Nanotechnology and its potential for improving the treatment of sufferers of Meningococcal diseases

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PASS

RESEARCH PAPER
BASED ON
PATHOLOGY LECTURES
AT MEDLINK 2010

ABSTRACT

Our paper is about the growing area of Nanotechnology and its particular relevance to medicine and progress in medical theory and practice. It describes the properties of Nanoparticles and how they are different to bulkier materials due to their size and surface area. It looks at current research into the possible uses of nanotechnology in medicine and how they improve on current techniques. It explains our ideas on how nanotechnology can be used to treat meningococcal disease through creating a nanoparticle with a complimentary shape to bind to and neutralise the toxins released by the bacteria. We conclude by discussing and summarising the likelihood of such a treatment being developed and the implementation of the technology throughout the world

INTRODUCTION

'If we can reduce the cost and improve the quality of medical technology through advances in nanotechnology, we can more widely address the medical conditions that are prevalent and reduce the level of human suffering.' (Merkle, 2000)

As the above quote suggests, nanotechnology has huge potential in addressing the problems faced by medical practitioners across the world in many different aspects of their profession. It is also plausible to say that nanotechnology could revolutionise the methods used when diagnosing and administering drugs to a patient, whilst also improving the knowledge, tools and techniques a surgeon has available whilst conducting a procedure.

However, before we can interpret the influence nanotechnology has on medicine it is important to understand the concepts that form the background for research and development of nanotechnology. Nanotechnology involves the manipulation of atoms on a molecular level to create products designed for a specific task. The Nano-scale ranges from 100nm down to the size on an atom which is around 0.2nm. The British Institute of Nanotechnology defines nanotechnology as 'engineering at a very small scale.' The influence of Nanotechnology as a field of science is becoming more apparent as seen by when Andre Geim and Konstantin Novoselov, won the Nobel Physics prize in October 2010, for the development of Graphene as seen in **Figure.1,** which shows an image of Graphene, notable for its high strength and electrical conductivity despite its lightweight and small size. This shows how research

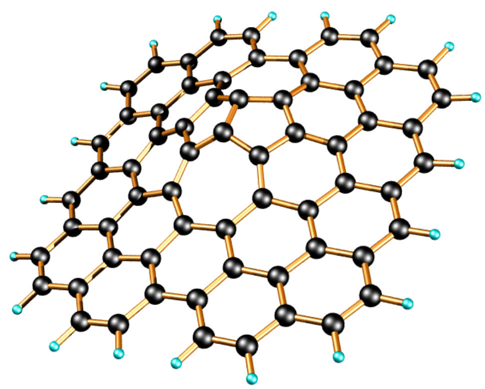

Figure.1

in nanotechnology and 'Nano' sized objects is becoming a more important and influential field of science.

Products which have elements of nanotechnology in their construction/ function are slowly becoming more available for widespread use by the public as more companies invest in this fledging technology to distribute to the public sector. Examples of the integration of such products into the market can be seen in **Table.1** below.

Table.1

Product	Nanotechnological components	Current Research Developers
Nanobatteries	Implemented a nano-structured lattice at the cathode and anode which resulted in an 80 times faster rate of recharge.	Undistributed, first public development, Toshiba 2005, stated they were developing a 'Lithium-Ion Battery'.
Electronic Memory Storage	Introduction of crossbar switch based electronics have offered an alternative to the traditional transistors by using interconnections between vertical and horizontal wiring arrays to create high density memories.	Nantero and Hewlett-Packard are both investigating the possibility of using this to replace current systems.
Sunscreen	Offer similar protection to that of traditional sunscreen but do not have the undesirable whitening associated with the prior.	Companies such as Beyond Skin Science and Crown Laboratories Inc use NanoChemistry in their suncream and an estimated 70% of all products use nanotechnological elements
Self Cleaning Surfaces	Nanoparticles can be used to make surfaces that can break down dirt using sunlight	In 2001 Pilkington glass created Pilkington Activ™ using Titanium Dioxide nanoparticles as they are highly efficient in photocatalysing dirt in sunlight

