

Nanotechnology and Cancer:

Do we need a reality check, Can Nanotechnology hold the solution to Cancer or should we continue with our previous methods of diagnosis and treatment?

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ABSTRACT

"We're very optimistic that nanotechnology can markedly improve cancer therapy."¹

The word Cancer has been said to be one of the most influential words in the English language that will strike fear and anguish into anyone's heart and as Cancer is continually becoming one of the biggest health problems that the NHS is dealing with, it is more important than ever to find the cure which will end the worldwide suffering from the disease. A staggering one in four people die due to the disease, with 30% of all male deaths being related to Cancer and 25% of all female deaths; in the USA alone one person will lose their battle with cancer every 56 seconds. This show that current methods do not seem to work, but is there any truth behind this and does this means that we need to turn to more advanced studies into nanotechnology and does it truly have the answer that everyone is looking for. Can Nanotechnology cure Cancer?

INTRODUCTION

Before explaining how nanotechnology may hold a solution to Cancer, we need to firstly know why Cancer occurs within the body, and why it is seen as being one of the most life-threatening diseases. Cancer is basically abnormal division and multiplication of cells within the body, and more importantly the body has no control over this cell division and so is therefore able to invade and damage various tissues and organs. The names of various types of cancer mainly relate to the origin of the mutation, for example lung cancer originates in the lungs and this can be either within a cell or within a specific organ or tissue. Cancer is usually linked with division in excessive amounts but it can also be in a decreased quantity also, therefore more cells are dying than are being created from cell division. Cancer has usually been seen as being due to a mutation that occurs within the DNA, this mutation can be due to either natural causes or due to things like prolonged exposure to radiation or carcinogenic.

Carcinogenic compounds can cause Cancer; Benzopyrene is an example of one of these compounds and is one of the most harmful. These compounds are in the cigarette smoke and are in the tar that lies on the surface of the lungs as a result of smoking cigarettes. Carcinogenic compounds enter the nucleus of the cells and have a direct effect as a result and there is a change to the genetic information within the cell.

Any change to the genetic material is called a mutation and if this genetic information is the gene that controls cell division, you can get uncontrolled cell division as a result. When you get an increased amount of cancer cells these can group together to form a tumour, the grouping of the tumour cells destroys the surrounding cells and tissues and so inflammation can occur as the surrounding cells try and destroy the abnormal cells. You can get malignant tumours which are able to spread by a process of invasion, where the cancerous tumour and a process called Metastasis, where it penetrates into the blood vessels and so is then able to spread to other parts of the body (see Figure 1 which shows how a cancerous tumour can spread to other parts of the body by either Metastasis or invasion methods. Malignant tumours are where the problems lie as they are very difficult to remove without damage both to surrounding cells but also due to the fact that the cancerous cells are able to spread to other parts of the body. Once a malignant tumour develops this can mean that organs do not function effectively and so is life threatening especially with cancer like lung or throat.

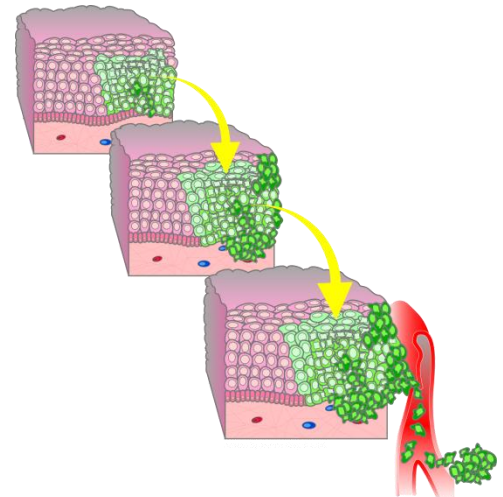


Fig 1- Shows the process of the spreading of cancerous growth.

¹ James Baker, Director, the Michigan Nanotechnology Institute for Medicine and the Biological Sciences.

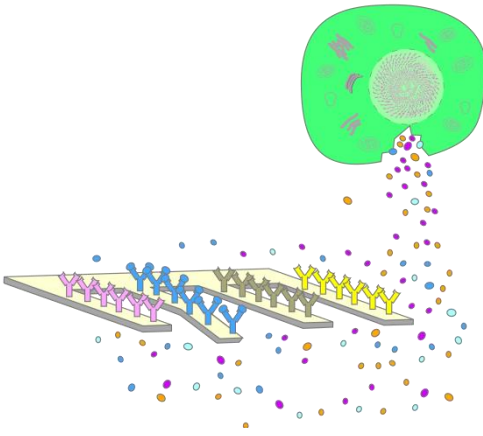


Fig 2- Shows how nanocantilevers work.

