Original Article

Current status of nanomedicine and nanosurgery

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Abstract

Nanotechnology is a multidisciplinary field that covers a vast and diverse array of devices derived from physics, biology, engineering, and chemistry. Applications of nanotechnology to medicine and physiology imply materials and devices designed to interact with the body at subcellular (i.e., molecular) scales with a high degree of specificity. There is considerable useful information about nanotechnology available and already in use. However, at present, it is very incomplete and scattered. We realized many doctors are unaware of nanotechnology used during surgery and its future prospects in patients. Though most medical products that use nanotechnology are still in the research and development stage, there are a few which are commercially available.

Nanotechnology has grown by leaps and bounds over the last few years; applications of this technology in the field of medicine and surgery have been an important spin-off. Many biological structures are at nanometer scale used by surgeons in orthopedic, dental, and neurosurgeries.

This article starts with the basics of the nanotechnology and how it is utilized through most medical products. This important article, which is felt to offer high educational value for the doctors, have been selected from an extensive search on the internet, and elaborately discussed. In this review, the scientific and technical aspects of nanotechnology are introduced, and some of its potential clinical applications are discussed.

**Key words:** Nanomedicine, nanosurgery, nanotechnology, smart sensors (Source: MeSH, NLM)

INTRODUCTION

The prefix nano derives from the Greek word for “dwarf.” Nano science refers to the science and discipline, and nanotechnology refers to the applied part of it including the engineering to control, manipulate, and structure the matter at an imaginably smaller scale: nano scale. This scale is also referred to as “atomic” or “molecular” scale that is 100 nanometers or smaller. One nanometer (nm) equals to one-billionth of a meter, or about the width of 6 carbon atoms or 10 water molecules. A human hair is approximately 80,000 nm wide, and a red blood cell is approximately 7000 nm wide. Atoms are smaller than 1 nm, whereas many molecules including some proteins range between 1 nm and larger.[¹] This capability also simultaneously gives us the ability to build materials and devices or shapes and products on that scale. Because of the brevity in operation, smarter and lighter products can be made from the molecules of the same matter with every atom in its specified place through “positioned assembly” or “self assembly.”
displays unimaginably different qualities and different products when manipulated and structured at nano scale. This is what the future unleashed by nanotechnology revolution is.

Mankind has seen several technological revolutions in the past, i.e., industrial, agricultural, medical, and infotech in the course of last two centuries. But through each of these, we have been able to exploit only a small fraction of the total possibilities. We have still been dealing with the matter at a bigger scale. The building blocks, our engineering skills, and products were bigger than the nano size, and hence had limitations in manipulation. It is this arrangement of atoms which defines the properties of matter. With its capacity to manipulate the smallest possible component of the matter, the nano technology has the potential to bring that cycle of technological revolution to completion, i.e. dealing with the matter atom by atom, molecule by molecule. It is this capacity of mankind to deal with matter at a molecular level that will give the mankind a historical new ability to shape, process, and create things which have never been thought of.\[2\]

Nanotechnology has grown by leaps and bounds over the last few years; applications of this technology in the field of medicine have been important and used in different fields of surgery. Many biological structures are at nanometer scale. Applications of nanotechnology for the treatment, diagnosis, monitoring, and control of biological systems have recently been referred to as “Nanomedicine” by the National institute of health (NIH), United States of America.

Nanostructures display unique mechanical, electrical, chemical, and optical properties. Understanding and controlling such properties is challenging, but harnessing them will provide exciting new opportunities for research, diagnosis and therapy of heart, lungs, blood, nervous, and sleep (HLBS) disorders. Nanotechnology will offer the tools to explore the frontiers of medical science at a cellular level. It can provide novel techniques in the treatment of a multitude of diseases including cardiovascular disorders. Richard Feynman, winner of the Nobel Prize in Physics, was a pioneer in area of nanotechnology. In his famous 1959 speech “There is plenty of room at the bottom,” he emphasized the role of nanotechnology in cardiac sciences and envisioned the potential applications of nanotechnology in cardiovascular medicine.\[3\]

Nanotechnology is an area where significant global investment is being made and current potential of what could be achieved using nanotechnology is practically limitless. As techniques for imaging and manipulating matter on the nanoscale improve, more uses for the technology are conceived. Though most medical products that use nanotechnology are still in the research and development stage, there are a few which are commercially available including:

(a) Nanosilver-coated dressings. Silver has anti-infective properties, and nanosized particles of it are proving to be more effective than other forms.
(b) Implants with a 30 nm thick coating of titanium, which gives strength and better biocompatibility to the implant.
(c) Bis-GMA cement and calcium phosphate cement (CPC).
(d) Smart coronary catheter – Verimetra.