Nanotechnology is particularly promising in medicine because of the size of the Nanoparticles relative to the biological molecules inside the human body. Nanoparticles have more surface area than their non-Nano equivalents and therefore are more chemically reactive, in essence allowing less dosage to treat the same problem or allowing a problem that couldn't be solved with normal particles to now be resolved. Feynman stated in his speech to the American Physical Society 'There's plenty of room at the bottom'. This rings true in Bottom-up production of nanoparticles, where single atoms are used to create perfect molecules which has the potential to allow specific cells to be targeted such as dendrimers which are combined nanoparticles. This is where branched molecules made from nanoparticles are joined to form a perfect shape which can be specific to bind to different cells. For example Dendrimers can be used to bind to the AIDS virus, whereas the branched molecule alone was too small to have an effect.

This allows a whole new style of custom designing molecules for specific purposes and it is this that is the key to progress in Medicine through Nano technological advancements.

Nanotechnology is becoming increasingly important in the research into the diagnosis and treatment of disease.

Current research in Nano medicine is extensive but there are a few at the very forefront of Medicine:

Qdots (Quantum dots) are nanoparticles with Quantum confinement properties due to the small size of the particles. When used instead of organic dyes, they give a much better image of the location of the tumour site when performing an MRI scan. The increased contrast of the image and the decreased cost make this research very promising as cancer will be able to be more effectively treated, as doctors and surgeons will be able to choose the best course of treatment with more confidence. The only problem being that Quantum dots are generally made from toxic elements so further research is needed to perfect this idea.

Aurimune is a drug being developed that specifically targets cancer cells with chemotherapy drugs. The drug uses gold nanoparticles combined with tumour killing agents to accumulate at the tumour site while passing through the blood stream without harming any healthy cells. This is because the small nanoparticles travel through small holes called fenestrations in the newly formed blood vessels around the tumour. Therefore the drug accumulates around the tumour cells. This also allows higher doses to be given due to only the tumour cells receiving the toxic drug. This highly increases the chances of successfully destroying the cancer cells while not having the toxic effect on the patient. With Cancer directly affecting around 13 million people a year worldwide, Aurimune among other drugs of the same type are very important research projects and have the potential to become an integral part of Modern medicine.

Other research projects involve using silver nanoparticles on bandages to stop infections as the silver nanoparticles destroy the enzyme which allows the bacteria to intake oxygen. Burn dressings coated with nanoparticles containing antibiotics which are released if bacteria are present as they break open the nanoparticle capsule. This allows infections to be treated faster and cuts down on the amount of dressings .Simple things such as oral administration of drugs that were previously frustratingly impossible due to the drug being broken down in the stomach is now possible due to nanoparticles being able to be move through the stomach into the bloodstream. This research is specifically helpful in the initial prevention of disease because more people are likely to take the vaccination if it is taken orally. It also shows that nanotechnology is definitely economically viable due to the benefits it can have in prevention as well as treatment.

Some other Medical Applications of Nanotechnology are briefly described in the **Table.2**, below

Application	Medical use
Nano-scaffolds	Tissue engineering used to regrow some organs and bones
Nano- Vectors	Delivery of genes to disease sites
Nanohyperthermic ablation	Alternative method of destroying tumours which can also be used to complement surgery

There are many problems with Nanotechnology such as the toxicology of some nanoparticles but overcoming such small problems will allow scientists to unleash the potential of Nanotechnology.

DISCUSSION

Though the research discussed within the introduction is promising and has hopes to improve the current treatment of their specific problems through their implementation, there is still great opportunity for further research to develop and introduce treatments to cure a greater range of disease. In particular, the treatment of Meningococcal disease could be altered to include future developments in Nanotechnology, which would severely reduce the lethality of the disease.

