The Applications of Nanotechnology In the Cure for Cancer

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PASS WITH MERIT

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Abstract:

Nanotechnology is a pioneering new science, which holds the ability to innovate medical treatments today and in the future, especially in regards to those treatments concerned with cancer. Nanotechnology is often described as the science of manipulating matter at atomic scale, with 'nano' referenced as 10^{-9}metres. Its term covers the building of structures on an atomic or molecular scale ranging from anywhere between 1 and 100 nanometres. The possibilities of such an exciting part of science are vast in medicine, with the possibility to eliminate cancer- the very thing everyone is out to do. This revolutionary technology has the possibility of destroying cancerous tumours with minimal damage to surrounding healthy tissue and organs. Being as I hold an interest in the cure for cancer, it has led me to focus my discussion on the use of applications of nanotechnology in cancer: Tumour Necrosis Factor attached to gold nanoparticles, Carbon Nanotubes and enhanced X-ray treatment of tumours.

Introduction:

What is Nanotechnology?

Now expected to have the potential to affect every aspect of daily life, in particular medicinal treatments, nanotechnology has raised hopes for many. Eric Drexler's book 'Engines of Creation' was the basis of where the ideas of nanotechnology came from. This is where he predicted that the ideas of creating very small scale structures that would do what you requested, was the future of nanotechnology. Nano being 10^{-9}metres (a billionth of a metre), makes the principles of nanotechnology being the creation and utilisation of materials, devices and systems by building from the level of atoms and molecules and then using these nanostructures as building blocks to construct larger material. The objective of this is to exploit the new properties that emerge at this scale which aids a more effective outcome, because it shifts the intended effect from the macroscopic to the sub-cellular level.

Why use Nanotechnology?

Nature operates at a sub-cellular level, at the nanoscale and so nanotechnology is aiming to imitate nature in a "bottoms up" approach, by using the nanoparticles to create devices, structures and more. Self assembly plays a significant role here, where disorganised systems of existing nanoparticles form an organised structure, without any encouragement from external environments. Nanoparticles are particles which are extremely small and can be manipulated into structures and other items which can then be used in treatment, (*Inman, M, 2008 The Shape of things to come. In New Scientist, 2645, 42-43*).

Nanotechnology has a vital role to play in medicine, with some roles more developed than others at this stage. One of the main focuses of nanotechnology in medicine is the potential greatness that can come out of it when it merges with the processes in the cure for cancer. Medicine has seen rapid developments in the field with the diagnosis and treatment of cancer being it's only void and for this reason exploring into nanotechnology was promoted amongst scientists in order to help fight cancer. Its use in Medicine can mean small devices working from inside your body to provide treatment to specific regions of the body to provide a more rapid and accurate treatment, hence why this will be great in the treatment for cancer. Small devices working inside one's body can also mean easier detection of cancer cells and therefore provide an improved diagnostic system. Nanotechnology can eliminate cancer before it becomes a problem.

Current Uses and Research of Nanotechnology

Due to the fact surgical tools are of a much larger scale than the cells and tissues in our body, surgery is not very precise and harming surrounding cells and tissues cannot be overcome whilst we continue to use surgical tools of this size. However, treatment is only successful using these tools because tissues and cells are good at healing after the surgery. Nanotechnology would not only allow tools to be made of a similar scale to the cells being dealt with inside the body and therefore minimise damage to surrounding calls and tissues because of the relative sizes of the cells and the molecular machines, but also minimise the post- surgery pain as the lack of damage done to surrounding tissue would aid the healing process. This one application of nanotechnology can be beneficial to the patient in more than one way as observed here. The tools such as the laser tweezers (shown in Figure 1) use light to manipulate objects as small as a single atom.

Figure 1: The Principle of Laser Tweezers

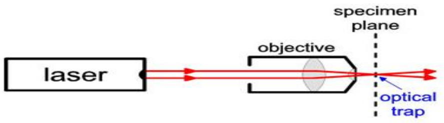

Figure 1 shows the most basic form of an optical trap using laser tweezers. The focus of the laser beam produces radiation pressure which traps small particles. The laser beam is focused to a spot on the specimen by a high- quality microscope and it is this spot which traps the particle at its centre due to the forces that the particle feels.

Nanocarriers, Nanotubes and nanoparticles are all being currently researched and developed. Their applications in the future and in cancer can be seen below.

