

**The role of nanotechnology in the treatment and diagnosis of
cancer**

By

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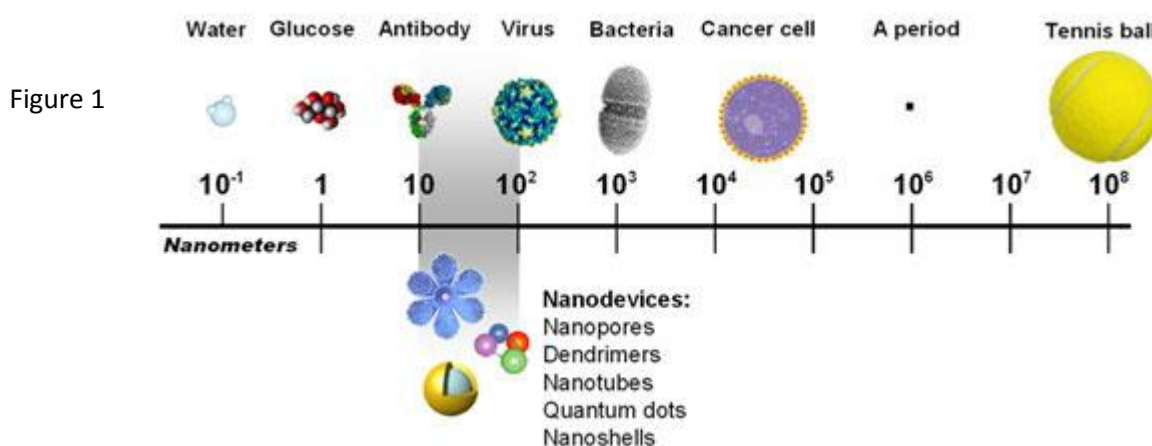
**RESEARCH PAPER
BASED ON
PATHOLOGY LECTURES
AT MEDLINK 2010**

Abstract

Nanotechnology is an area of science which has the potential to treat many known diseases. In the future nanotechnology will play a large part in the application of medicine, leading to higher standards of health care. In my paper I will be investigating the role of nanotechnology in the diagnosis and treatment of cancer. The shortcomings of current treatment of this disease will be highlighted and how nanotechnology can fill the gap will be shown.

Introduction

Nanotechnology is the manipulation of individual atoms, on a scale of 1 billionth of a metre. To be able to do this is of great interest to us because bacteria and cells are microscopic structures. By manipulating atoms we are able to create structures of equal size. This allows us to directly affect bacteria and cells as well as other microscopic structures. Laser tweezers and atomic force microscopes give us control over individual atoms. Figure 1 shows the relative sizes of various objects when placed on a nanometer scale.



It has only been in the last 52 years that an understanding of nanotechnology has been gained. Prior to this nature alone had the power to create structures on a nanoscale. It is now the work of scientists to work out ways to copy nature in the assembly of atoms. Richard Feynman introduced nanotechnology in 1959 with his speech "there's plenty of room at the bottom." Eric Drexler published one of the first works on nanotechnology in 1986 in a book called "engines of creation." In his book he envisioned a world where the use of nanotechnology was widespread. The discovery of buckminsterfullerene was made soon afterwards. Buckminsterfullerene is a sphere which consists of 60 carbon atoms. It is made by vaporising graphite (carbon) and then condensing it. The spherical structure of Buckminsterfullerene leaves a hollow centre. This can be used to hold other substances for example drugs to treat cancer. The discovery prompted further research into nanotechnology leading to the current applications of nanotechnology today.

