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ORIGINAL ARTICLE

A Mini Review on Nanorobots in Medical Field: Applications and Challenges

Abdirisak Mubarik Muhumed[1], Sarah 'Atifah Saruchi [2*], Mahmud Iwan Solihin [1], Teh Boon Hong [1], and Ng Weng Kent [1]

[1]Department of Mechanical and Mechatronics, Faculty of Engineering, Technology and Built Environment, UCSI University, 56000 Kuala Lumpur, Malaysia.
[2]Faculty of Manufacturing and Mechatronic Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.

ABSTRACT – Technology advancements have expanded our ability to affect the world around us on a progressively smaller scale. Nanotechnology provides substantial advantages over traditional approaches for diagnosis and therapy. The field of nanorobot development is captivating and holds great promise within the realm of nanotechnology research. Nanorobotics involves the exploration of robotics at the nanometer scale, encompassing both nanoscale robots and larger robots capable of manipulating objects with nanometer precision within the nanoscale domain. Nano-robotic manipulation, with its capacity to position and orient nanometer-scale objects, is a viable technique to build nano-systems, including nanorobots. nanorobotics has provided a ray of hope in various disciplines, particularly in medicine. Nanorobots find applications in the medical field, where they are employed for various purposes such as cancer treatment, blood analysis, diagnostics, and precise drug delivery. This mini review of the literature centers on exploring the applications and obstacles associated with the utilization of nanorobots in the medical domain.

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INTRODUCTION

Researchers have defined progression in science and medicine's ability to examine and comprehend the world on an ever-smaller scale. Nanorobots, alternatively referred to as nanobots, are extremely small robots programmed to do a specific task with exceptional precision. Nanorobots are devices that possess the ability to sense, actuate, transmit signals, process information, and exhibit intelligent behavior at the nanoscale level [1]. The scale of 1 nanometer is equal to one billionth of a meter. Therefore, the size of biological cells and organelles is approximately equivalent to nanorobotic devices [2]. Nanorobots' application in medicine provides diverse tools for treating disease and enhancing the human biological system. Medical nanorobots can perform a variety of functions related to the diagnosis, monitoring, and treatment of significant diseases. Additionally, these nanorobots can deliver medicine or drugs to specific locations within the human body [3]. Drug delivery plays a crucial role in tasks like tissue repair, blood vessel cleaning, and targeted drug transportation to infected cells. Dentists have also witnessed the advantages of nanorobots, enabling them to carry out intricate procedures with enhanced precision at the microscopic scale [4]. As advancements continue in diverse fields, the incorporation of nanorobots in medical practices has the potential to shift the focus from treatment-oriented approaches to preventive measures.

Furthermore, nanorobots encounter certain limitations, such as the high costs associated with their development and design, as well as the complexity and interface challenges they present. When it comes to drug-carrying nanorobots, the viscosity of blood at the nanoscale poses a significant hurdle as it obstructs their passage through blood arteries. The Brownian motion of molecules further compounds the issue, leading to collisions and rendering the behavior of nanorobots unpredictable and uncontrollable [5]. Overcoming this instability has become a critical task for researchers. Moreover, the field of nanotechnology lacks efficient methods for designing the necessary nanoscale structures for various applications [6], [7]. Researchers also face obstacles in the form of designing and fabricating nanorobots with diameters below the nanoscale range and developing suitable programming and feedback sensors [8]. Additionally, nanorobotics presents formidable challenges in areas such as sensing, navigation, power communication, locomotion, and component manipulation [9]. In the upcoming sections, we will delve into a review and discussion of the applications and challenges associated with nanorobots in the medical field.

APPLICATIONS OF NANOROBOTS

Nanorobots can be utilized in a variety of fields, including medical and space technology [10]. Nanorobots in medicine provide a vast array of instruments for treating disease and enhancing the human biological system. Nanorobots are capable of diagnosing, monitoring, and treating life-threatening disorders. In addition, these nanorobots can administer medicine or pharmaceuticals to specific body sites/targets [11]. In this literature review, we will provide a brief overview of the potential applications of nanorobots in the field of medicine. Specifically, we will focus on their potential roles in surgery, dentistry, and drug delivery.

