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Nanomedicine and Nanorobot: Mini Review

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Mini Review

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Abstract

Nanotechnology is now recognized as an emerging field for scientific study and technological advancement, along with associated concepts like nanomaterials, nanostructures, and nanoparticles. Electronics and other disciplines have already benefited greatly from the development and use of nanotechnology or the manufacture and use of devices and materials at the nanoscale. The field of nanomedicine is a developing one that combines medical science with nanotechnology to create new therapeutics and enhance current ones. When interacting with human cells, nanomedicine uses the manipulation of atoms and molecules to produce nanostructures the same size as biomolecules. This technique offers a variety of cutting-edge choices for diagnostics and intelligent therapies by supporting the body's inherent healing systems. One of the most exciting uses of nanomedicines is the development of nanobots, which is leading multidisciplinary research. Nanotechnology breakthroughs have led to an increased application of nanobots in cancer diagnosis and treatment. They allow the creation and deployment of functional molecular and nanoscale machines. The use of nanobots in cancer treatment has moved from theory to reality in recent years, with a shift from in vitro trials to in vivo applications.

Keywords: Nanomedicine; Nanorobots; Nanomachinery; Nanotechnology

Introduction

Nanotechnology has become a significant tool in various industrial sectors, including electronic storage systems, biotechnology, magnetic separation, and gene and drug delivery [1]. Technological advancements have created novel nanomaterials with higher surface-to-volume ratios, making them ideal for biomedical applications. The field of nanomedicine, which combines illness screening, diagnosis, and treatment, can potentially transform individual and population-based health in the coming century [2]. Nanoparticles enable Molecular treatment, improving our understanding of illness pathophysiology and treatment. Nanomedicine is seen as a refinement of molecular medicine, enhancing genomes and proteomics discoveries for more personalized treatment.

Nanotechnology has significantly impacted medication release, regenerative medicine, and diagnostic approaches. It enables early illness identification and fast treatment through diagnostic tools like imaging techniques. These methods are crucial in diagnosing, treating, and following patients with cancer, cardiovascular disease, and neurological disorders. Nanoparticle-based diagnostic methods enhance sensitivity, improve prognosis, and increase therapy chances [3]. Medication is crucial in treating illnesses, but traditional treatments like chemotherapy and anti-diabetic drugs are limited due to their non-specificity and inadequate doses. Nanotechnology can help create new pharmaceuticals with improved cell selectivity and drug-release mechanisms, targeting specific targets while preventing degradation. This allows for more effective but lower dosages, reducing side effects. Nanotechnology can also enhance therapeutic formulations by improving solubility and modifying pharmacokinetics to maintain drug release and extend bioavailability. It may be applied to develop intricate, cell-targeted therapies and combine many medications to produce a single nanotherapeutic agent with synergistic effects [4]. A promising treatment for many degenerative illnesses has been suggested: regenerative medicine. To achieve this goal, Nanomedicine uses biomaterials, signaling molecules, tissue engineering, gene therapy, and cell therapy.

Nanomedicines have shown significant potential in treating cancers, particularly in the development of nanorobots [5]. These untethered nanostructures can perform various medical procedures and access difficult-to-reach body parts (Figure 1). They are an interdisciplinary technology that deals with constructing and using functioning machines at the nano-to-molecular scale [6-8]. Nanorobots are nanoscale devices that can deliver payloads, perform specific biomedical tasks, target disease/tumour sites, and have a passive or active power system that can draw power from external sources or existing biological systems. The goal is to update medicine by applying nanorobots in clinical settings. Using nanorobotic instruments in real-world therapeutic settings is one of the most unsolved issues in the field. The active power system is one of the main distinctions between nanorobots and nanocarriers, and they can also include nanomedicines and nanocarriers, even without an active power source [9].

