The applications of nanotechnology in medicine, and the ethical issues on the development of such technology.

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Research Paper
Based on
Pathology Lectures
At Medlink 2010

Abstract:

In our modern world, with diseases and viruses continually advancing, it is vital that our technology develops to keep one step ahead. Since the useful properties of nanoparticles were first discovered and used in industry, research into this area of science has grown enormously. Now scientists are looking at how nanotechnology can be used in medicine to aid in diagnosing and treating patients. Quantum dots that target specific cells are being used to locate malignant tissues, and alternative methods of drug delivery, currently being developed, could mean the end of insulin injections for diabetes sufferers.

However, such huge leaps in technology can be a cause for concern. Development into nanotechnology must be done with caution, and products must not grow out of control, or be so expensive that they can only be afforded by the rich.

Introduction:

What is nanotechnology?

Nanotechnology is a rapidly developing field of science, with new discoveries being made year on year. There are already several medical applications this technology, such as in cancer treatment, drug delivery and in brand new diagnostic methods, and research is continually being carried out in the field. But what exactly is nanotechnology? And how can it contribute to healthcare and medicine?

"Nanotechnology, shortened to "nanotech", is the study of the controlling of matter on an atomic and molecular scale. Generally nanotechnology deals with structures of the size 100 nanometres or smaller in at least one dimension, and involves developing materials or devices within that size"

This is one dictionary definition of nanotechnology, creating and building with materials on an extremely small scale. The ability to manipulate individual atoms and particles was first envisioned by the physicist Richard Feynman in 1959 and after this, many scientists starting researching the area. In 1965 Gordon Moore, one of the founders of Intel Corporation, having observed that silicon transistors were continuously reducing in size, predicted that each year, for ten years, the size of electrical transistors would halve. The term "nanotechnology" was first coined in 1974 by a Japanese researcher from Tokyo Science University. Since the turn of the twenty first century many extremely small, microscopic appliances have been developed, which could hold potential for carrying out functions in the human body. Due to the extremely small size of nanoparticles, the way they interact with cells differs to how larger materials do, which is what makes them so unique. Particles have been shown to target specific types of cells, aid in drug delivery, and even kill cancer.

One of the only clinical uses of nanotechnology today is the use of silver particles in wound dressings and surgical equipment to combat infection. The potential of silver was first noted by Hippocrates, often cited as the father of modern medicine, who wrote that it had beneficial healing properties. Silver ions have been found to be an effective antimicrobial agent when at a sufficient concentration and as such are used to kill bacteria in external wounds, and also prevent infection from arising following surgery. Research is going on into the possibility of combining silver nanoparticles, and other antimicrobial materials, into surgical suture to provide an immediate defence against pathogens post-surgery. Thus far, clinical trials that have been carried out in recent years have proved successful. Another current use is that of titanium oxide nanoparticles in suntan lotion to block harmful UV rays. Many ideas about future uses of nanotechnology in medicine have been theorised for several years, and research is constantly producing new and exciting contributions to the world of modern medicine.

Discussion:

So how can nanotechnology help?

Since research into nanotechnology began, one particular area that scientists have been interested in is targeted drug delivery. For those suffering with diabetes injecting insulin on a daily basis can cause pain and discomfort, limit someone's social life and also affect their daily routine quite significantly. Should it be possible to deliver insulin orally, then this would not be the case. However, insulin, as it is a protein molecule, is broken down into its constituent amino acids in the stomach, and so tablets would prove ineffective. Much research has gone into how nanotechnology can help with this.

This is where micelles come in. Amphiphiles, molecules which are composed of a hydrophilic head and a hydrophobic tail (e.g. phospholipids), when placed in water, congregate together to form spherical arrangements called micelles, which have a group of hydrophobic tails together in the centre with the hydrophilic heads outside. This effect can be seen on a macro scale when oil is poured into water. When enough amphiphiles are present they will automatically come together to form micelles, which can be observed as globules of oil in the water. The orientation of micelles can be reversed by placing the amphiphillic molecules in oil. Here, the hydrophobic tails will point outwards and the heads will group together at the centre.

One interesting point about micelles, which scientists are trying to exploit, is that they can be formed in various different sizes. When the medium in which micelles are made is varied, their size can be controlled and water-insoluble materials can gather at the centre, shielded from the outside environment. By using phospholipid amphiphiles a bilayer micelle can be formed, which effectively forms a vesicle similar to those used for transporting materials in our cells, which can be used to delivery drugs and hormones to specific parts of our body. These bilayer vesicles, carrying certain drugs, can be prepared in a laboratory and designed to target specific cells. When injected into the bloodstream they make their way to the target cells and bind to them, slowly releasing the drug in a manner which can be controlled. The release of the drug can correspond to increased levels of insulin or water, resulting in efficient delivery when needed.

