Nanomaterials in medicine

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What is Nanomedicine?

The term nanomedicine encompasses a broad range of technologies and materials. Types of nanomaterials that have been investigated for use as drugs, drug carriers or other nanomedicinal agents include:

- Dendrimers
- Polymers
- Liposomes
- Micelles
- Nanocapsules
- Nanoparticles
- Nanoemulsions

Around 250 nanomedicine products are being tested or used in humans, according to a new report that analyzed evolving trends in this sector. According to experts, the long-term impact of nanomedicinal products on human health and the environment is still not certain. During the last 10 years, there has been steep growth in development of devices that integrate nanomaterials or other nanotechnology. Enhancement of in vivo imaging and testing has been a highly popular area of research, followed by bone substitutes and coatings for implanted devices.

Active and passive cell targeting will continue to be an important focus in nanomedicine.

Targeted nano-enhanced solutions have been shown to often enhance existing treatments, and some nanomedicinal techniques are being developed which work as diagnosis and treatment stages simultaneously.

The unknown factor as far as nanotechnology is concerned is whether the increased production, exposure and handling of products and nanomaterials will result in serious impact on the environment and humans. It is possible that toxicity will be the restricting factor for the public acceptance and commercial success of nanotechnology-based products.[1]

2. What is on the market?

The market for medical implant devices in the U.S. alone is estimated to be $23 billion per year and it is expected to grow by about 10% annually for the next few years. Implantable cardioverter defibrillators, cardiac resynchronization therapy devices, pacemakers, tissue and spinal orthopedic implants, hip replacements, phakic intraocular lenses and cosmetic implants will be among the top sellers. Current medical implants, such as orthopaedic implants and heart valves, are made of titanium and stainless steel alloys, primarily because they are biocompatible. Unfortunately, in many cases these metal alloys with a life time of 10-15 years may wear out within the lifetime of the patient. They also might not achieve the same fit and stability as the original tissue, and in a worst case, the host organism might reject the implant altogether.

While available implants can alleviate excruciating pain and allow patients to live more active lives, there often are problems getting bone to attach to the metal devices. Small gaps between natural bone and the implant can increase over time, requiring the need for additional surgery to replace the implant. In the quest to make bone, joint and tooth implants almost as good as nature's own version, scientists are turning to nanotechnology.

Researchers have found that the response of host organisms (including at the protein and cellular level) to nanomaterials is different than that observed to conventional materials. While this new field of nanomedical implants is in its very early stage, it holds the promise of novel and improved implant materials. There is a huge demand for tissue regeneration technologies, which covers a wide range of potential applications in such areas as cartilage,

[1] AzoNano, Nanotechnology in Implantable Medical Devices, [online]Mar 6 2013,[viewed on 20.12.2018] [available from:https://www.azonano.com/article.aspx?ArticleID=3207]

vascular, bladder and neural regeneration. Just consider the need for bone and dental implants: Each year, almost 500,000 patients receive hip implants worldwide, about the same number need bone reconstruction due to injuries or congenital defects and 16 million Americans loose teeth and may require dental implants.There seems to be growing consensus among scientists that nanostructured implant materials may have many potential advantages over existing, conventional ones.[2]

Types of devices

Implantable Biosensors

Micro-electromechanical systems (MEMS) and silicon chips that are capable of implantation within the human body may permit interfacing semiconductor devices with living tissues.

This will pave the way for implantable biosensors that can evaluate disease indicators or symptoms and regulate drug release to help in disease treatment.

For example, an implanted glucose sensor can be coupled with an insulin release system and help sufferers of diabetes control their sugar levels without the need for insulin injection or pin-prick tests.

While biocompatibility and long-term stability are being addressed, a number of prototypes have begun to emerge for the management of patients having acute diabetes or to treat epilepsy and other debilitating neurological disorders, and to monitor patients suffering from heart disease.

Integration with Monitoring Systems

Virtual Medical World published an article in November 2005 that stated that a research project financed by the Academy of Finland was underway to develop of minute subcutaneous sensors that can be used for active monitoring of the heart or prosthetic joint function even over long time periods.

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[2]Nanotechnology could lead to improved implant devices[online]Mar 22, 2007,[viewed on 20.12.2018] [available from:https://www.nanowerk.com/spotlight/spotid=1652.php]

For instance, a subcutaneous EKG monitor can detect cardiac arrhythmia, and this data can be wirelessly transmitted to the PC or mobile phone of the physician.

Chronic Disease Monitoring

Guidant is a specialist in treating vascular and cardiac disease and has invested in CardioMEMS based on an article published in Virtual Medical Worlds in November, 2005. CardioMEMS develops novel devices based on MEMS technology to help physicians monitor remotely the progress of chronic diseases like heart failure.

The University of Texas received a grant in 2006 to fund the research and development of an implantable intravascular biosensor that will monitor disease and health progression.