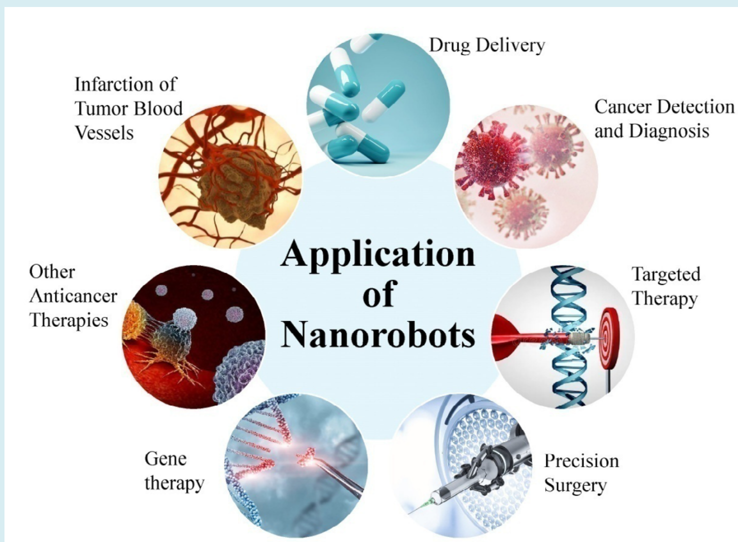

Figure 1: An illustration showing how nanorobots might be used to fight cancer [9].

Challenges in Nanorobots Application

Micro/nanomotors are essential for in vivo applications like cargo transport and medication administration, as they must pass immune system clearance to avoid rejection as foreign material. They must also pass through barriers made of tissues and cells to reach remote parts of the host body, providing treatment with extreme accuracy. The performance of nanorobots depends on their design, which must be carefully studied to be efficient in various biological applications. It is vital to carefully assess the nanorobot's form, propulsion source, and structure to project it as an ideal sensor or delivery system for theranostics (a combination of the terms therapies and diagnostics) applications [10]. Autonomous micro/nanomotors enable the active distribution of therapeutic molecules to the place of interest due to their tissue retention, directed movement, and penetration capabilities. This method often involves encasing the medicine, gene, or protein within micro- or nanorobots, guiding them to the desired location, and releasing them in response to internal or external cues.

Wang, et al. [9] have illustrated the potential of artificial catalytic micromotors in surgical procedures, including medication administration and release [11]. Ultrasound-triggered microbullets have been used in precision nanosurgery and biolistic circulation. Self-propelling nanotools can perform surgeries at an organism's remote location. However, challenges remain, such as tiny motors needing improved penetration and resolving biocompatibility concerns [12].

Nanorobots in dentistry can enhance orthodontic therapies, tooth durability, and dentine hypersensitivity.

Some notable applications include nanoneedles, facilitating painless tooth rotation, vertical repositioning and uprighting during orthodontic operations, osseointegration and anaesthesia, and transferring dentine tubules to reduce tooth hypersensitivity [13]. The availability of polymeric materials makes these applications possible. Examples of bio nanocomposites made with polymers include silk, alginate, collagen, poly (lactic acid), poly (lactic-co-glycolic acid), poly (caprolactone), and poly (glycolic acid). The inorganic materials used are bioactive glass nanoparticles, hydroxyapatite, magnetic nanoparticles, carbon nanotubes, TiO_2, Ag or Au nanoparticles, graphene oxide, and silica nanoparticles.

Nanorobots can significantly improve treatment for spinal cord injuries and nerve damage by using enriched scaffolds to enhance nerve reconnections and regrow axons. Axon surgery uses a 40 nm diameter nano knife regulated via dielectrophoresis and electrofusion [14]. Other methods include polyethene glycol or laser-induced cell fusion. Nanorobots also have applications in selective cancer cell eradication and precise nerve reconnecting. They can also monitor and screen for developing aneurysms, preventing premature death in patients with brain aneurysms.

