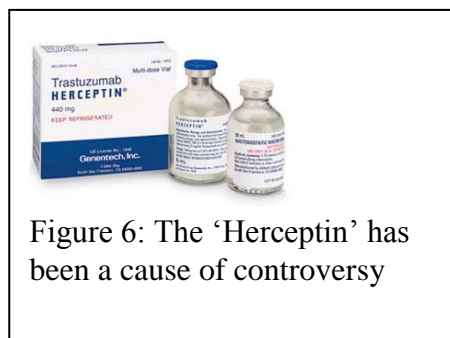


Figure 6: The 'Herceptin' has been a cause of controversy

Different ethical theories can also be used to 'work out' how 'right' or 'wrong' nanomedicine in cancer cure is. The theory of utilitarianism can be used, where the 'greatest good for the greatest number' is considered. In this case, nanomedicine has a great potential to save many lives, and would cause a great deal of happiness for many people. However, complications occur later when considering the possible side-effects of nanotechnology- which are explained below- in which case the most ethical action would be to not to administer potentially dangerous treatments.

From an economic perspective, it is important to note that, despite new areas being created because of nanotechnology, existing areas of the pharmaceutical industry, such as the chemotherapy drugs industry, will be affected, and many jobs will be lost. The ethics of this are also important.

## CONCLUSION

Nanotechnology has the potential to completely change many industries, and can have

large effects for medicine. Nanotechnology can also be used alongside current advancements, to help advance other potential areas of change in medicine, such as stem cell research. In particular, nanotechnology into cancer research could potentially provide a cure for the disease that as of yet has no definite cure but kills millions. For these reasons, this paper is for the research of nanotechnology for curing cancer.

However, there are problems with the current ideas. Every time a new drug is considered for the market, it has to undergo a very long course of clinical trials. There are many stages of these, from testing on organs and organ systems, followed by animal testing and then eventually human testing, which makes the process for confirming a drug 'safe' very long, around 10-15 years.

For the possible developments discussed in this paper, the developments are at very early stages in their trials. For example, the nanovaccines to treat cancer; although there are currently vaccinations for cancer, the idea of nanovaccines for cancer is only hypothetical and there have been no ground-breaking advancements or trials in this area. The area of nanovaccines is, however, very promising and there is potential for there to be fully developed cancer vaccines within a few decades. In fact, in Canada trials on nanovaccines in mice for the treatment of diabetes have been promising, showing potential for nanovaccines.

There are also worries for exposure pathways and how exactly the medicine will reach the site where it is needed. For example, with regards to the earlier discussion of brain tumour treatment, it is proving very difficult to actually find a pathway which would deliver the drugs to the brain tumour; the complication is in finding a way across the blood-brain and brain-tumour barriers to find access to the tumour, and scientists are currently conducting research in this area to hopefully overcome this problem.

There may also be issues once nanoparticles are fully developed and introduced into the medical world. As the article *Medical Journal of Australia* highlights, the fact that nanomedicine is a new development, with nanotechnology treatments being completely different from other cancer treatments, there could be a lot of confusion and difficulty in regulating nanotechnology treatment and its uses. For these reasons, it could be hard to create rules and risk assessments for nanotechnology, which could therefore allow it to be used unsafely. However organisations such as the EU nanosafe network and others have already been set up to monitor the safety of nanotechnology

Another worry is that little is known about individual nanoparticles. The main reason nanotechnology is so fascinating is that the properties of nanoparticles are so different to the properties of the elements in bulk. This, however, means that currently, little is known about their properties. In order to ensure their safety, each nanoparticle of an

element must be thoroughly researched to check for any unknown, potentially dangerous side-effects. There are currently worries that nanoparticles, once in the body, could affect the metabolism of the body. Therefore, it is clear that currently not enough is known about nanoparticles. This causes a potential problem and health risk, but with more research, this problem should be overcome. For example, if there are unwanted side – effects, perhaps scientists could research using the nanotechnology treatments alongside other drugs to minimize any side-effects. Eventually, nanotechnology could become advanced enough to offer cancer treatment without any side-effects at all.

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