The nano pressure sensor can monitor pressure within the cardiovascular system while the data is transmitted to a wristwatch-like data collection device. The data is transmitted by this external device to a central remote monitoring station where it can be seen by health care providers in real time.[3]

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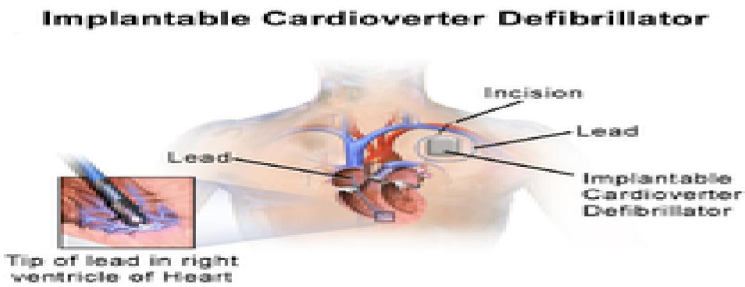
Implantable Cardioverter-Defibrillators

The implantable cardioverter-defibrillator (ICD) has transformed treatment of patients at risk for sudden cardiac death because of ventricular tachyarrhythmias.The Medtronic CareLink Monitor is a small, convenient device that allows patients to gather information by holding an antenna over the implanted cardiac device. The data is automatically downloaded by the

[3]AzoNano, Nanotechnology in Implantable Medical Devices, [online]Mar 6 2013,[viewed on 20.12.2018] [available from:https://www.azonano.com/article.aspx?ArticleID=3207]

[4]https://aetonix.com/wp-content/uploads/2018/08/UPDATED-tablet-with-devices-compressed-1080x675.png

monitor and sent through an internet connection directly to the secure Medtronic CareLink Network. The patient's data is accessed by clinicians by logging onto a website from any internet-connected computer in their home or office or through the laptop while travelling. The ICD systems also include portable computer systems that program the implantable cardioverter defibrillators or pacemakers. This interactive system has an LCD touch screen with a user-friendly interface that helps clinicians retrieve and study patient information during routine follow-up visits and easily makes programming changes to the implanted devices.



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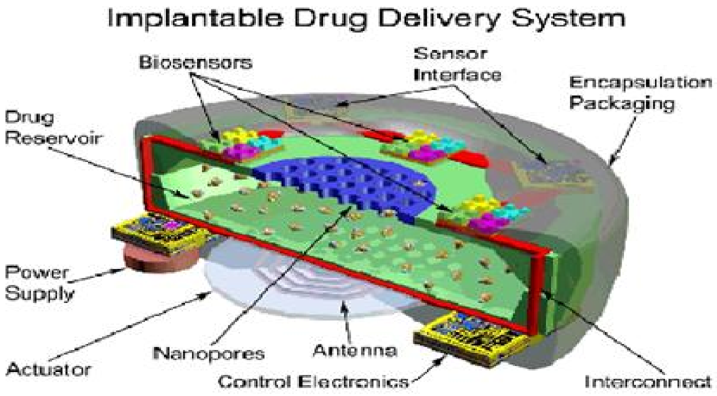
Implantable Drug Delivery Systems

More and more advances in modern medicine are relying on electronic devices implanted inside the patient's body, to minimize the need for regular examinations, surgery, or in-patient time. Nanotechnology allows us to create materials and coatings to construct these devices that are fully biocompatible, so that they integrate seamlessly with the body's systems. Implantable drug delivery systems can deliver small amounts of drugs on a regular basis, so that the patient does not need to be injected. Implantable drug delivery systems give a more consistent drug level in the blood compared to injections, which often makes the treatment more effective and reduces side effects.By using active monitoring capabilities built into the device, the dosage can be adjusted to suit changes in physical activity, temperature changes

[5]https://upload.wikimedia.org/wikipedia/commons/thumb/d/d1/Blausen_0543_ImplantableCardioverterDefibrillator_InsideLeads.png/220px-Blausen_0543_ImplantableCardioverterDefibrillator_InsideLeads.png

and other variables.



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What is the future of the Nanomaterials?

For instance, with their large surface area, reactivity and electrical charge, nanomaterials create the conditions for what is described as "particle aggregation" due to physical forces and "particle agglomoration" due to chemical forces, so that individual nanoparticles come together to form larger ones. This may lead not only to dramatically larger particles, for instance in the gut and inside cells, but could also result in disaggregation of clumps of nanoparticles, which could radically alter their physicochemical properties and chemical reactivity.

It would appear, therefore, whether actual or perceived, the potential risk that nanotechnology poses to human health must be investigated, and be seen to be investigated. Most nanomaterials, as the NCI suggests, will likely prove to be harmless.

But when a technology advances rapidly, knowledge and communication about its safety needs to keep pace in order for it to benefit, especially if it is also to secure public confidence.[7]

[6]https://ai2-s2-public.s3.amazonaws.com/figures/2017-08-08/47781f62275c45df25f149634c837403b60f698d/2-Figure1-1.png

[7]Paddock, C., Nanotechnology In Medicine: Huge Potential, But What Are The Risks? [online] Friday 4 May 2012,[viewed on 20.12.2018] [available from:https://www.medicalnewstoday.com/articles/244972.php]

Bibliography

1. AzoNano, Nanotechnology in Implantable Medical Devices, [online] Mar 6 2013,[viewed on 20.12.2018] [available from:https://www.azonano.com/article.aspx?ArticleID=3207]

2. Nanotechnology could lead to improved implant devices [online] Mar 22, 2007,[viewed on 20.12.2018] [available from:https://www.nanowerk.com/spotlight/spotid=1652.php]

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6. https://ai2-s2-public.s3.amazonaws.com/figures/2017-08-08/47781f62275c45df25f149634c837403b60f698d/2-Figure1-1.png