*CORRESPONDING AUTHOR | Sarah 'Atifah Saruchi | sarahatifah@ump.edu.my

Nanorobots in Surgery: Surgical nanorobots are introduced into the human body through vascular systems and other cavities, where they function as semi-autonomous surgeons. These nanorobots are programmed by human surgeons [11]. A recent breakthrough by researchers at the University of California, San Diego involved the development of nanobots coated with gold nanowires. This coating enables the nanobots to freely navigate through the bloodstream and effectively eliminate pathogenic bacteria without causing any harm to the patient's immune system [12]. The programmable surgical nanorobot is capable of performing various tasks, including pathogen detection, lesion diagnosis, and treatment through nano-manipulation techniques. These functions are synchronized by an on-board computer, while the nanorobot conserves energy and communicates with the supervising surgeon using encoded ultrasonic signals [11].

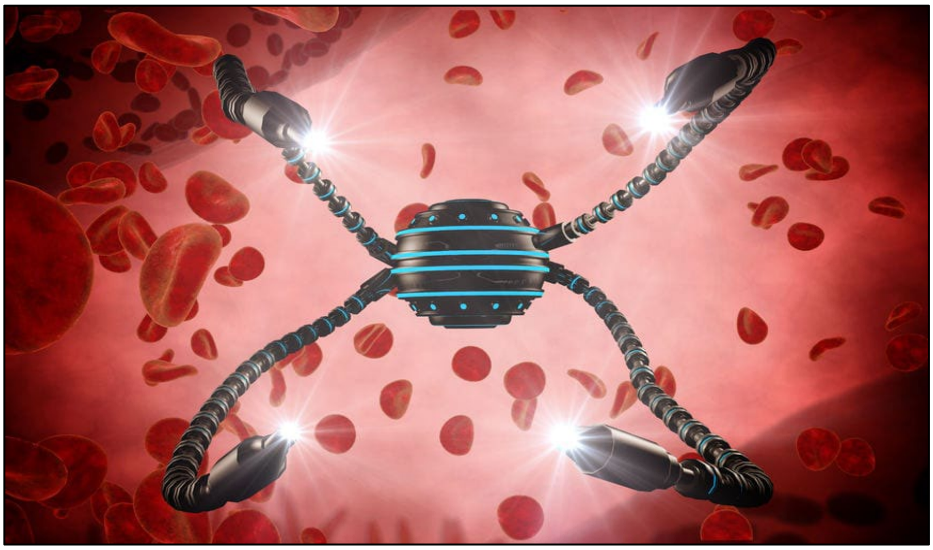

Figure 1. Nanorobotics in Surgery [13].

Currently, researchers are investigating advanced techniques for cellular nano-surgery. One such method involves the use of a vibrating micropipette with a tip diameter of less than 1 micron, which is capable of rapidly cutting dendrites from individual neurons. This procedure is designed to minimize any potential damage to the cell's functionality [11]. Although these miniature devices have not yet left the research laboratory, their potential to revolutionize surgical practice is significant [13].

Nanorobots in Dentistry: Nanorobots have found significant applications in the field of dentistry, making it one of the prominent areas of their use. These tiny robots play a vital role in various dental procedures, including desensitizing teeth, administering oral anesthesia, aligning misaligned teeth, strengthening tooth structure, repairing severe tooth damage, and improving the aesthetic appearance of teeth [11]. In the context of dental treatment, nanorobots can employ specialized mechanisms for precise tissue penetration, energy acquisition, real-time sensing, and manipulation of their surroundings. To control the functions of these nanorobots, an onboard nanocomputer can be utilized, executing preprogrammed instructions triggered by local sensor stimuli [15].