In the next decade, the number of such products available is expected to rapidly increase.

**Impact of nanotechnology on surgery**

Nanotechnology has considerable potential in the field of surgery that anesthesiologists should be aware of, though it has yet to be fully realized. While there are many products and techniques in various stages of development, few have yet to make it onto the general market. With surgical procedures becoming progressively less invasive, nanotechnology could have a particularly large impact in the area, whether through totally non-invasive procedures performed from outside the body or the development of nanoscale tools for surgery. For example, the Danish research group Nanohand has developed “nanotweezers,” which can be used for both imaging and manipulation of nano-sized objects. As the technology to view things on a nanoscale improved, outcome of various procedures and surgeries is also improved.\[4\]

The use of anti-infective material such as nanosilver could prove very beneficial, especially given the increasingly prevalent problem of hospital-acquired infections. Nanosilver does not appear to be toxic and bacteria are not known to become resistant against it.\[5\]

**SMART SENSORS**

“Smart” instruments have sensors embedded in them, which provides the anesthesiologists and surgeons with data on internal conditions, as they are performing venous approach to vena cava, right atrial, right ventricle, and pulmonary artery in adults. The catheter position can be visualized and the sensor tracks blood flow changes on both sides of the heart valve to test effectiveness. In pre-natal cardiac surgery through the abdominal wall and uterus of pregnant bovine and into fetal heart.\[6\]

**Nanostructuring/Nanocoating**

Biomimicry or biomimetics is the process of utilizing the way nature successfully produces something to create a manmade material. For example, nanopatterned polymer scaffolds, mimicking the natural way minerals are arranged and being used to make teeth and bone implants.\[7\] Nanopatterning involves depositing molecules on a surface. Various techniques can be used, e.g., nanolithography where a beam can be used to deposit
ions, or microcontact printing where “ink” is transferred onto a surface using a mould to alter the scaffold surface. Nanopatterning can also be used to place calls in particular locations on the scaffold. In doing so, this could create channels to help nutrient exchange within the new tissues. One of the main properties required of a scaffold is a large surface area. By altering the scaffold surface on a nanoscale level (i.e. by making nanoscale grooves), the surface area can be vastly increased. Cell adhesion is then increased, leading to a greater amount of growth. Similarly, cell attachment is important in order to create a better bond between an implant and the surrounding tissue. The direction of cell growth can also be affected by nanostructuring, which can aid cell migration. Hydroxyapatite (HA) is used as a scaffold material, but can also be utilized as a thin coating on metal alloy implants to mimic natural tissue and promote bonding with the surrounding tissue. Nanostructured HA has been found to give better results than standard HA coating.

**Titanized synthetics**

German company GFEMedizintechnik GmbH, using nanotechnology, has developed synthetic materials with a titanium coating for implants. While titanium has excellent biocompatibility and is often used for orthopedic implants, its use was otherwise limited by its rigidity. The first product to be made of titanized synthetics was a mesh implant for use in hernia surgery, called TiMESH. Use of TiMESH reduces scarring and post-operative pain, in comparison with regular plastic meshes, due to the biocompatibility of titanium.

**Nanoneurosurgery on a chip**

Miniaturization has been the buzzword that brought about a revolution in science and technology and as a consequence in the way we live. By shrinking into tiny little chips, whole rooms full of electrical devices, miniaturization has for example, resized powerful computers into palmtops. Recently, there has even been talk about miniaturizing laboratories into tiny chips, which scientists lovingly refer to as the lab-on-a-chip. Now, the group led by Adela Ben-Yakar at the University of Texas at Austin (USA), along with researches from University of Michigan (USA) and University of Queensland (Australia), have shown that an entire surgery room, except the surgeons, can be put inside a chip a few tens of micrometers in dimension and it can be put inside a chip a few tens of micrometers in dimension and it can successfully perform neurosurgery.