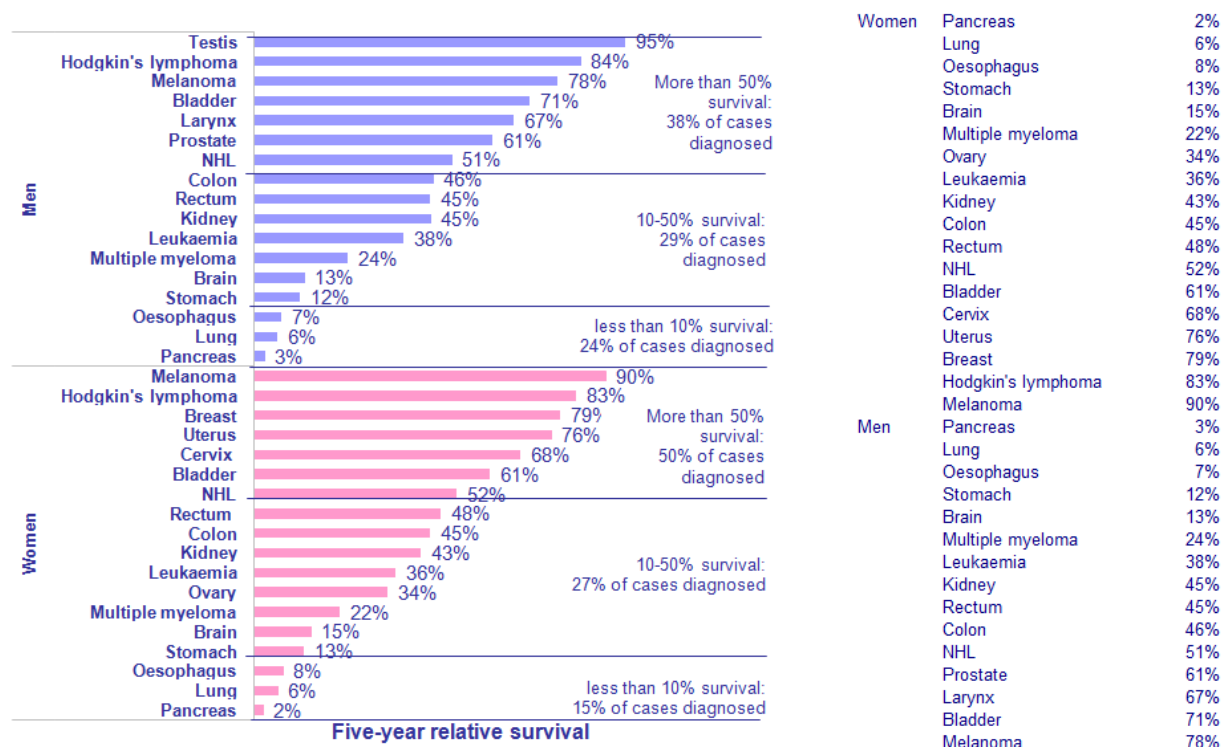
Current applications of nanotechnology

There are many devices today that can be applied to medicine. One such device is the nanotube. It consists of folded sheets of carbon atoms. Being one sixth the weight of steel and 100 times as strong, it has many uses. In medicine it could be used to support broken bones. Also it is used in a gadget which is 250 times smaller than a human hair. A gold blade is attached to an axle made from carbon nanotubes, which is anchored to two silicon dioxide electrodes. Volts are sent through the nanotubes and cause the blade to rotate. The device could nanomaterials around the body.

Nanocapsules can hold substances such as antibiotics. These can be placed in a dressing. In the event that harmful bacteria enter the wound, the bacteria would cause the nanocapsules to break down releasing the antibiotics and killing the bacteria. The advantage of this is that the antibiotics take effect as soon as the wound becomes infected. Under normal circumstances you would have to wait for symptoms of an infection to become apparent, and then generally the antibiotics would be taken orally, resulting in a significant delay between the start of infection and the antibiotics taking effect.

The problem to be solved in this paper is how nanotechnology can aid the diagnosis and treatment of cancer. As you can see in figure 2 there is a large scope for expansion when it comes to cancer survival rates. The general consensus is that the earlier a cancer is diagnosed, the higher the rate of survival. Nanotechnology can help detect cancers and treat them. Therefore when applied to cancer, survival rates should increase significantly.

