Application of Nanobiotechnology in Medical Practice

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Abstract--- *Nanomedicine is the application to medicine of the nanobiotechnologies. The paper begins with the fundamentals of nanobiotechnology, followed by its uses in molecular diagnostics, nanodiagnostics, and advancements in drug discovery, design and distribution, like nanopharmaceutics. Biological treatments including vaccines, cell therapy, and gene therapy will be improved. Nanobiotechnology provides the basis for the creation of many modern medical and surgical technologies, such as nanorobots. It has applications in nearly every scientific field, where examples of neurological disorders (nanoneurology), cancer (nanooncology), cardiovascular disorders (nanocardiology), joint and bone diseases (nanoorthopedics), and infectious diseases are identified. Safety issues are also discussed about the in vivo use of nanomaterials. Nanobiotechnology will promote the integration of the diagnostics with therapy and facilitate the development of the personalized medicine, i.e. prescribing specific therapies that are best suited to an individual. Many of the changes have already begun and a significant effect in the practice of medicine will be experienced within a decade.*

Keywords--- *Nanomedicine, Nanoparticles, Nanobiotechnology, Nanodiagnostics, Nanosurgery, Nanooncology, Nanopharmaceuticals.*

I. INTRODUCTION

Nanotechnology (Greek word nano means "dwarf") is the development and use of devices, materials, and processes on a scale of nanometer-length, i.e. at level of molecules, atoms, and supramolecular structures, via the control of matter[1]. It is the common term for the design and use of the functional structures measured in nanometer scale. Given the inherent practical nanoscale elements in living cells, the use of nanotechnology in biotechnology became unavoidable, giving rise to the word nanobiotechnology. As shown in table 1, nanomedicine is the application of the nanobiotechnologies to medicine[2]. Nanobiotechnology is already beginning to affect the healthcare sector. Over the past 50 years, early nanotechnology advances have grown into various inventions, and a number of nanotechnology-based drugs are on the market. The word "nanobiopharmaceuticals" will include various uses in the pharmaceutical industry such as drug discovery and drug delivery[3]. The microscope technology innovated medicine by allowing microorganism identification and the study of disease histopathology. Microsurgery was a substantial refinement of the crude macrosurgery and opened the possibilities to procedures that either not been done before or had high mortality and morbidity. Nanotechnologies will have significant effects on medicine and surgery, by opening up the world

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beyond the microscale[1], [3]. That's because on a nanoscale, metabolic and pathological mechanisms exist at cell level.

Nanomedicine may also be considered a modernization in molecular medicine which integrates developments in proteomics and genomics to help develop personalized medicine. Nanobiotechnology's relationship to nanomedicine and other developments is graphically represented in Figure 1[2]. This diagram drawing illustrates how nanobiotechnology can affect both directly on the advancement of nanomedicine and by developing other fields such as nanopharmaceutical delivery and molecular diagnostics. The same innovations make it easier to produce personalized medicine alongside nanomedicine[1]–[3]. Essential molecular diagnostic and the drug delivery applications will be listed briefly before exploring the role of nanobiotechnology in different diseases. Table 1 shows nanomedicine in 21st century.