**Surgical nanorobotics**

Nano-robots that can function as tiny surgeons remain the realm of science fiction. There is research being conducted into various types of computer and robot assisted surgery and virtual reality interfaces. Surgical nano robots could be introduced into the body through the vascular system or at the ends of catheters into various vessels and other cavities in the body. A surgical nanorobot, programmed or guided by a human surgeon, could act as a semi-autonomous on site surgeon inside the body. Such a device could perform various functions such as searching for pathology and then diagnosing and correcting lesion by nanomanipulation, coordinated by an onboard computer while maintaining contact with the supervising surgeon via coded ultrasound signals. The earliest forms of cellular nanosurgery are already being explored today. For example, a rapidly vibrating (100 Hz) micropipette with a <1-mm tip diameter has been used to completely cut dendrites from single neurons without damaging cell viability. Axotomy of roundworm neurons was performed by femtosecond laser surgery, after which the axons functionally regenerated. A femtolaser acts like a pair of “nano-scissors” by vaporizing tissue locally while leaving adjacent tissue unharmed.

Future nanorobots equipped with operating instruments and mobility will be able to perform precise and refined intracellular surgeries which are beyond the capabilities of direct manipulation by the human hand. Biocompatible surgical nanorobots that can find and eliminate isolated cancerous cells, remove micro vascular obstructions and recondition vascular endothelial cells, perform “noninvasive” tissue and organ transplants, conduct molecular repairs on traumatized extracellular and intracellular structures and even exchange new whole chromosomes for old ones inside individual living cells may be produced in the future.

The greatest power of nanotechnology will emerge perhaps in the 2020s, when one can design and construct complete artificial nanorobots using rigid diamondoid nanometer scale parts like molecular gears and bearings. These nanorobots will possess full panoply of autonomous subsystems including onboard sensors, motors, manipulators, power supplies, and molecular computers. But getting all these nanoscale components to spontaneously self assemble in the right sequence will prove increasingly difficult as machine structures become more complex.

**Nanotechnology in cardiac therapy**

Cardiac diseases are the major cause of mortality, and morbidity in human beings. Ever more people are having various cardiac problems including arrhythmias, ischemic heart disease, myocardial infarction, atherosclerosis, and restenosis. Oral and systemic administration of drugs does not provide appropriate therapeutic drug levels in the target arteries for sufficient periods of time. Even though, biomedical engineers have already succeeded in developing microscale instruments to open blocked arteries and to treat other cardiovascular diseases. But these tools are bulky, infection prone, and subject to other disorders. Currently, nanotechnology offers a broad platform in the field of cardiovascular science by...
offering tools to explore the frontiers of cardiac science at the cellular level. Nanotechnology-based tools can be effectively used to treat the cardiovascular diseases. These tools can be used in the areas of diagnosis, imaging, and tissue engineering. Miniaturized nanoscale sensors like QDs, nanocrystals, and nanobarcodes can sense and monitor biological signals such as the release of proteins or antibodies in response to cardiac or inflammatory events. Nanotechnology can also help in revealing the mechanisms involved in various cardiac diseases. It also helps in designing atomic-scale machines by imitating or incorporating biological systems at the molecular level. The use of these newly designed nanomachines can have a paradigm-shifting impact in the treatment of the dreaded cardiovascular diseases. These machines have three key elements meant for sensing, decision making, and carrying out the intended purpose. For instance, Tenecteplase (TNK-rt-PA) used in cardiac therapy, is a tissue plasminogen activator (tPA) produced by recombinant DNA technology using an established mammalian cell line (Chinese hamster ovary cells). It differs from rt-PA by three sets of substitution mutations that decrease its plasma clearance rate and is used to dissolve blood clots that have formed in the blood vessels of the heart that seriously lessen the flow of blood in the heart. Abciximab, a chimeric mouse-human monoclonal antibody used to lessen the chance of heart attack in people who need percutaneous coronary intervention (a procedure to open blocked arteries of the heart), can be considered as an example of a simple nanomachine. It has sensors that bind to the GP2b3a receptor and also has an effector that inhibits the receptor through steric hindrance. Thus, by inhibiting the ability of the GP2b3a receptor to bind fibrinogen, abciximab changes platelet behavior, impeding platelet aggregation and activation.