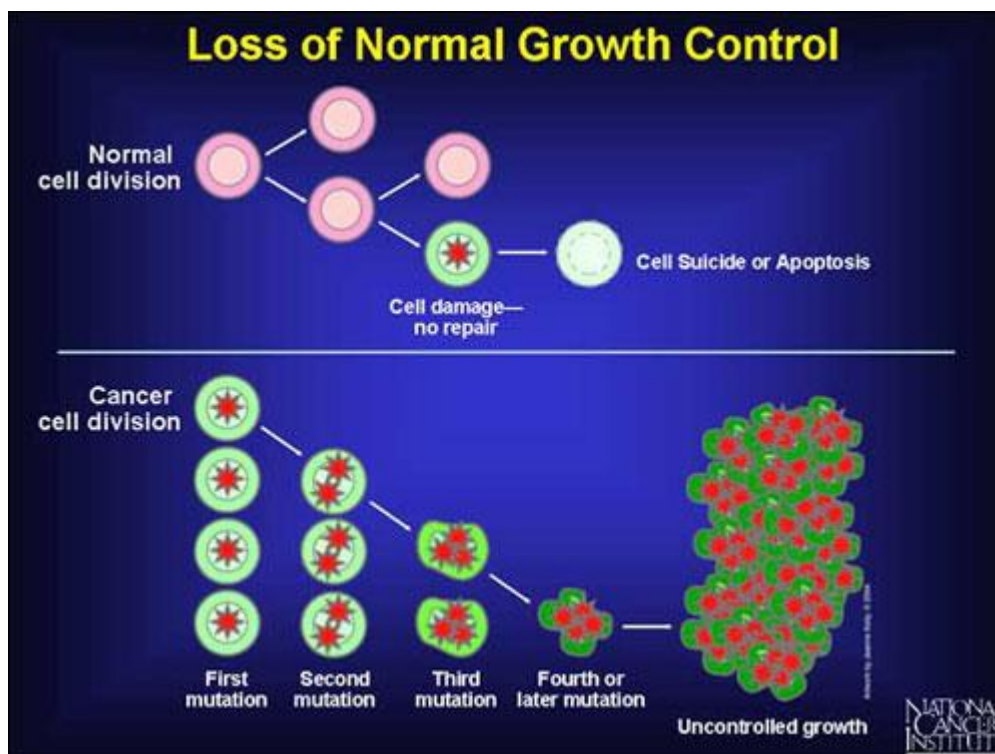
Figure 2: Relative five-year survival estimates based on survival probabilities observed during 2000-2001, by sex and site, England and Wales



Discussion

Cancers are a result of damage to the DNA in a cell nucleus. This produces mutations which may affect cell growth and division. If the cell then goes on to divide rapidly it is classed as a tumour. Not all tumours are cancerous though. Benign tumours are cancers which do not invade other parts of the body. Malignant tumours are cancerous; these tumours will spread to other parts of the body rapidly, and are damaging unlike benign tumours. Figure 3 compares normal cell division to cell division in cancerous cells.

Figure 3



Diagnosis

If a medical practitioner suspects his patient may have cancer for any reason, ranging from abnormal lumps, to the patients relatives being diagnosed with cancer. He will order a series of tests to establish whether the patient has a tumour, and whether or not it is malignant. There are four tests that can be carried out:

Biopsy – This is perhaps the most reliable way to test for a cancer. A doctor will send a piece of the patients tissue to a lab. A pathologist will then observe the tissue under a microscope to see if there are any cancerous cells in the sample.

Imaging test – This can be in the form of a MRI or a CT scan. These involve the use of radiation being subjected to the body to produce an image of a cancerous growth. The patient may take substances orally which will increase contrast in the picture produced.

Laboratory tests – Substances in the blood or urine can be used to tell how advanced a tumour is.

Genomics tests - Polymerase chain reaction (PCR) is a process which can be used to test for mutations in the DNA base sequence. Mutations which are known to cause cancer can be identified in this way.

In the introduction I mentioned that the earlier a cancer is diagnosed the higher the survival rate. Current techniques for detecting cancers fail to detect cancers in the very early stages. It is not uncommon for a misdiagnosis' to be made as to whether a patient has a cancer. Of course if we could detect cancers when there is a relatively low amount of diseased tissue, this would brighten the patient's future prospects.