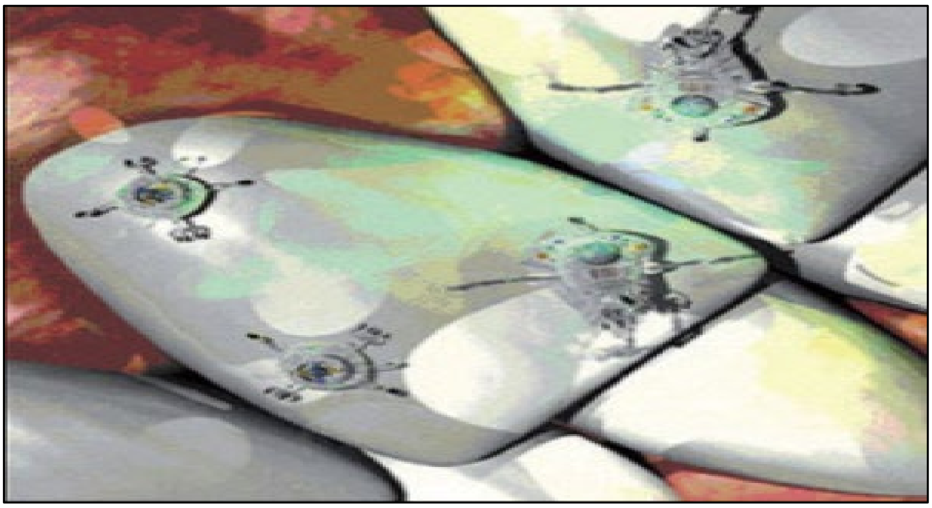

Figure 2. Nanorobots in Dentistry [11].

Pain relief in the oral cavity is achieved by administering a mixture containing numerous nanorobots orally. These nanorobots possess the capability to penetrate the gingival sulcus and reach deep into the pulp. By controlling the nanorobots in a controlled manner, medication is delivered to the specific treatment areas. The encapsulation of nanorobots within a capsule allows for interaction and detection, enabling procedures such as root canal treatments and the treatment of dental infections to be carried out effectively. Besides, tiny cameras are installed in the nanorobots to visualize infected roots, which aids the doctor in the surgery, thus making the root canal therapy a success [16].

Nanorobots' potential in treating dentine hypersensitivity has earned much attraction from the public. Hypersensitive teeth have more dentinal tubules than non-hypersensitive teeth. Thus, when nanorobots are inserted into the dentinal tubules, they perform selective ablation, eventually preventing the patient from feeling pain. Nanorobots are also employed in dental care through their incorporation into mouthwash and toothpaste. Regular use of these products allows the nanorobots to directly modify the periodontal tissues, thereby assisting in tooth relocation [16].

Nanorobots in Drug Delivery: Nanorobots in drug delivery are microscopic biological machines that can deliver pharmaceuticals to their intended location to increase their efficacy and decrease adverse effects, which are the two most significant obstacles in drug delivery. Traditional pharmacological therapies, such as chemotherapy for cancer, may contain toxic substances that irreparably harm healthy tissues. Nanobots could bypass this problem by safeguarding the medicine until it reaches its intended recipient. The objective is to provide the correct dose to anybody location without causing collateral damage [17], [18].

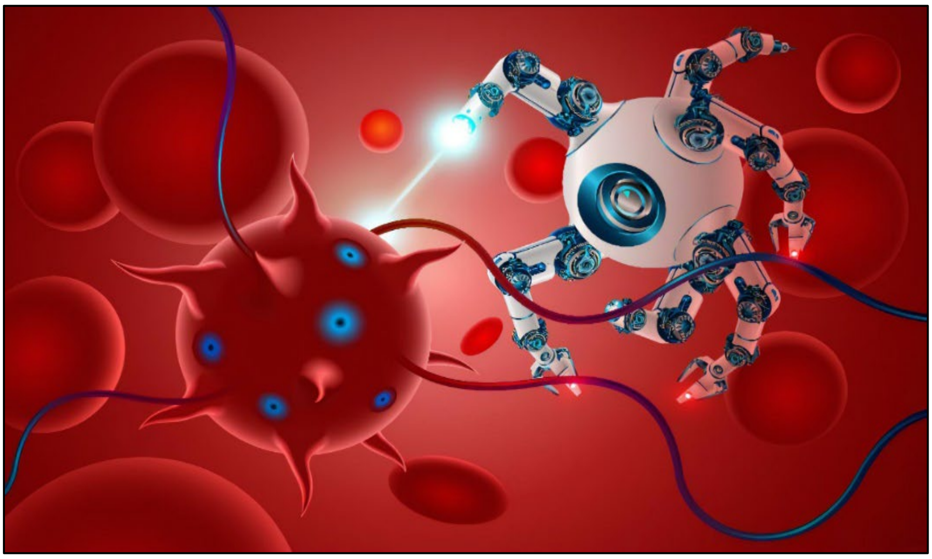

Figure 3. Nanorobots in Drug Delivery [19].