Nanotechnology is technology which is based on a nanometre which is a billionth of a meter and the research into this technology has been relatively successful with some very accurate techniques, an example of which is nanowires which could be currently applied to the diagnosis of malignant tumours as they are able to find a cancerous cell within a drop of blood (due to the spread of the tumour by the process of Metastasis, as described above), due to research by the Harvard University in 2005, it has been discovered that molecular markers that indicate cancerous cell growth can be found within the blood stream via silicon nanowires. The structure of nanowires is called a “nanowire array” and this array has been said to be able to scan a drop of blood and therefore supply instantaneous results about whether the molecular markers are present or not.

Similar to these nanowires are nanocantilevers (fig 2), these are used for detecting proteins and induce them in order for the proteins to be able to stick to these cantilevers, and therefore bend them in the process. The protein markers found were proteins called PSA (a Prostate Specific Antigens) which is released by the cancerous cells that cause Prostate cancer in men, and according to the University of California in 2001 are sensitive enough to detect levels 20 times lower than what would be considered as being significant enough to show the onset of Prostate Cancer. Of course this method does not just relate to Prostate Cancer, the cantilevers are also able to be designed to bind to other proteins released by the cancerous cells, they can also bind with mutated DNA sequences. Once these molecules bind with the cantilevers they bend, scientists are able to measure the bending of these Cantilevers and therefore scientists are able to tell whether the certain molecules are present.

“Cancer does not discriminate. It knows no nationality, no creed, no gender, no age”²

John Kanzius is an influential person in the development of nanotechnology for cancer as he believed that by using Gold Nanoshells he was able to target cancerous cells within the body and eliminate them by using Radio waves which were not harmful to the body. His idea was relatively straightforward as the patient was injected with a high concentration of gold nanoparticles each of which had an antibody attached; these nanoparticles then take approximately 45 seconds to completely circulate throughout the body. Once the malignant tumour has been found, the antibody attaches to sites on the surface of the cancerous cells and are then drawn into the cells. Harmless radio waves³ are then applied to the body, penetrating it, and once they reach the malignant tumour cause the buried nanoshells to heat up and therefore destroy the cancerous cells leaving unaffected cells and tissues alone. Unfortunately John Kanzius was also diagnosed himself with Cancer and passed away in 2009, but this just makes the foundation more determined than ever to continue with the work that John started.

So this is an idea of what research in nanotechnology has produced, but what are the advantages and disadvantages of these methods compared with previous methods of diagnosis and treatment such as using chemotherapy or CAT scans?

² John Kanzius, founder of the Kanzius Cancer Research Foundation

³ Radio waves are simply waves which enable us to listen to a music station on a stereo system and what enables us to pick up television signals.

DISCUSSION

Diagnosis is very important as before a treatment can be prescribed to the patient the doctors must first know what and where the cancerous growth is and whether this tumour is malignant or not. Some methods of diagnosis currently used is things like CT scans⁴ which is similar to an x-ray but takes sliced images which then build up a 3D image. Another method of visually searching for cancerous growth is by using an MRI scanner⁵ and once the patient has been scanned a doctor would then examine the image which was produced by the scanner and see if there is any unusual growths or possible tumours.

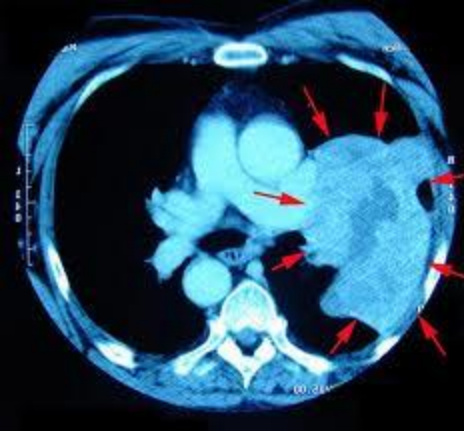


Fig 3- A CT image of the chest and the dark areas are the lungs with the area that the arrows are pointing to being the tumour

These scans have an advantage in the way that what looks like cancerous growth can be isolated and that unlike some nanotechnology methods you know exactly where the cancerous growth is. Another advantage is that you also know if there is a primary and secondary cancer as a result of a malignant tumour that has spread and so if the case does arise both of the tumours can be isolated. However, there are some problems with using these scanners, as you are unable to see early onset of the cancer and must be in a more advanced and developed stage.

So, in these circumstances nanocantilevers or nanowires can be used as these are able to detect cancerous cells with a very high level of accuracy. Therefore if a small trace by either method was to be detected than the patient can be monitored to see if the number of cancerous cells does indeed increase.