Nanotechnology, in brief, in the Future of Cancer Treatment

The prospects nanotechnology has for the variety of cancers are very exciting. The cure for cancer is one of the most talked about and researched, not to mention one of the most costly, topics in medicine. Today's tackle at cancer involves the use of radiation therapy which kills healthy cells surrounding the cancerous cells as well as the cancer cells and therefore results in other regions of the body not functioning as they should and also results in side effects that harm one's health. The exciting thing about nanotechnology in cancer is it can help us avoid the many dangerous side effects including hair loss, nausea and more. Nanotechnology offers the chance of drug treatment by buckyballs- an application of nanotechnology. The rigid structure that carbon gives allows the attachment of other molecules to create precise meetings with the target molecule and this reduces the effect on surrounding cells. Nanocarriers are also a possibility in cancer treatment. It's sensitivity to temperature and acidic levels, due to the core shell nanoparticles they contain, mean that once the nanoparticles comes into contact with the acidic environments, for example tumour tissue, they break apart and release the chemicals they contain. This is another example of the specificity that cancer treatments involved in nanotechnology achieve because treatment is directed to single dysfunctional cells and those that have become cancerous, which also leaves us to believe that there's the possibility of being able to cure cancer in one go. Carbon Nanotubes and gold nanoparticles which aids the tumour necrosis factor alpha, more commonly known as TNF, are also being researched and further developed to enhance cancer treatment.

Discussion:

Cancer Statistics

It is a well known fact that cancer is a leading cause of death. Approximately over 10 million people are diagnosed with cancer, annually, worldwide and a shocking 6.7 million people die of cancer annually. 24% of deaths in the UK are from cancer alone. Statistics from the year 2005 show that, in the UK, 1 in every 4 people died from cancer and of these 29% were males and 24% were females. In England, in 2008, the 4 most common types of cancer contributed a massive 47% of all deaths by cancer that year. Figure 2 shows the percentage of all deaths accounted for by cancer in the different regions of the world.

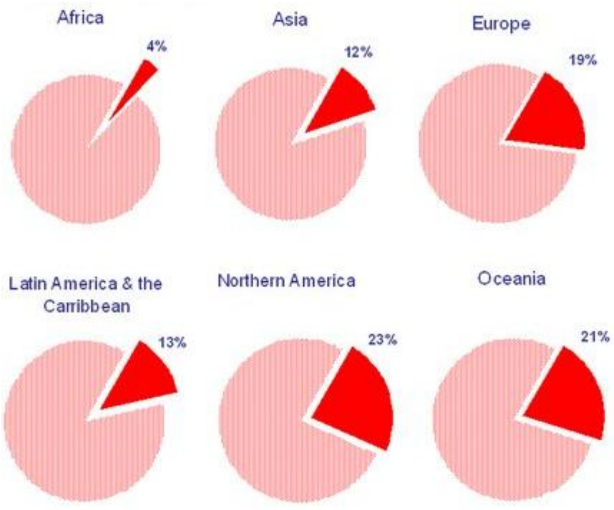

Figure 2: % of all deaths accounted for by cancer in the different regions of the world.

Possible Future Developments, in detail, of Nanotechnology in Cancer:

Nanoparticles in conjunction with TNF

Specific methods of using nanotechnology to destroy cancerous tumours are still being developed, for example the use of nanotechnology in chemotherapy. Chemotherapy is the drug treatment which aims to either cure cancer or, when the tumour has become too advanced, reduce symptoms cancer patients show. Different cancers are sensitive to different types of chemotherapy and when the two meet in the bloodstream, when the cancer cells are in their dividing phase, the chemotherapy will either kill the cancerous cells or just reduce the rate of them dividing. This therapy is used in conjunction with radiotherapy, surgery, or sometimes a mixture of the two. Tablets, infusion, injections, entry into a body cavity and ointments are all ways that chemotherapy can be received. All these methods involve treating an entire area with radiation or drugs.

Nanotechnology offers the opportunity for targeted chemotherapy which delivers tumour killing agent, tumour necrosis factor alpha (TNF), to the cancer cells and that is all. The aspect of nanotechnology here is the use of the gold nanoparticle which attaches to the TNF. In addition to the attachment of the TNF molecule, a molecule of Thiol-derivatized polyethylene glycol is attached to the gold nanoparticle. The Thiol-derivatized polyethylene glycol molecule permits the gold nanoparticle to flow through the blood stream without risk of attack, as it hides the nanoparticle from the immune system to prevent any chance of the immune system recognising the nanoparticle and putting defences in place to attack it. The TNF carrying nanoparticle has been seen to accumulate in cancer tumour regions but no other regions of the body, during the pre-clinical stages of the treatment. This prevents the effect the toxic chemicals would have to normal healthy cells when nanotechnology is not used.