Currently, even when treated by antibiotics, Meningococcal disease kills between 10-20% of those infected by it. This occurs because the toxins produced by Meningococcal diseases have various effects, of which occurrence and severity is dependent upon the strain of the bacterium. The sepcis strain of infection causes severe blood poisoning in which bacterial toxins rupture blood vessels and can cause organ failure within hours of its development, whilst on the other hand, the N. meningitidis strain rapidly produces (at rates of 100 to a 1000 times faster than other bacterium) an endotoxin which affects the heart's ability to pump blood, which thereby can cause lung or kidney damage. The problem with current treatment is that, though the antibiotics swiftly travel through the bloodstream and kill the meningococcal bacterium, the destruction of said bacterium causes the release of even more toxins which may take days to Dissipate. This therefore, causes a patient to remain in a critical condition in which they have a continued possibility of death until the toxins are naturally removed from the body of the patient. Even if a treatment proves successful there is still a high percentage chance of permanent disability, of which deafness, blindness and required amputation are just a few of many possible problems.

Currently, there is a vaccine in place within many areas of the developed world to prevent contraction of Meningococcal diseases, however, the vaccines in use do not cover all strains of the disease and are not 100% foolproof. According to Meningitis.org, there are approximately 2000 cases of Meningococcal diseases in the UK and Ireland every year and approximately 5% of these cases result in death. . In the UK 85% of cases are caused by the strain MenC due to the use of a widespread vaccine against the strain MenB. However, in the developing world the problem is far more serious with frequent epidemics killing more than 10,000 in each wave, primarily caused by MenA. **Figure 2,** following page, shows how developing countries particularly in Africa are worst affected

Nanotechnology is already making an impact on the diagnosis and treatment of Meningococcal diseases as seen by the research conducted by Dr Thoduka with Nanotechnology Victoria. His research developed a gold nanoparticle solution which undergoes a colour change upon contact with Meningococcal DNA. This could help reduce the fatality rate of the disease as the sooner the diagnosis and treatment of the disease occurs, the reduced risk there is of death or permanent disability.

However, even if the use of gold nanoparticles is implemented into the diagnosis of the disease, there will still remain certain cases where detection of the disease will occur too late and so we would continue to see the disease cause pain, disability and death to people which is seen today. Therefore, if nanoparticles specific to the toxins produced by the meningococcal strains could be produced then we would see the exposure time of patients to the toxin reduced, therefore, the percentage of cases which result in serious implications for the patient would decrease.

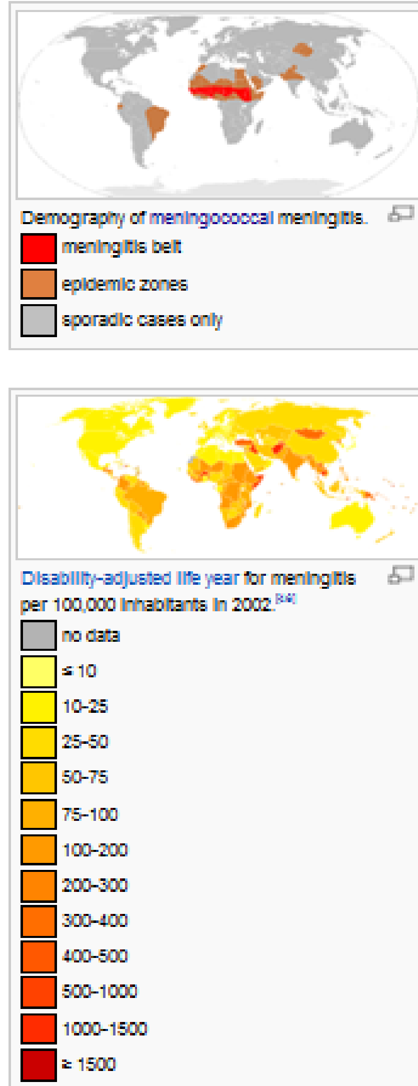

Figure.2

The neutralisation of the toxin is the next step in nullifying the impact that the meningococcal bacterium has upon the world. This is because the toxin is the cause of complication which causes the symptoms of the disease. As a result, if a nanoparticle were to be produced with a surface coat which has a complimentary shape to the toxins, then said nanoparticle would be able to neutralise it, through binding to it, and therefore prevent it from causing further complications by preventing the toxin from functioning. This is because the toxin would now not be able to attack the body due to the formation of a toxin-nanoparticle complex. This is similar to how the anti-toxins produced by our white blood cells, function and so should have a similar impact in the inhibition of toxin activity.