RESTENOSIS

The obstruction of an artery after interventional procedures such as balloon angioplasty, remains a major problem, in that about 50% of patients develop reocclusion, and with 20% requiring additional intervention. Although different therapeutic strategies have been investigated for the inhibition of restenosis, the main drug therapy approach is targeted toward inhibiting the proliferation and migration of smooth muscle cells.

Systemic administration of therapeutic agents has been ineffective in preventing restenosis. The main reason for the failure of drugs in clinical trials is the inefficacy of such an approach in providing therapeutic drug levels in the target tissue for a sustained period of time. Therefore, researchers have a great hope that nanotechnology-based localized drug therapy using sustained-release drug delivery systems could be more effective, because it can provide higher and prolonged drug levels in the target tissues without causing systemic toxicity. Nanotechnology could also have an impact in the diagnosis and treatment of unstable plaques and in the management of other cardiovascular problems like calcification of valves. Thus, nanotechnology could be an effective treatment modality to achieve localized and sustained arterial and cardiac drug therapy for the prevention of cardiovascular diseases.

**Nanotechnology in drug delivery**

From nanotechnology, there is only one step to nanomedicine, which may be defined as the monitoring, repair, construction, and control of human biological systems at the molecular level, using engineered nanodevices and nanostructures. It can also be regarded as another implementation of nanotechnology in the field of medical sciences and diagnostics. One of the most important issues is the proper distribution of drugs and other therapeutic agents within the patient’s body.

During the past two decades, however, researchers involved in the development of pharmaceuticals have understood that drug delivery is a fundamental part of drug development, and a wide range of drug delivery systems has thus been designed. Ideally, all these systems would improve the stability, absorption, and therapeutic concentration of the drug within the target tissue, as well as permit reproducible and long-term release of the drug at the target site. In addition to reducing the frequency of drug administration and thus improving patient comfort, novel drug delivery systems would offer protection and improve the pharmacokinetics of easily degradable peptides and proteins, which often have short half-lives in vivo. For the pharmaceutical industry the field of drug delivery represents a strategic tool for expanding drug markets, because new delivery technologies could repackage classical drugs, offering a competitive edge after the expiry of patents and avoiding competition from generics. Demonstrating this advantage clearly, 13% of the current global pharmaceutical market is related to the sale of products that include a drug delivery system. The final aim of pharmaceutical research is the delivery of any drug at the right time in a safe and reproducible manner to a specific target at the required level. For many drugs, however, these ideal requirements constitute hype rather than hope. For example, although the oral route is one of the preferred methods of drug delivery, because it is non-invasive, adequate peptide, or protein drug delivery has not yet been attained.
all macromolecules, thus reducing their bioavailability. As a result, millions of diabetics worldwide have to take self administered insulin injections daily, provoking a high percentage of negligence in this treatment.

Applications of nanotechnologies in medicine are especially promising, and areas such as disease diagnosis, drug delivery targeted at specific sites in the body, and molecular imaging are being intensively investigated and some products undergoing clinical trials.[35-36] Nanotechnology is relatively new, and although the full scope of contributions of these technological advances in the field of human health care remains unexplored, recent advances suggest that nanotechnology will have a profound impact on disease prevention, diagnosis, and treatment.[37,38] The current generation of drugs is based chiefly on small molecules with a mass of 1000 Da or less that circulate systemically. Common deleterious consequences of systemic biodistribution include toxicity to nontarget tissues, difficulty in maintaining drug concentrations within therapeutic windows, and metabolism and excretion of drugs—all of which can reduce efficacy.[39] Drug solubility and cell permeability issues are also common with small molecules and biologically active compounds. Nanotechnology-based delivery systems could mitigate these problems by combining tissue- or organ-specific targeting with therapeutic action. Multifunctional nanodelivery systems could also combine targeting, diagnostic, and therapeutic actions.[39,40] In the near term, the most important clinical applications of nanotechnology are likely to be in pharmaceutical development. There are already an astonishing number of emerging applications.[41] These applications either take advantage of the unique properties of nanoparticles as drugs or components of drugs per se or are designed for new approaches to controlled release, drug targeting, and salvage of drugs with low bioavailability. For example, nanoscale polymer capsules can be designed to break down and release drugs at controlled rates and to allow differential release in certain environments, such as an acid milieu, to promote uptake in tumors versus normal tissues. Substantial research is now designed for creating novel polymers and exploring specific drug-polymer combinations.[42] Drug bioavailability is a related problem to controlled release, drug targeting, and also prolong the duration of exposure of a drug by increasing retention of the formulation through bioadhesion.[43]

