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A Review On: Novel Approaches In Nano Robotics

Sampada Rajendra Gadekar, Dr. Sachin B Somwanshi , Ms Bushra S sayyed

Department of pharmaceutics, Savitribai Phule university, PRES's, college of Pharmacy (for womens), Chincholi, Nashik, Maharashtra, India

Abstract

Nanorobotics is emerging field of a nanotechnology having nanoscale dimensions and is predictable to work at an atomic, molecular and cellular level. Nanorobot skeleton is made up of carbon and its toolkit contains components like medicine cavity containing medicine, microcamera, payload, capacitor and swimming tail. As nanorobots have special sensors i.e. physical or chemical which detect the target molecules in the human body can be used for the diagnosis and treatment of various vital diseases i.e. cancer, diabetes, atherosclerosis, hemophilia, kidney stones, etc. Nanorobots till date are under the line of investigation, but some primary molecular models of these medically programmable machines have been tested. This review on nanorobots presents the various aspects allied i.e. introduction, history, ideal characteristics, Approaches in Nanorobotics, basis for the development, tool kit recognition and retrieval from the body, application considering diagnosis and treatment. The outstanding achievements in nanorobotics have significantly expanded the field of medical robotics and yielded novel insights into the underlying mechanisms guiding life activities, remarkably showing an emerging and promising way for advancing the diagnosis & treatment level in the coming era of personalized precision medicine. In this review, the recent advances in nanorobotics (nanorobots, nanorobotic manipulations) for biomedical applications are summarized from several facets (including molecular machines, nanomotors, DNA nanorobotics, and robotic nanomanipulators), and the future perspectives are also presented.

Keywords nanorobotics, nanotechnology, medicine, cancer, diagnosis.

Introduction

"Nano" is derived from the Greek word which stands for "dwarf". Nanotechnology is the science of manipulating matter, measured in the billionths of meters or manometer, roughly the size of two or three atoms. It is distinguished primarily by the scale at which it acts, one billionth of a meter or one ten thousand the width of human hair. In simple terms, it is engineering at the atomic or molecular scale.[1]

Nanotechnology is an extremely diverse and multidisciplinary field, ranging from novel extensions of conventional physics to completely new approaches based upon molecular self-assembly, to developing new materials and machines with nanoscale dimensions. The growing interest in the future of dental applications of nanotechnology lead to the emergence of nanodentistry which involves the maintenance of oral health by the use of nanomaterials, biotechnology and dental nanorobotics.[2]

According to nanorobotic theory "nanorobots are microscopic in size, it would probably be necessary for very large numbers of them to work together to perform microscopic and macroscopic tasks".[3]

What is Nanorobot?

Nanorobots are theoretical microscopic devices measured on the scale of nanometers (1 nm equals one millionth of 1 mm). When fully realized from the hypothetical stage, they would work at the atomic, molecular and cellular level to perform tasks in both the medical and industrial fields that have heretofore been the stuff of science fiction.[4] Nanomedicine's nanorobots are so tiny that they can easily traverse the human body. Scientists report the exterior of a nanorobot will likely be constructed of carbon atoms in a diamondoid structure because of its inert properties and strength. Supersmooth surfaces will lessen the likelihood of triggering the body's immune system, allowing the nanorobots to go about their business unimpeded [5]. Glucose or natural body sugars and oxygen might be a source for propulsion and the nanorobot will have other biochemical or molecular parts depending on its task. Nanomachines are largely in the research and development phase, but some primitive molecular machines have been tested. An example is a sensor having a switch approximately 1.5 nm across, capable of counting specific molecules in a chemical sample. Another potential application is the detection of toxic chemicals, and the measurement of their concentrations, in the environment.[6]

Characteristic properties of Nanorobots

Nanosclae materials used to diagnose the disease in rapid and sensitively. The nanoparticles also involve in the diagnosis of action of diseased cells. The various chemical reactivity of nanoscale materials greatly different from more macroscopic form, e.g., gold. Vastly increased surface area per unit mass, e.g., upwards of 100 m2 per gram. Quantum size effects result in unique mechanical, electronic, photonic, and magnetic properties of nanoscale materials. New chemical forms of common chemical elements, e.g., fullerenes, nanotubes of carbon, titanium oxide, zinc oxide, and other layered compounds [7].

Medical nanorobots

The research and development of nanorobots with embedded nanobiosensors and actuators is considered a new possibility to provide new medical devices for doctors. As integrated control mechanisms at microscopic environments differ from conventional control techniques, approaches using event-based feed forward control are sought to effectively advance new medical technologies. In the same way the development of bioelectronics in the 1980s has led to new tools for biomedical instrumentation, the manufacturing of nanoelectronics . The use of microdevices in surgery and medical treatments is a reality, which has brought many improvements in clinical procedures in recent years. A first series of nanotechnology prototypes for molecular machines are being investigated in different ways . More complex molecular machines, or nanorobots, having embedded nanoscopic features represent new tools for medical procedures.[8]

Applications of nanorobots in disease diagnosis

Nanorobots are expected to enable new treatments for patients suffering from different diseases, and will result in a remarkable advance in the history of medicine. Studies targeted at building biosensors and nanokinetic devices, required to enable medical nanorobotics operation and locomotion, have also been progressing. The use of nanorobots may advance biomedical intervention with minimally invasive surgeries, and help patients who need constant body functions monitoring, or ever improve treatments efficiency through early diagnosis of possible serious diseases. The nanorobots may be utilized to attach on transmigrating inflammatory cells or white blood cells, thus reaching inflamed tissues faster to assist in their healing process. Nanorobots will be applied in chemotherapy to combat cancer, through precise chemical dosage administration, and a similar approach could be taken to enable nanorobots to deliver anti-HIV drugs. Nanorobots could be used to process specific chemical reactions in the human body as ancillary devices for injured organs.[9] Monitoring diabetes and controlling glucose levels for patients will be a possible application of nanorobots.[10]