A problem with both methods is you are unable to tell if the cancerous tumour that has been found is indeed malignant as this will mean that a different treatment may need to be carried out as if the tumour is not malignant it may not necessarily need to be removed from the body. The only way that a malignant tumour can be distinguished is if there are two tumours, a primary and a secondary tumour. The other problem is that CT scanners and MRI scanners are very expensive and so require a large amount of investment but once the research has been done the costs are not that high. Another problem especially with CT scanners is that the amounts of radiation given out by the CT scanners mean that you are only able to have a certain number of scans in ones lifetime due to the amount of radiation used.

With nanotechnology we are able to view cancerous cells which are not visible with simple imaging techniques such as Ultrasound or CT scanners, a method for viewing cancerous cells is by the use of nanoparticles. Ferric oxide nanoparticles are used and are injected in large numbers into the body, these nanoparticles then travel the body using blood vessels to get to the desired tissues, and the particles then preferentially bind to the cancer cells. This means that the cancer cells are now labelled and can then be picked up and tracked showing where conglomerations of cancer cells are and whether any of them are moving to other areas of the body showing signs of a malignant tumour, as they define the contour edges of the cell. They can also use similar methods to see if the tumour is actually mortally wounded or is actually activated and therefore dividing and so can produce a more concise diagnosis than simply using imaging techniques.

So from a CT scan or MRI you are unable to tell very much just the area in which the suspicious tumour is located, normally without nanotechnology methods you would use a biopsy where you take a section of tissue. This does not usually require an operation and most biopsies can be taken in a normal office environment opposed to having to go to theatre or needs any special equipment. However, problems can arise if the tissue sample is too small, or you are unable to reach

⁴ Computed Axial Tomography Scans

⁵ Magnetic Resonance Imaging Scanner

the affected area and so an incision biopsy may be needed where an incision in the body is made and either part of the tumour, or in some cases the entire tumour, can be removed. Biopsies do have a large amount of risk attached to it. If the tumour is in or on a vital organ than an incision can be very risky as it could in fact damage the organ. Another problem is that once the tissue sample is collected it must be sent to a specialist lab to view the tissue samples and produce a verdict from this. However if a verdict cannot be made another sample may have to be made by other techniques. For example if you used a simple needle biopsy you may now need an incision biopsy instead.

With nanotechnology, operations are completely avoided and so the risk of damaging organs is greatly reduced. Also, with nanotechnology methods, most results are instantaneous and so a verdict can be made in a very short space of time speeding both the diagnosis and hopefully the recovery of the patient. Some methods using nanotechnology do not even need any injections as with some of the previous methods the nanoparticles are injected into the patient, as it has been found that by using gold nanoparticles lung cancer can be distinguished from the exhaled breath of the patient. Using chromatography methods it has been found that in the exhaled of breath of cancer patients there is an elevated level of certain organic compounds compared to a healthy person and so by using an array of gold nanoparticles these organic compounds can be distinguished, this means that an immediate diagnosis can be made, of whether the patient has lung cancer.

“With some cancers, notably liver, lung, pancreas, bone and advanced breast, our 5 year survival from traditional therapy alone is virtually the same as it was 30 years ago.”⁶

Traditional treatment methods have been said to be failing, but at the moment the most popular method of treatment is still Chemotherapy. Chemotherapy works primarily by giving the patient chemotherapeutic drugs, these drugs target fast-dividing cells and then they impair mitosis⁷ within these cells therefore slowing the progress of cancer within the body. Some drugs even make the cells perform Apoptosis⁸. Most people know the obvious side effects that happen with these drugs such as hair loss. This is due to the fact that within your hair resides fast dividing cells and so chemotherapy targets these cells. This is an obvious disadvantage as they are definitely not specific to which cells they act upon and another disadvantage is that it has been found that cancerous cells can become more resistant to the drugs, meaning that if it returns it becomes a lot more difficult to remove it.



Fig 4- Chemotherapy drugs

This is where nanotechnology could be used as the research work of John Kanzius shows that silicon nanoshells are able to target the cancerous cells unlike chemotherapy and so the number of side effects as a result is dramatically reduced as you do not get problem such as hair loss. Another advantage of using this method opposed to chemotherapy as it has been found to have a 99% success rate but this has not yet been fully explored and so the figure cannot be truly believed. The nanoshells avoid damage to the other surrounding cells and tissues and so try to not destroy or damage organs and tissues. This form of therapy does not make the use of any dangerous waves onto the body as research has found that radio waves are on the most part harmless the human body even in large quantities.