The nanoparticle does not affect healthy cells because it's made in such a way that allows for it to be ignored and unaffected if it came into contact with a healthy cell- it is too big to exit the healthy blood vessels and secondly it's constructed in such a way that it will bind to the tumour and therefore have no contact with healthy cells which prevents damage and loss of healthy cells. This idea of treating the tumour and destroying it from the inside out is a more specific way to do it rather than treating an entire area with radiation or drugs and therefore risking damage to large areas. This procedure is probably the most effective in comparison to other chemotherapy drugs, but it still has some problems which can affect the outcome. For instance, some blood vessels, a minute number however, have holes in them, which are not large enough for you to bleed but are large enough for the plasma to flow through and leak into the tumour bed. Due to the difference in osmotic pressure on either side of the tumour's periphery, that this will cause, the tumour then grows as a balloon shaped tissue where the pressure inside the balloon is greater than it is outside and so substances do not penetrate this physical barrier very well which would lead to the gold nanoparticle leaving the bloody vessel at the site of the tumour and therefore not accumulating which consequently prevents a high concentration of the toxic chemicals to build up at the site of the tumour and instead allows healthy cells and organs to be attacked.

This application of nanotechnology is an example of the Trojan horse concept, where the gold nanoparticles are considered to be the dendrimer as it allows the two other substances to attach to its structure and the chemicals are 'smuggled' into the tumour without possibility of detection. As a lot of the ethical issues of using chemotherapy lie within the side effects it could cause, the use of nanotechnology here would eliminate the majority of the ethical issues.

Carbon Nanotubes

Carbon Nanotubes are microscopic synthetic rods which are immensely strong, although very light and small. It's been said that these carbon Nanotubes, when inserted into the cancerous cell, can kill the cancer cells without harming surrounding cells because they are heated up with infra-red. As demonstrated by the work of the Stanford University team (2005), a solution of carbon nanotubes would heat up to about 70$^{\circ C}$ within the space of approximately two minutes when put under an infra red laser beam. The heat generated by the laser beam kill the cells immediately. Infra red promotes healing as it raises the white blood cell count which results to greater immunity. This use of nanotechnology is another great example of killing the cancer cells by working from the source, hence working inside out, which further prevents damage to surrounding tissues as it only destroys the cells it needs to. It will only destroy the cancer cells because cancer cells, unlike normal cells, are covered with receptors for the vitamin, folate, so by attaching folate molecules to the nanotubes, the nanotubes only bind with the cancerous cell. These results need to yet be proved on the human body. This is another great application of nanotechnology which shows how the tools and drugs required will only ever affect the cancerous cells, which consequently then avoids the side effects, such as hair loss. This can make the treatment to cancer a less traumatic experience. This has not been put into clinical action as of yet though and is still being developed further. However, the application of Nanotubes in medicine, generally, is present.

NanoXray Therapeutics

The latest research into nanotechnology probably comes from the technology that is known as nanoXray therapeutics, with its main objective being able to overcome the problems radiation therapy has- destruction of healthy tissue when a high dose of X-rays is required. It is believed to be the pioneer in the future of cancer therapy as it can be controlled outside the body, unlike the above examples. It involves the work of NBTXR3 nanoparticles (diagram shown in figure 3), which is a suspension of inert crystalline nanoparticles of hafnium oxide, which acts as the therapeutic source, with a simple coating that is formulated in water. As the therapeutic source here is inert, it only becomes active when its electrons come into contact with the external beam of x-rays. When inert these nanoparticles have no effect on the body at all, as they only become effective once activated by x-rays. The ionising radiations of the x-rays are absorbed by the coating of the nanoparticle, which in this case are the molecules of water. The absorption by the water molecules leads to the electrons losing energy and becoming free radicals, which are highly reactive unpaired electrons. The energy from the x-rays generates kinetic energy that activates the inert substances within the core of the nanoXray which increase the dose of x-ray in the region of the tumour so that healthy cells go unharmed.