Other approaches

Microbiology

A highly customizable structure can be ligated to the bacteria, containing therapeutic compounds such as pharmaceuticals and artificial antibodies for function at the target site. There is also the potential for use of these device to collect information and function as sensors [11]. Larger robots have higher ability to function in and navigate through larger vessels with limited function in capillaries and small vessels. Smaller nanorobots are highly useful in capillary environments and the microvasculature, but cannot achieve high enough velocities for control in large vessels. A two-component robotic system including a larger system for transport and control through large vessels, followed by release of the smaller component into small vessels has been proposed, and is a promising idea for pursuing practical development this field [12].

Haematology

There is a rich base of research and potential applications for nanomedicine and nanorobotic applications in the field of hematology. From uses ranging to emergency transfusions of non-blood oxygen carrying compounds to restoring primary hemostasis, there is a wide array of applications under study for nanorobotics in hematology[13].

One of these devices currently under design is a nanorobot dubbed a respirocyte. This robot is equipped to have three functions as it travels through the bloodstream. First, collecting oxygen as it passes through the respiratory system for distribution throughout the bloodstream. Second, collecting carbon dioxide from tissues for release into the lungs. And finally, metabolizing circulating glucose to power its own function. The total size of the robot would be about one micron, or 1,000 nanometers [14]. However, the contained components would be constructed on the nanoscale. These include an onboard computer of 58 nm diameter, and oxygen and carbon dioxide loading rotors with a maximum 14 nm diameter in any one dimension. The respirocyte is designed to carry 236 times more oxygen per unit of volume compared to red blood cells. Development and use of this technology could provide an effective and lower risk alternative to blood transfusions [15].

Vascular

The use of nanorobots intravascularly greatly expands the potential for screening and monitoring for life-threatening health conditions, as well as monitoring the development and progression of chronic diseases[16]. Examples of life-threatening conditions that could be screened for include brain aneurysms, cancers with no current screening protocols such as lung cancer, and unstable atherosclerotic lesions. Intravascular nanorobots would constantly circulate and provide current information at any desired moment. Integration with current technology would also allow constant syncing wirelessly, and immediate notifications of changes in health status. The monitoring of chronic health conditions such as diabetes increases the capability for optimally managing chronic diseases [17]. Improvements in primary prevention capabilities have been the hallmark of improved quality of life and life expectancy in our society, in addition to cost savings. Intravascular nanorobots are potentially the next stage in the continued development of our primary prevention capabilities, and will likely contribute to making our health care system more lean and effective [18-21]].

Oncology

Improving the treatment quality and clinical outcomes of cancer patients, and reducing the mortality and morbidity associated with oncological conditions and their treatment has been identified as a goal by the Institute of Medicine [22]. This need is underscored by the increasing number of seniors in the population, and the increasing number of cancer diagnoses that comes with an aging population. Nanotechnology has already shown much promise in improving the management of cancer [23]. Increasing the sensitivity of cancer imaging tools, overcoming drug resistance, and improved treatment of metastasis are some examples of nanoparticle technology's increasing role [24]. There have also been some promising developments in the subfield of nanorobotics for the treatment of cancer, which will be discussed below.

One of the limitations of conventional chemotherapy has been the toxic effects on normal cells by the chemotherapeutic agents limiting the dose. This limitation has been improved upon as targeted therapies have developed, and as nanoparticle technology has improved the selectivity of treatment. The development of a nanorobot that can autonomously detect cancerous cells, and release treatment agents at the site of these cancerous cells has been successfully developed. This nanorobot can be constructed to respond to a number of different cell surface receptors, and the payload it releases upon activation can also be changed as necessary. This nanorobot has been constructed using engineered DNA strands that have been made to fold into a desired tertiary structure [25]. Upon binding the desired target, the conformation of the DNA nanorobot undergoes a structural reconfiguration and shifts from a closed to an open state, releasing the stored therapy [26].

The topic of spinal cord injury and nerve damage is an important area of concern within neurosurgery as a field, and as a significant life-altering event for affected patients [27]. The practice of reconnecting transected nerves has been done for more than 100 years, with progressive advancement in technique and technology. Currently, there are several different routes being pursued with the goal of optimizing and improving nerve reconnection outcomes, including promoting the regeneration of axons via growth factors and enriched scaffolds. Restoring connectivity to transected axons is an integral step to the restoration of function [28]. The ability to do this is limited by technical limitations to surgery on that scale. Advancements in technology have led to the development of devices on the nanoscale which allow manipulation of individual axons [29]. A nanoknife with a 40 nanometer diameter has been developed and found to be effective for axon surgery. The use of dielectrophoresis, which involves the use of electrical fields to manipulate polarizable objects in space, has been found to be effective in achieving controlled movement of axons within a surgical field [30]. Following controlled transection of axons and maneuvering them into position using dielectrophoresis, fusion between the two ends can be induced via electrofusion, polyethylene glycol, or laser-induced cell fusion, amongst other methods [31]. Nanodevices are enabling a new dimension of precision and control with the reconnection of nerves [32].

Conclusion

This review provided a brief outline of nanodevices and nanorobotics in medicine, a small subset of the massive field of nanotechnology and are developing wide potential applications across all fields of medicine, and expanding the number of therapeutic options available, while also improving the efficacy of existing treatments. It is certainly possible within a generation of time that the use of nanorobotic technology will become ubiquitous in medicine.

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