A company called CytImmune have developed a way of using gold nanoparticles to deliver a molecule of an agent called TNF⁹ to cancer cells, however there were problems as the molecule was getting attacked by the body's natural immune system. It obviously saw it a suspicious molecule and so another molecule PEG-THIOL simply helps hide the molecule from the immune system and so is

⁶ P Quillin, Ph.D

⁷ The process by which cells divide in the body

⁸ A term called when a cell “suicides” or destroys itself

⁹ Tumour necrosis factor alpha

able to enter and travel using the blood stream without being constantly attacked by the antibodies in the immune system. The nanoparticles tend to concentrate in areas of cancerous tumour and so therefore limits the effects on other parts of the body i.e. Hair cells. The nanoparticle has even been designed so that it is unable to exit blood vessels due to the fact that the size is too big, but in areas where there is a cancerous tumour the blood vessels become leaky and so allow the nanoparticle to exit directly at the site of the tumour opposed to anywhere else in the body. Another advantage of using this method is that the TNF molecules bind to the cancerous tumour cells and nothing else limiting the damage to the rest of the body.

Radiotherapy is commonly related to chemotherapy but in fact they are two separate techniques. An example of these differences is that radiotherapy uses harmful concentrated rays on the body in order to damage the DNA that resides within cancerous cells therefore killing the cell as it is unable to repair the breaking of the DNA chain. Another difference is that unlike chemotherapy there are no specific cells that this will act on and so can cause significant damage to the rest of the body if the rays are not concentrated properly. Due to the fact that these rays can alter the DNA of cells if any stray radiation was to interfere with other cells then this can cause cancerous cells to develop and so a secondary cancer could actually form as a result of the radiotherapy.

The research into silicon nanoshells by the John Kanzius Research Foundation show that these silicon nanoshells are able to target the cancerous cells unlike chemotherapy and so the number of side effects as a result is dramatically reduced as you do not get problem such as hair loss. Another advantage of using this method opposed to chemotherapy and radiotherapy as it has been found to have a high success rate but this has not yet been fully explored and so the figures quoted by the foundation cannot be truly believed. The nanoshells avoid damage to the other surrounding cells and tissues and so try not to destroy or damage organs and tissues, and unlike radiotherapy this form of therapy does not make the use of any dangerous waves onto the body as research has found that radio waves are on the most part harmless the human body even in large quantities and so would not cause any secondary mutations of cells as a result of using the waves.

Opposed to the current methods of diagnosis and treatment of cancer nanotechnology seem to hold the answers so why doesn't the hospitals make more use of nanotechnology when battling against the constant war against Cancer?

CONCLUSION

“Nanotechnology isn’t a magic solution to cancer, but provides additional tools in the arsenal, some with new and unique properties. As with any cancer therapy, the key issue is to get the therapeutic agent to tumor sites and metastases at high concentrations, then destroy cancerous cells while minimizing damage to normal cells.”¹⁰

I totally agree with Jennifer West, there is and probably never will be a magic cure or solution to cancer and this “battle” against cancer for the most part will continue and will probably never truly be won. As with all of the research that I have explored and mentioned they have all got something in common and that is that there is a lack of clear supporting evidence and statistics to suggest that these methods using nanotechnology truly do give a solution to Cancer. As with all new medicinal methods they must all go through concise clinical trials as what may work on a mouse or a dog or simply in theory may not happen when applied to the human body.

Some of the research, especially the work of the Kanzius Cancer Research Foundation and CytImmune, has started clinical trials into their research. Maybe sometime in the future their methods and practices may become recognised and used worldwide, but until the research passes the regulations it is unable to be used in this country. The other problem with this is the cost; most of the research into nanotechnology is on the most part privately funded. So once their treatment methods have passed through the clinical trials, the companies may make the NHS pay large amounts of money to them in order for the NHS to use their patented methods. The companies could in fact go private meaning that even if these methods were to pass the needed clinical trials; patients may have to pay extortionate prices to get the needed medication or treatment. This of course would not benefit those whom are on lower incomes as they may not be able to afford the costs and so would on the most part have to do without and continue with the NHS’s more “conventional” methods of diagnosing and treating cancer.

In conclusion, it seems that nanotechnology does provide solutions to cancer that the NHS currently are unable to provide. These researched methods do seem to eliminate many of the disadvantages that the traditional methods have such as not being specific to cancerous cells. Even if these methods do become available to the NHS and similar organisations I feel due to the budget deficits in the medicinal area, both the NHS’s lack of research into nanotechnology, accompanied by the fact that they will be unable to purchase patented ideas from companies, may mean that the amount of people that will in turn benefit, if the research efforts do actually work, may be lower than initially expected.

So, to answer my original question I feel that the realms of nanotechnology are not out of the question but the question about whether these methods are actually viable is a different matter altogether. My opinion is that with the current economical climate and with strict rules and regulations the technology would have to pass, make the chances of any of us being cured by nanotechnology in the near future very unlikely indeed, but not out of the realms of possibility. So I finish from a quote from an unnamed source which states:

“I don’t think that the field needs a reality check but rather ways to move more of the discoveries and developments into humans”

¹⁰ Jennifer West, Professor of Bioengineering at Rice University

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