CONCLUSIONS

The multidisciplinary field of nanotechnology is bringing the science of the almost incomprehensibly small device closer and closer to reality. The effects of these developments will at some point be so vast that they will probably affect virtually all fields of science and technology. As such, nanotechnology holds the promise of delivering the greatest technological breakthroughs in history. Over the next couple of years, it is widely anticipated that nanotechnology will continue to evolve and expand in many areas of life and science, and the achievements of nanotechnology will be applied in medical sciences, including diagnostics, drug delivery systems, and patient treatment so anaesthesiologists should be aware of these new changes.

REFERENCES

1. Whitesides GM. The drightT size in nanobiotechnology. Nat Biotechnol 2003;21:161-5.
2. Ernest H, Rahul, S. Impact of nanotechnology on biomedical sciences. Review of current concepts on convergence of nanotechnology with biology. Online J Nanotech 2005;10:224-6.
3. Feynman RP. There’s plenty of room at the bottom. Engl Sci 1960;23:22-36.
4. Kohil V, Robles V, Cancela ML, Acker JP, Waskiewicz AJ, Elizabzi AY. An alternative method for delivering exogenous material into developing zebrafish embryos. Biotechnol Bioeng 2007;98:1230-41.
5. Jain P, Jain S, Yadav R, Singh AJ, Butola V. Nanotechnology: Future prospects in veterinary surgery. J RVC 2013;51:64-81.
6. Scott NR. Nanotechnology and animal health. Rev Sci Tech 2005;24:425-32.
7. Saito K, M. Biomimetics: Materials fabrication through biology. Proc Natl Acad Sci U S A 1999;25:14183-5.
8. Malchesky PS. Artificial organs and vanishing boundaries. Artif Organs 2001;25:75-88.
9. Lima RS, Dimitrievska SM, Bureau N, Marple BR, Petit A, Antoniou J, et al. HVOF-Sprayed nano TiO2-HA coatings exhibiting enhanced biocompatibility. J Therm Spray Technol 2009;19:336-43.
10. Chun AL, Moralez JG, Fenniri H, Webster TJ. Helical rosette nanotubes: A more effective orthopedic implant material. Nanotechnology 2004;15:1-6.
11. Sahoo SK. Applications of nanomedicine. Asia Pacific Biotech News 2005;9:1048-50.
12. Yanik MF, Cinar HH, Chisholm AD, Jin Y, Ben-Yakar A. Neurosurgery: Functional regeneration after laser ablation. Nature 2004;422:822-9.
13. Kirson ED, Yaari Y. A novel technique for micro-dissection of neuronal processes. J Neurosci Methods 2000;98:119-22.
14. Freitas RA Jr. Current status of nanomedicine and medical nanorobotics. J Comput Theor Nanosci 2005;2:1-25.
15. Drexler KE. Nanosystems: Molecular machinery, manufacturing and computation. New York: John Wiley and Sons; 1992.
16. Kong DF, Goldschmidt-Clermont PJ. Tiny solutions for giant cardiac problems. Trends Cardiovasc Med 2005;15:207-11.
17. Wickline SA, Neubauer AM, Winter P, Caruthers S, Lanza G. Applications of nanotechnology to atherosclerosis, thrombosis, and vascular biology. Arterioscler Thromb Vasc Biol 2006;26:435-41.
18. Guccione S, Bednarski MD. Vascular-targeted nanoparticles for molecular imaging and therapy. Methods Enzymol 2004;386:219-36.
19. Sahoo SK, Parveen S, Panda J. The present and future of nanotechnology in human health care. Nanomedicine 2007;3:20-31.
20. Brigger I, Dubernet C, Courpere P. Nanoparticles in cancer therapy and diagnosis. Adv Drug Deliv Rev 2002;54:631-51.