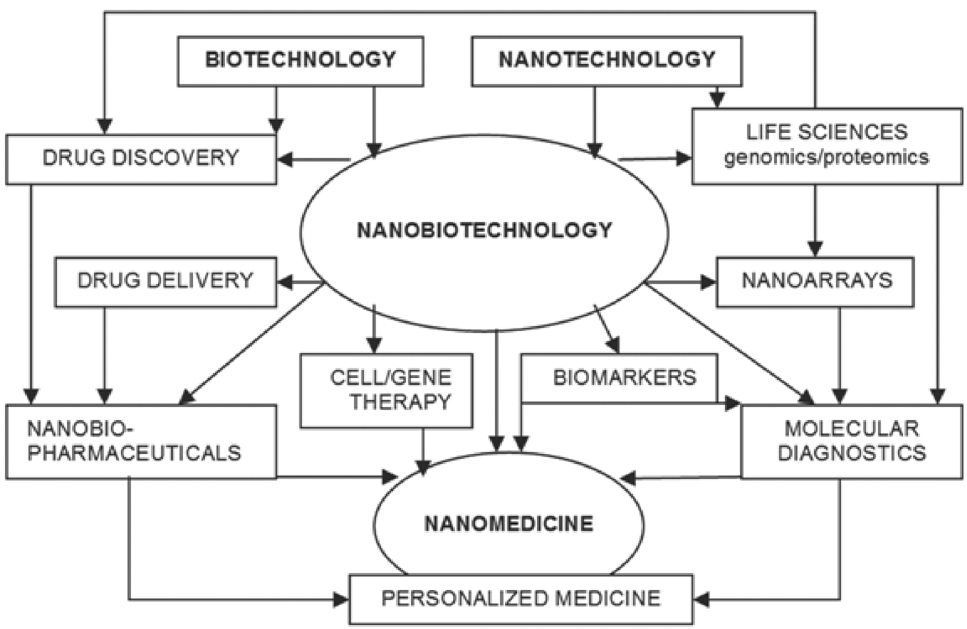

Figure 1: Relationship of nanobiotechnology to nanomedicine and other biotechnologies

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Table 1: Nanomedicine in the 21st century

Nanodiagnostics	• Molecular diagnostics • Imaging with nanoparticle contrast materials • Nanobiosensors
Nanopharmaceuticals	• Nanotechnology-based drugs • Targeted drug delivery to site of action • Drug delivery from implanted nanopumps and nanocoated stents
Reconstructive surgery	• Tissue engineering with nanobiotechnology scaffolds • Implantation of rejection-resistant artificial tissues and organs
Nanorobotics	• Vascular surgery by nanorobots introduced into the vascular system • Remote controlled nanorobots for detection and destruction of cancer
Nanosurgery	• Nanosensors implanted in catheters to provide real-time data during surgery • Nanolaser surgery

I.I Nanotechnology-Based I Drug Delivery

Drug delivery is an essential consideration in the therapeutics. One of the purposes why some presently available medicines lack the efficacy is poor delivery to the required site of action. One of the main problems of medication development is solubility, which is an important factor for the effectiveness of medications, regardless of the path of administration[4]. It is also a great challenge for pharmaceutical companies to develop innovative pharmaceutical products, since almost half of new chemically-based medicines are insoluble or partially water-soluble. New technologies are implemented to develop and produce novel formulations. A detailed account of the drug delivery systems is given elsewhere. The current focus lies on delivering targeted drugs. Nanobiotechnology enhances the drug delivery through the following approaches[5]:

- Reduces the particle size to nanometer size range to increase the surface area, thus increasing dissolution rate.
- Develop new formulations of nanoparticles with improved shelf-life and stability.
- Design of formulations of nanoparticles to enhance the absorption of insoluble substances and macromolecules allows increased bioavailability and release levels, possibly reducing the amount of dosage needed and increasing safety through minimizing side effects[6].
- Formulations of nanoparticles which can provide sustained-release profiles up to 24 h may improve patient compliance with the drug regimens.
- The nanoparticles may be combined with the targeted drug delivery ligands.
- The nanotechnology is especially useful for biological therapy delivery.

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I.II Role of Nanobiotechnology in Biological I Therapies

Biological treatments reflect the contribution of molecular biology to treatment. Biological therapies broadly cover cell therapy, vaccines, gene therapy, antisense therapy and RNA interference. Some of these include the use of proteins and nucleic acids while others involve genetic manipulation. By using nanobiotechnology, biological therapies, especially their delivery, may be refined[7]. Uses of biological therapies based on the nanobiotechnology are briefly introduced in this paper and will be described in numerous therapeutic areas later.

I.II.I Vaccination

DNA vaccines have ability as new vaccines for essential pathogens such as malaria, hepatitis C, HIV, and tuberculosis, but methods are not satisfactory for their delivery. The nanoparticles are effective as DNA vaccine delivery systems. Nanoemulsions or aerosol vaccines with nanoparticles are also under development[5]. Immune system components identify particulate matter more easily than soluble proteins. Because of their nanoparticulate nature, Proteosomes TM (GlaxoSmithKline) act as vaccine delivery vehicles, containing vesicles and vesicle clusters similar to the size of small viruses[8]. Nanoencapsulating potent viral antigens for controlled release in biodegradable polymer nanospheres may induce the development of the protective and neutralizing antibodies. This sustained release vaccine delivery system has the ability to deliver various vaccine forms and combinations include whole virus inactivated cells, DNA plasmids and/or antigens[6].