Quantum dots

Quantum dots are luminescent nanoparticles. They are sensitive to the bases contained within DNA. As cancers are a result of several mutations within the DNA of a cell, quantum dots can be designed to bind to certain sections of DNA which contain these mutations. When the dots are subjected to UV light they will emit light of their own which can be used to form an image. Quantum dots allow even the smallest tumour to be located due to the luminescence of the Quantum dots. They also produce a better image than conventional scans.

Nanopores

Nanopores cannot be used to treat cancer directly. However they are useful in determining future treatments for cancer. Nanopores are simply a pore through which a strand of DNA can slip through. The usefulness of this is due to the nature of the pore, it allows the DNA bases to be examined, paying careful attention to the sequence of the nitrogenous bases. It is changes to this sequence which causes cancer. So by studying the DNA strand it could perhaps be possible to identify weaknesses in the sequence, which could lead to a cancer forming. Even if this were not possible I am sure that nanopores would aid research into gene therapy, which I will discuss later.

Nanowires

Working on a nanoscale holds great promise in the diagnosis of cancers. Nanowires are a clear example of this. Their size alone allows them to detect individual molecules that attach to it. Nanowires are made from carbon or silicon and have an extremely small diameter. This means that a single molecules binding to it would disrupt the flow of electrons along the wire. They can detect the presence of changes in the DNA sequence which causes cancer. Like Nanopores they are useful to study genes and also locate the exact position of mutations in the DNA. Also they are useful in the diagnosis of cancers and they could provide information to nanorobots (which can replace DNA in cells) to which genes to replace in a cell.

Cantilevers

Cantilevers make it possible to monitor the progress of cancerous cells in real time. Cantilevers consist of a nanoscale board which is covered in antibodies. These antibodies are complementary to the shape of the proteins secreted by cancerous cells. The cantilever is designed to detect specific molecular expressions which can be interpreted. When the protein binds to the antibody the cantilever changes shape, it is this change of shape which can be interpreted. This is useful in confirming the presence of cancerous cells but also can provide rapid and sensitive detection of cancer related molecules.

Nanorods

Nanorods allow for the diagnosis of specific cancer types, for example breast cancer. Specialised antibodies on the nanorod attach themselves to the proteins produced by cancer cells. A property of the nanorod-protein complex is that it scatters light in a unique way. This means an extremely accurate diagnosis of the specific cancer type can be made which will be invaluable when contemplating possible treatments for the disease.

Treatment

Non competitive inhibitor

The body's immune system is there to protect you from disease. Pathogens have specific antigens which is what triggers an immune response. Phagocytes detect the foreign antigen and consume the pathogen. Lysosomes then go on to digest the pathogen. This is just the start of the immune response. Cancer is tackled by the immune system in the same way except with a crucial difference. Some cancer cells present the same antigens as those of the body's own cells. Under these circumstances the body may or may not attack the cancer cells. I'm suggesting that a non competitive inhibitor could bind to the antigen and change the shape of the antigen. After this transformation the cancerous cell could no longer be identified as the body's own cells and would be attacked by the immune system in the normal way. Although generally the immune system is not strong enough to remove a cancer on its own; there are some cases where cancers have been known to just "disappear." Even if this did not happen it would certainly help for the body to be attacking the cancerous cells, and would give more time for conventional treatments to be applied such as chemotherapy.

Nanoshells

Nanoshells consist of a core of silica and a metallic outer layer. Due to their small size they are able to move through the body and they accumulate where the tumour resides. This is due to the enhanced permeation retention effect (PRE). Radiation can then be sent through the body which heats up the nanoparticles surrounding the tumour cells. The end results of this is the destruction of the tumour.