21. Popeja JI, Pana RN, Prpic R. Clinical trials in interventional cardiology. Curr Opin Cardiol 1999;14:412-8.
22. Hamon M, Lecluse E, Monassier JG, Grollier G, Potier JC. Pharmacological approaches to the prevention of restenosis after coronary angioplasty. Drugs Aging 1998;13:291-301.
23. Panyam J, Labhasetwar V. Biodegradable nanoparticles for drug and gene delivery to cells and tissue. Adv Drug Deliv Rev 2003;55:329-47.
24. Emerich DF, Thanos CG. Nanotechnology and medicine. Expert Opin Biol Ther 2003;3:655-63.
25. Moghimi SM, Hunter AC, Murray JC. Nanomedicine: Current status and future prospects. FASEB J 2005;19:111-30.
26. Shaffer C. Nanomedicine transforms drug delivery. Drug Discov Today 2005;10:1581-2.
27. Labhasetwar V. Nanotechnology for drug and gene therapy: The importance of understanding molecular mechanisms of delivery. Curr Opin Biotechnol 2005;16:674-80.
28. Kubik T, Bogunia-Kubik K, Sugisaka M. Nanotechnology on duty in medical applications. Curr Pharm Biotechnol 2005;6:17-33.
29. Kayser O, Lemke A, Hernandez-Trejo N. The impact of nanobiotechnology on the development of new drug delivery systems. Curr Pharm Biotechnol 2005;6:3-5.
30. Orive G, Hernandez RM, Rodriguez Gascon A, Dominguez-Gil A, Pedraz JL. Drug delivery in biotechnology: Present and future. Curr Opin Biotechnol 2003;14:659-64.
31. Mazzola L. Commercializing nanotechnology. Nat Biotechnol 2003;21:1137-43.
32. Sahoo SK, Labhasetwar V. Nanotech approaches to drug delivery and imaging. Drug Discov Today 2003;8:112-20.
33. Hamman JH, Enslin GM, Kotze AF. Oral delivery of peptide drugs: Barriers and developments. Bio Drugs 2005;19:165-77.
34. Pawar R, Ben-Ari A, Domb AJ. Protein and peptide parenteral controlled delivery. Expert Opin Biol Ther 2004;4:1203-12.
35. Wilkinson JM. Nanotechnology applications in medicine. Med Device Technol 2003;14:29-31.
36. Li KC, Pandit SD, Guccione S, Guccione S, Bednarski MD. Molecular imaging applications in nanomedicine. Biomed Microdevices 2004;6:113-6.
37. Cheng MM, Cuda G, Bunimovich YL, Gaspari M, Heath JR, Hill HD. Nanotechnologies for biomolecular detection and medical diagnostics. Curr Opin Chem Biol 2006;10:11-9.
38. Jain KK. Nanodiagnostics: Application of nanotechnology in molecular diagnostics. Expert Rev Mol Diagn 2003;3:153-61.
39. Greish K, Fang J, Inutsuka T, Nagamitsu A, Maeda H. Macromolecular therapeutics: Advantages and prospects with special emphasis on solid tumour targeting. Clin Pharmacokinet 2003;42:1089-105.
40. Yokoyama M. Drug targeting with nano-sized carrier systems. J Artif Organs 2005;8:77-84.
41. Ferrari M, Downing G. Medical nanotechnology: Shortening clinical trials and regulatory pathways? Bio Drugs 2005;19:203-10.
42. Mayer C. Nanocapsules as drug delivery systems. Int J Artif Organs 2005;28:1163-71.
43. EI-Shabouri MH. Positively charged nanoparticles for improving the oral bioavailability of cyclosporin-A. Int J Pharm 2002;249:101-8.
44. Hu L, Tang X, Cui F. Solid lipid nanoparticles (SLNs) to improve oral bioavailability of poorly soluble drugs. J Pharm Pharmacol 2004;56:1527-35.
45. Arbos P, Campanero MA, Arangoa MA, Irache JM. Nanoparticles with specific bioadhesive properties to circumvent the pre-systemic degradation of fluorinated pyrimidines. J Control Release 2004;96:55-65.

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