The best route to reach different body sections is through the blood vessels, which serve as the circulatory system's highways. However, nanobots won't have an easy journey. There are numerous free-moving cells and other substances that can impede their movement in the blood. Researchers at the Max Planck Institute for Intelligent Systems in Stuttgart created specialized microdevices called "microrollers." These microrollers are designed to attach to the inner walls of blood vessels and can navigate through blood veins, even in the presence of blood flow, by utilizing a magnetic field. One side of the microrollers is coated with magnetic materials used to drive them through the body, while the other side is coated with antibodies to detect cancerous cells. Moreover, the drug carriers employed in this approach have remarkably thin walls, measuring only 5-10 atoms in thickness, while the internal compartment containing the drug is 50-100 nm wide. These thin-walled structures feature delicate wires that emit an electrical pulse when they detect disease-related signals, causing the walls to dissolve and release the medicine. The electrical pulse can be adjusted to precisely control the volume and duration of drug release, providing a convenient means of regulating drug delivery when utilizing nanobots for this purpose [19]. However, despite the potential of nanorobots to carry and deliver substantial amounts of anti-cancer drugs to cancer cells without causing harm to healthy cells, thus reducing the side effects associated with conventional therapies such as conventional chemotherapy-induced damage, they are still a long way from being available for public use [19].

CHALLENGES OF NANOROBOTS

Today's nanorobot designers have a significant challenge in understanding nanoscale physics. Robots become smaller as technology advances to the nanoscale. Fluid dynamics and surface effects play a dominant role in the behavior of nanobots, surpassing the traditional forces based on mass. Nanobots are comparable in size to molecules, allowing them to exhibit floating behavior. The phenomenon of Brownian motion, arising from thermally induced collisions between molecules, greatly influences their movement. Due to these factors, nanobots cannot be treated as rigid bodies and are subject to various forces. Deformation refers to changes in the nanobot's properties, often resulting from a shift in the center of mass. Consequently, a deformed nanobot may require a process of relearning, similar to a person with a paralyzed leg needing to learn to walk again. The dynamics of motion are altered by a change in the center of mass, causing a force applied along the center to be offset or angled differently in order to achieve the same motion as before. Embedding artificial intelligence at such a minuscule scale appears unlikely and would entail constructing essentially inflexible nanobots. Furthermore, one of the primary technological obstacles in the development of functional nanorobots today revolves around energy generation and storage. Another difficulty would be to produce engineering materials suitable for nanobots fabrication using NEMS technology while still being biocompatible. Effective methods of energy generation are yet to be discovered.

Besides, nanorobots still have some limitations on the interface: high development costs and complications of designing. To design a nanorobot should consider the motors, transmissions element, sensor, and mechanical joint. On the other hand, design, simulation, assembly, and prototyping for the nanorobot is a big issue as nanorobots have a length of 1nm and build of 500 to 1000 live cells. Nanorobots are created with a tiny length to flow through blood vessels to target the cancers or bacteria and clear the clots. Consequently, transmitting to a specific location is simpler while placed along with blood flow.

Nonetheless, the biggest issues are dealing with important organs such as the brain, heart, and kidney. The most difficult part is the power supply. Heat method from body temperature is implemented as a power source for the nanorobots in use in entire of the body. Thus, the body temperature differs in different places of the body. It is a big issue as an energy gradient is required to make power flow to the nanorobots.

CONCLUSION

The application of nanorobotics in medicine has a broader scope than any other subfield that has developed yet. It can be applied almost wherever human physiology is present. It has various advantages over conventional medicine, including lower costs, faster recovery, and almost no invasion. However, the dynamic features of nanorobots are still being investigated and tested; this is mostly because nanorobots must interact with their environment at the cellular level, which remains a significant challenge. Miniature motors and other propulsion devices must fit inside these tiny machines to successfully combine movement and navigation of nanorobots at the nanoscale. Furthermore, several types of nanoscale sensors should be developed. By overcoming nanomanufacturing limitations, the domain of nanorobotics in medicine can be made achievable. As a result, the numerous applications outlined in this paper may be realized in the future, making nanorobotics a one-of-a-kind medical equipment. This review attempted to address a variety of challenges and issues related to the design and development of nanorobots and their applications to make them a feasible treatment for a variety of diseases in the next decades. We expect that we will witness a great medical revolution similar to the industrial revolution that transformed the world. With a swarm of nanobots protecting us from the inside, we may be disease-free in the next few decades.

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