Therefore, if injected into the bloodstream alongside the antibiotics currently prescribed when conducting treatment, the nanoparticles would negate the activation of the toxins released upon the destruction of the Meningococcal bacterium. Problems caused by the residual toxins in the blood which are seen today would be no longer the problem they are today.

Currently, there is already research which concerns specifically designed nanoparticles which bind to toxins, however; it is primarily used for the detection of a disease in the environment. For example, the University of Central Florida has developed a complex sugar compound, called Dextran, coated in iron oxide nanoparticles which can detect the presence of cholera toxins in water. This works because the sugar molecule has a similar structure to that of the cholera toxin receptor in the epithelial cells of the gut. This shows that it is possible to create a nanoparticle with a structure specific to a toxin and therefore, as well as being used to detect the toxins presence it could be used to render the toxins harmless.

However, though the development of this idea may look promising it is likely to face opposition from certain sectors of society. This may stem from religious or environmentalist groups who disagree upon the principle of nanotechnology as a whole due to personal belief and the fact that some nanoparticles are toxic to the human body. Though the problems face by nanotechnology now (toxicity) were eradicated there would continue to be skepticism and rejection due to faith and superstition. Consequently, if mass production and usage of such nanoparticles was achieved, it may not prove to eliminate the problems caused by the disease due to objection from those who disapprove of nanotechnology's use in the human body.

Economical issues are also to be considered due to the costs involved in the production of the proposed nanoparticle. The majority of the 1.2 million cases which occur each year happen in lower economically developed countries and so the governments of these countries may not be able to afford to integrate this treatment into their healthcare system. On the other hand, aid agencies such as the Red Cross may be able to afford to distribute the treatment in the frequent epidemics which occur in Africa and thereby, alleviate and cure those who become infected which will help prevent the spread and impact of the disease. These aid agencies would not even have to pay large sums to fund the use of the treatment as they would purchase the product of developed countries that would be producing the nanoparticle for their own use. Therefore, we can see that on a global scale the medical benefits can be applied without the financial limitations faced by lower economically developed countries as the developed countries would bear the burden of research costs. The cost of each treatment procedure would not be expensive either as the most likely form of delivery would be a drip working simultaneously with the drip delivered antibiotic treatment used today.

Though the possibility of implementing this treatment looks promising it would be many years before it could be used on a widespread scale. This is because of the time that is taken to initially conduct the research that will be needed to produce the correctly shaped molecule. Furthermore, there would be a further time lapse in which the nanoparticle would be extensively tested to ensure that is completely safe for human use and does not cause any problems for patients and the environment.

CONCLUSION

We believe that the use of Nanoparticles which neutralise anti-toxins as part of the treatment applied to patients who are suffering from Meningococcal diseases would be extremely beneficial due to the elimination of the direct cause of the problems associated with these diseases. The proposed treatment is quick and simple to apply and is not invasive therefore patient satisfaction is likely to remain high whilst also being viable due to the widespread problem it causes around the world. On a global scale, the development and distribution of the nanoparticle would be economically viable due to the ability of aid agencies to deliver this medicine to those countries that may not be able to afford it for themselves. We recognise that problems of social rejection faced by nanotechnology today may remain though it is likely further research and evidence of it safety will dispel the current opposition to the use of Nanotechnology in all aspects of life. It is also important to understand that this is not an immediate solution and will be many years before it can begin to make an impact. However, we are confident that the medical benefits provided by the nanoparticles usage outweigh the economic problems of development and years of clinical trial and research as its implementation will save countless lives and prevent many from suffering the injustice of being left handicapped.

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