Just as there are intrinsic proteins in a cell's plasma membrane, other molecules can be added to the vesicle to strengthen it and allow for more flexibility in its functions. Ligands can be added to attach to specific cells and polymers can be introduced to slow the controlled release. In this way, micelles have provided both the facility to target certain cells, and controlled release. As such, they have already been employed in the more efficient injecting of insulin, and also in the use of cancer killing drugs. However, these nanoparticles are not perfect and are usually identified and destroyed by our body's immune system and they do not cut down on the need of injections. Although at the moment these micelles would not survive the acidic environment of our stomachs, it is hopeful that micelles and other chemical shells can be developed to withstand strong acid solutions and not be broken down by our body's enzymes. This could eventually lead to a hugely beneficial scientific breakthrough and hence a higher quality of life for diabetes sufferers worldwide. Further research is being conducted into this area of huge potential.

Other nanoparticles that could potentially be utilised in medicine are quantum dots. These are very small crystalline substances, about 5nm in diameter, which fluoresce under certain wavelengths of radiation. The frequency of the waves they emit can be controlled by scientists in their growth phase; the smaller a quantum dot is, the smaller the wavelength of the light emitted, meaning it emits light closer to the gamma ray end of the electromagnetic spectrum. This glowing property of quantum dots means that they could be used in the tracking and imaging of certain tissues, such as cancers, as the fluorescing can be detected and displayed by high-tech medical imaging equipment. In tests conducted at Cambridge Research and Instrumentation antibodies specific to a prostate cancer were bound to quantum dots made of cadmium selenide-zinc sulphate, which, when injected into mice, were found to attach themselves to the cancer cells in their bodies. Since these quantum dots have a relatively large surface area (on the nanoscale), they could be also be used for the treating of cancer, by attaching drug molecules to the surfaces of individual crystals.

Quantum dots themselves are not toxic to the body. However if they were to break down into their constituent heavy metal ions then they could cause quite a lot of harm in high concentrations. In order to prevent this scientists have developed techniques for coating quantum dots in polymers which are resistant to a wide range of pHs and temperatures. In experiments, carried out in conditions that mimic that of the human body, quantum dots have performed excellently, and in the near future could be of common usage in hospital treatment. Also being developed as fluorescent indicators are carbon nanotubes, which, as they do not contain any heavy metal ions, cause no concern over toxicity. These nanotubes can be engineered to fluoresce light in a greater variety of wavelengths, giving more flexibility in their use in diagnostics, giving them as much, if not more, potential than current nanocrystals.

Imaging potential has also been found in another interesting carbon allotrope, the buckminsterfullerene. First discovered by Richard Smalley et al. (1985) at Rice University, buckminsterfullerenes are composed of sixty carbon atoms arranged in a series of hexagons and pentagons, in a similar fashion to a football. These ball shaped molecules look like and can effectively act like cages, keeping molecules inside of their lattice; this protects the substances inside from the outside environment, and also vice versa. Fullerenes can be used to encase certain radiopaque molecules, which are employed in medical imaging such as MRI scans and angiograms, guarding our body from any harmful side effects. However, due to their very small size (each about 1nm in diameter) buckminster fullerenes cannot yet be used in medicine as they would cross the blood/brain barrier, potentially passing into the brain and causing harm.

Surely there must be some problems with developing such a new technology?

One of the largest concerns surrounding the application of nanotechnology to medicine is the cost. As with any recently discovered technology, there comes a high price of developing and utilising new methods of treatment. Already there is a huge gap between the standard of healthcare in rich countries, such as America and the UK, and poorer countries, such as many in Africa. With ever increasing costs and insecurity it is likely that nanotechnology will become something that is only available to the most privileged of people, and those who are worse off shall be left with a poorer level of treatment.

Although this new technology holds the key to many exciting possibilities, some see its development as tampering with nature, and even playing God. This could stem from nanotechnology essentially building substances up from nothing. Several ethical issues have been raised over the continuing research into nanotech. With the possibility of making self-replicating machines, fears that they could multiply out of our control have arisen, raising concerns about a robotic apocalypse, as described in many science-fiction movies. Similar machines could be designed which dissemble goods, rather than assemble them, causing concern over nanomachines which could break down anything they come into contact with into its atomic state. More relevant to medicine, doctors believe that with nanoparticles being so small, they could get lost in the body, and diffuse into tissues where they could cause harm, such as in the brain. It is even possible, that, in theory, with the application of nanotechnology we could improve our strength, endurance and intelligence, potentially extending our lives by several years. Would it be ethical to transform ourselves in such a way, to a point where we could be considered part human, part machine?

Conclusion:

This paper shows and supports the ongoing research into nanotechnology and how its applications to medicine could revolutionise healthcare. Although some might argue that it is immoral to spend so much money developing products which will only benefit the rich minority, it is important to remember that at some point in the future new discoveries will benefit people worldwide. The results shown by current studies are very positive, and the sheer potential of nanotechnology outweighs the concern over continuing with research.

Nanotechnology is a rapidly growing science, set to grow hugely in the twenty first century. Research into alternatives to insulin injections could change the lives of over twenty five million people suffering from diabetes in the United States alone. Cancer screening and treatment could change radically over the next decade as studies into quantum dots progress. Although nanotechnology may have its drawbacks, in that some particles could prove harmful to the body, it holds the potential to play a major role in the diagnosing and treating of patients in years to come.

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