I.II.II Gene Therapy

Gene therapy can be characterized simply as transmitting specified genetic material to a patient's specific target cells for the ultimate purpose of protecting or changing a specific disease state. Vectors are generally viral but also use numerous non-viral techniques. DNA and Genes are being now introduced without the utilization of vectors and different techniques are being used to alter in vivo gene function without the gene transfer[8]. For non-viral gene delivery a variety of nanoparticles and other nanostructures may be used. These include gelatin nanoparticles, nanoliposomes, calcium phosphate nanoparticles, dendrimers and other compounds. The unique characteristics needed for smart distribution as well as for the production of genetic material in mammalian cells are biocompatible, inorganic nanoparticles of carbonate apatite[7].

I.III Nanodevices for Medicine and Surgery

In addition to the laboratory tests, many instruments are being developed for the clinical diagnostics focused on nanobiotechnology. Nanotechnology-based biosensor systems may identify emerging diseases in the body at a potentially curable level. That is extremely important in illness and cancer treatment. Nanosensors will allow for analysis of body functions and the patient reactions without the need for bulky laboratory equipment. Some instances are nanoradiotransmitter small enough for the measurement and recording of heart sounds in a cell and in nanoacoustic devices[9].

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I.III.I Nanodiagnostic Devices

An X-ray system is based on the carbon nanotubes which emit a scanning X-ray beam consisting of several smaller beams whereas remaining stationary as well. As a result, the computer may create images of the objects without the mechanical motion from various angles that is a distinct advantage for any system since it improves image quality, decreases device size and needs less maintenance[5]. New technology will allow for the development of smaller and faster X-ray imaging devices for medical tomography, like CT scanners, that will generate higher resolution images.

Early diagnosis will include the use of nanotechnology to enhance the image quality generated by one of the most popular diagnostic tools used in the offices of doctors–the ultrasound machine. In a test, a high-resolution ultrasonic imaging system injected mice intravenously with the silica nanosphere (100nm) suspensions spread for agarose and imaged[6]. Upon particle injection, B-mode images of the liver were obtained at various points of time. Ultrasonic reflections in the agarose gels were detected from suspensions of nanoparticles. For particle size and concentration the picture visibility, i.e. mean gray scale point, improved. Such results showed that use of solid nanoparticles as contrast-enhancing agents for the ultrasonic imaging is feasible. The long-term aim is to utilize this technology to enhance the ability to recognize tumors and other illnesses very early on[4], [7], [8]. The ultimate goal is to detect illness at the very early stage, at the cellular level.

I.III.II Nanodevices for Drug Delivery

Many drug delivery systems are inserted for therapeutic drugs release into the body. Nanotechnology may improve the lining of those devices. The creation of microcapsules by depositing coatings on the particle surface would allow the regulation of drug release kinetics by: (a) diffusion of the drug via a polymeric coating, (b) degradation of biodegradable polymer coating on drug particles, releasing the core drug substance[5], [6]. DNA-containing polymeric nanotraps or nanocontainers can maintain an encapsulated enzyme's maximum action against aggressive external conditions, and the release can be regulated as necessary. Due to their metallic existence MRI I can easily track the position of cubic containers in the body. Such medical tubes can be immediately inserted at the site of an injury or a disease[2]–[4]. Finally, the microcontainers may include electronic components which would require the cubes to serve as biosensors in body or release medicine on demand in response to radio frequency signal remotely controlled.

I.IV Nanomedicine

Nanobiotechnology has applications in nearly every medical and surgery branch. Even though nanomaterials were available for a number of years and many structures in molecular biology have been assessed on a nanoscale, in recent years, further research on systematic application of this knowledge to life sciences and especially to healthcare is being vigorously pursued. This is parallel to other biotechnology advances[10]. New technologies historically are gradually incorporated into the mainstream medical practice. The decision to use a new technology relies on the physicians taking care of their patients' clinical judgment. Many of the new technologies are being implemented in difficult environments where either there are no suitable treatments available, or strategies based on the nanobiotechnology were shown to be more successful than traditional approaches[11]. Cancer is one region where the application of nanobiotechnology has made rapid advances.