Nanoshuttles

Current cancer treatment involves a variety of drugs which are used to treat different cancers. Like chemotherapy for the drugs to be most effective they have to be targeted on the right spot, to prevent healthy cells being affected. Nanoshuttles provide the means to transport drugs to the site of the cancer. In the introduction buckminsterfullerene was mentioned to have a hollow centre where substances may be stored. Nanoshuttles use this principle to transport drugs around the body. The nanoshuttle needs to have two main characteristics. Firstly it must be able to navigate it's self to the target cancer, and secondly it must be able to deploy the cancer fighting drug. The nanoshuttle will contain a virus. The virus will have been modified to contain peptides with amino acids that exactly match certain proteins in the body. This allows the nanoshuttle to move through the body until it reaches its complementary protein and will stop. It can then be laser activated to release the contents of the shuttle, whether that is cancer fighting drugs or even other nanoparticles.

Gene therapy – Nanorobots

Since mutations have occurred in the base DNA sequence in a cancerous cell. It seems logical that to repair the cell, we have only to replace the DNA in the cell to restore it to normal. Some viruses have developed a way of transferring their DNA into other cells. Through the use of Nanopores and Nanowires we can detect the damaged gene. After the virus genome has been altered to prevent harmful effects to the body, it can be inserted into the body at the tumour site containing an undamaged version of the gene. The virus would then go to replace the gene inside the cancerous cell with the undamaged version. The disadvantages of using a virus are:

- It may be attacked by the body's immune system.
- It is difficult to replace multiple genes.
- Cells containing the mutated DNA may rapidly divide and thwart the efforts to replace the DNA in all the cells.
- There is a fear the virus may regain its potential to cause disease once inside the patient.

Nanorobots can be used as an alternative. A chromalocyte is a hypothetical mobile cell-repair nanorobot capable of travelling through blood cells, and replacing all the chromatin in a cell. For further reference to this process please visit <http://jetpress.org/v16/freitas.pdf>. By using a nanorobot the, implications of using a virus are negated. There would be no immune responses from the body or threat from a virus. Also all the chromatin can be replaced in the cell by nanorobots eliminating the problem of multiple mutations, although nanopores and nanowires eliminate the need to replace all the chromatin. In the future nanorobots could replace the DNA in large numbers of cells in well established cancers, saving people whose prognosis would be fatal today.

Ethical issues

Nanotechnology is a new development which will be involved in extensive testing before it will be used in mainstream medicine. As is the case in all drugs this testing will require animals and human volunteers. The theory behind a nanodevice working may be sound, but there is still the chance that once inside an animal it could cause damage, or if it gets to the human experimental stage it could cause damage to humans.

In this paper the use of nanotechnology in treating cancer was investigated. If nanotechnology can be used to treat cancer then I have no doubt that it can be used to inhibit bodily functions. There are numerous ways that nanotechnology could be used to damage humans. The advancement of nanotechnology may bring about a new era, where acts of terrorism are committed through the use of tiny nanoparticles, which are too small to detect easily.

Nanoparticles can be excreted through the anus or urine. Although I am sure the effect of nanoparticles on the humans will be researched extensively. The affect on nanoparticles on, for example fish, or any other organisms which may be brought into contact with nanoparticles, will be less clear and potentially damaging.

In this paper I discussed how nanorobots could be used to replace DNA in a cell nucleus. Research in this area may lead to breakthroughs in genetic engineering. Genetic engineering is seen as playing God and could encourage the idea of “designer babies”. This is also seen as playing God and is highly controversial.

Conclusion

Nanotechnology is clearly the way forward to treat diseases in the future. Their size allows them to be able to move around the human body, and be able move in and out of cells with ease. In the future it may be possible to create nanorobots, though at the moment this seems far from sight. Already a nanomotor has been invented and I am sure this invention will aid the fight against cancer. It could be particularly useful in drug delivery techniques. Through the use of nanowires and nanopores a greater knowledge of the DNA can be built. This could lead to many possible developments in the fight against cancer, since cancers are caused by mutations in the DNA.

I believe that nanotechnology has the potential to revolutionise the way cancer is treated today. This is because there are so many ways that nanotechnology can improve current treatment methods, and can aid in the diagnosis of cancer. The ideas explored in this paper could significantly reduce the time taken to detect and treat cancer. There is a lot of work to be done before we can design robots to seek out cancerous cells and replace their DNA. But if this can be achieved, then even the most advanced growths could be rendered harmless.

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