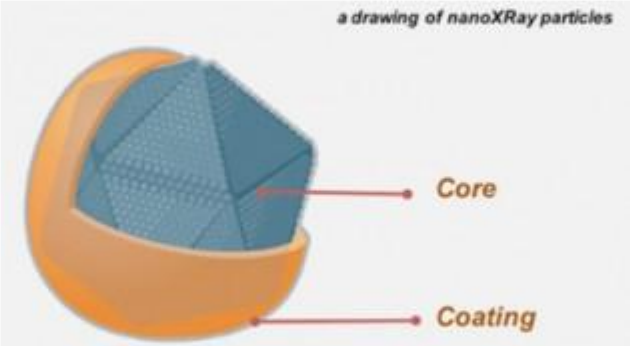

Figure 3: A diagram of a nanoXRay Particle

Here the inert crystalline nanoparticles of hafnium oxide are within the core, and the coating is formulated in water.

Nanotechnology to aid Cancer Treatment in its use in Pain Relief:

As seen above, nanotechnology is being used in many ways to help the cure for cancer by targeting the cancer cells. Nanotechnology is also being used in the aftermath of cancer treatment. Pain is a common feature experienced in the majority of cancer victims, and complications often occur with some patients who have been under cancer treatment for some while. Sometimes it's the fact that the cancer treatment has harmed regions elsewhere within the body. This is for all the above mentioned reasons and hence why using nanotechnology to specifically destroy cancer cells is a vital goal in the upcoming inventions to medicine. Nanotechnology can be used in pain relief in post operative patients, where pain relief drugs are sent to the specific region of the body. A nanoparticle would be the carrier of the drug, just like in the use of nanoshuttles and nanoshells. By focusing the pain relief to the region of the body that requires it, aftermath treatment would be of a shorter period of time which provides economical reasons for why we should use nanotechnology, as the treatment involved becomes focused to the area needing treatment meaning the whole treatment is a lot more cost effective.

Conclusion:

Many of the developments and ideas we have observed in nanotechnology have gone past theoretical ideas and have passed pre-clinical trialling. Some of the above developments have passed pre-clinical trialling, and so there will not be very long left in the wait we have, to see it being used, as described above, on a daily basis in cancer treatment. However, it may not be as pleasing as we expect.

Nanotechnology is very advanced and technical and because it has the potential to be a revolutionary technology it will be extremely costly. This, therefore, may be of no use to cancer patients because the money needed to perform such treatments will not be fundable to most. The situation gets worse when you consider the trouble the NHS is in currently, with huge cuts being made to their spending budgets in order to pay off the debts they have. This leaves us with a problem where even the minimal treatment may be hard to get hold of because there are not enough resources within the trust. With rumours circling the fact that the NHS may collapse within the next few years, it will be even more of a struggle to practice these treatments as the expense will be extremely difficult to cover. In addition to curing cancer, nanotechnology will be useful in detecting cancer within seconds at an early stage which would then minimise the amount of treatment needed at a further stage, and hence minimise the costs of this expensive treatment. So by using nanotechnology, you can eliminate cancer at an advanced stage and therefore eliminate the costs of the expensive treatment nanotechnology may hold as it may not even be necessary to reach this stage.

Stanford University's nanotechnology expert Stephen Quake predicted, in 2005, that within a decade the diagnosis and treatment for cancer will be "carried out automatically, in a few seconds or minutes, on just a handful of cells of their contents." However, extraordinary or ambitious his statement may seem, it is only telling us the truth. Nanotechnology will only take us forwards in our fight to find the cure for cancer and for this reason future generations will receive more effective and less harmful treatments than those already available, which shows us that nanotechnology will make a positive effect in some way in curing cancer.

Many ethical issues arise from the use of nanotechnology in medicine generally, with the common issue being the fact we shouldn't play with nature. If nano medicine found cures for everything to keep us alive, we would be an over populated, never mind an over aged world and it has come into discussion that we may have to stop having children to prevent overpopulation.

Another ethical problem that has arisen is the fact that research into nanotechnology is usually originally done on animals and so the common issue whether testing on animals is right comes into question here. However, this process is needed to eliminate any possible precautions which may arise from the results when the treatments are tested and the treatment has to be legally safe before testing on humans. But as the majority of results from such testing on the animals,are coming out with positive outcomes it shows that the testing is not unnecessary.

Concluding, the use of nanotechnology will play vital roles in diagnostic treatments, treatments and then post- treatment. Nanotechnology will be part of everything to ensure that only the specific cancer cells are killed to minimise the effects treatment would have on the patient. Just having knowledge of such things can show you the possibilities of such fantastic future developments which hold the prospect of being the most beneficial development to medicine in all of its time. It can very well be the cure to cancer.

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