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I.IV.I Nanooncology

Nanotechnology use in cancer may be termed as nanooncology. This includes diagnostics as well as therapeutics. Two nanotechnology-based products have already been licensed for cancer treatment-Abraxane (paclitaxel in the nanoparticle formulation) and Doxil (doxorubicin liposome preparation). Nanoparticles can specifically transmit chemotherapy drugs to tumor cells and afterwards send off a signal after the cells have been killed[12]. Effective conversion of highly absorbed light to heat energy by plasmonic gold nanoparticles and their fast bioconjugation recommend their use as active photothermal agents in targeting molecular cancer cells. Two dental squamous carcinoma cell line and one benign epithelial cell line was incubated with an anti-epithelial growth factor receptor (EGFR), antibody conjugated with the gold nanoparticles and then exposed to a continuous transparent argon ion laser at 515nm[11]. Upon incubation with anti-EGFR antibody conjugated silver nanoparticles, malignant cells needed less than half the laser energy to be killed than the benign cells. Any photothermal death was found for all cell types in the absence of nanoparticles, at several times the energy required to kill the malignant cells bound with anti-Au/EGFR conjugates.

I.IV.II Nanoneurology

Nanobiotechnology has an impact on enhancing the understanding of the nervous system of human and developing new, surgical and medical treatments for nervous system disorders. Scientists have successfully observed the activity of individual neurons lying adjacent to the blood vessels operating with platinum nanowires and using blood vessels as conduits to direct the wires[12]. Using non-intrusive, biodegradable and biocompatible nanoprobes enhances the understanding of the human brain at the level of interaction between neurons. The distribution of medicines to the central nervous system is a problem, and other nanobiotechnology-based approaches are addressed elsewhere[8], [11]. Most of these address the breaking of the blood-brain barrier that is a major hurdle in the distribution of drugs to the brain.

Nanobiotechnology can make the neuroprotection simpler. The use of carboxyfullerenes has shown effective neuroprotection against apoptotic, excitotoxic and metabolic insults in cortical cell cultures. Ongoing trials of neurodegenerative disorders in animal models indicate that these new antioxidants are possible neuroprotective agents[11], [12]. Nanobiotechnology was used to facilitate neuroregeneration. Thin films of the carbon nanotubes deposited on the transparent plastic may also act as a surface on which cells can expand and these nanotube films may theoretically serve as electrical interface between the living tissue and prosthetic equipment or biomedical instruments. If nanotubes turn out to be sufficiently reactive to monitor ongoing electrical activity in cells, they may form the basis of a device capable of both detecting and transmitting feedback to cells for prosthetic function, such as a person's control of an artificial arm at will[13].

I.IV.III Nanocardiology

In cardiovascular disorders, perfluorocarbon nanoparticles offer an opportunity to combine the molecular imaging and the local drug delivery. The usefulness of the targeted perfluorocarbon nanoparticles has been shown for a wide range of applications in the animal models including diagnosis of the ruptured plaque, quantification and antiangiogenic treatment of the atherosclerotic plaque, and delivery and localization of antirestenotic therapy after angioplasty[14].

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Nanoscale particles could be synthetically engineered to theoretically interact with the accumulation of lipoprotein matrix and the processing of lipoprotein in cells-processes that are central to atherosclerosis. Due to elevated levels of lowdensity lipoproteins, nanoengineered molecules called nanolipoblockers could be used to combat the atherosclerotic plaques. An experimental study in rats utilizing the injectable self-assembling peptide nanofiber attached to the platelet-derived growth factor demonstrated continuous myocardial distribution resulting in reduced cardiomyocyte death and maintained systolic activity following myocardial infarction[11], [12], [14]. This approach to nanobiotechnology has the potential to improve the efficacy of myocardial infarction cell therapy currently undergoing clinical trials.

II. CONCLUSION

Nanobiotechnology technologies are starting to demonstrate an effect on the conventional medicine practice. Nanotechnology should allow more efficient medications to be formulated and administered with a controlled delivery that improves the effectiveness and reduces toxicity. Although substantial progress has been made in understanding the molecular components of mitochondrial system, no effective treatment has been created for diseases caused by mitochondrial dysfunction. Nanotechnology developments are providing new methods with the ability to diagnose and treat mitochondrial disorders. Nanotechnology provides a framework for computer-controlled molecular tools, which are much smaller than human cell and are built with the precision and accuracy of the drug molecule. These devices are being used for molecular and cellular level therapies in a precise and controlled manner. They may eliminate circulatory system obstacles, kill cancer cells or take over the subcellular organelles function. Although many nanomedicine-related nanobiotechnology applications are being developed or are nearing marketing, they experience the normal regulatory approval obstacles experienced in the implementation of other innovative products and technologies. Considering the success and growing interest in this area over the past decade, more positive developments in the nanomedicine are expected in the next decade.

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