Nanorobots have the potential to revolutionize biomedical procedures, including less invasive surgery, patient monitoring, and early illness detection. They can control blood pressure in heart patients, identify cancer early, and monitor blood glucose levels in diabetics. Clinicians can also optimize medication and food consumption using gathered data.

Wearable technology and nanorobots are expected to be combined for medical purposes shortly. Despite the acceptance of wearable technologies, concerns about toxicity, biocompatibility, and introduction-related dangers hinder their practical use. Due to a lack of official regulations, the FDA is reluctant to approve such systems. Despite these obstacles, the potential of nanorobots in medicine remains promising [15].

Nanotechnology Application in Medicine in the Future

Nanotechnology is a growing field that combines traditional scientific fields like biology, materials science, chemistry, physics, medicine, and physics to create novel technologies. It has numerous potential uses, including developing new instruments and refining existing methods (Figure 2) [16]. The field has seen an exponential rise in interest, leading to the discovery of new uses in medicine and the formation of nanomedicine. Nanomedicine encompasses various scientific and technological fields, such as diagnosing, treating, preventing, and mitigating pain, trauma, and illness, optimizing human health through nanoscale architectured materials, genetic engineering, and biotechnology, and developing sophisticated machine systems and nanorobots [17].

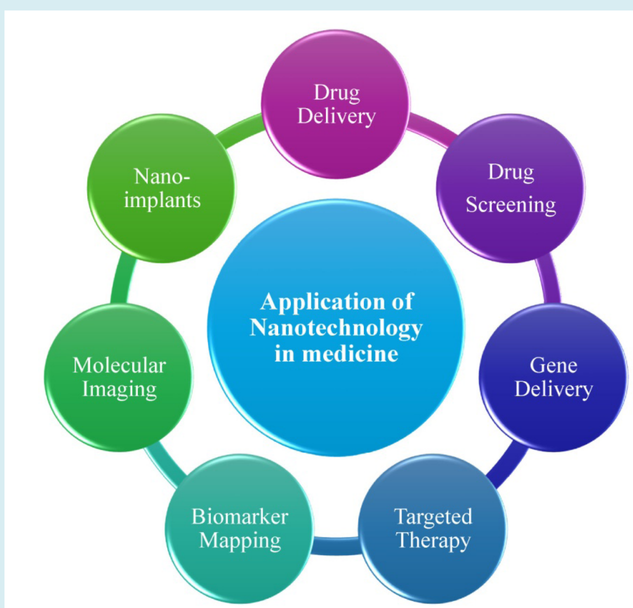

Figure 2: Demonstrating various uses of nanotechnology in medicine [18].

Nanotechnology has revolutionized medicine by developing nanoparticles for various applications, including drug and gene delivery, theranostics, drug screening, tissue engineering, cancer treatment, illness detection, biomarker mapping, and bio-imaging.

In vivo, diagnostics and nanomedicine enable the development of medical devices to detect and quantify harmful substances and tumour cells within the human body. With the help of an inbuilt computer, these gadgets may perform semi-autonomous on-site surgery. They can also interact with the supervising surgeon via coded ultrasonic signals. Scientists have created self-sustaining, implanted medical devices, sensors, and portable electronics by transforming mechanical energy from body movement, muscle stretching, or water flow into electricity [16]. Power is generated in nanogenerators made on polymer-based films by bending and releasing piezoelectric and semiconducting zinc oxide nanowires. The long-term impact of nanomedicine research is the description of quantifiable molecular-scale components known as nanomachinery. The precise control and management of nanomachinery within cells can yield a more sophisticated understanding of organic cell functioning and develop novel technologies for illness diagnosis and treatment. This study aims to create a platform technology that influences nanoscale imaging techniques to look into molecular pathways in organic cells [18].

Discussion and Conclusion

Nanotechnology, a field combining engineering, chemistry, and biology, aims to improve biomarker detection and diagnostics, leading to significant advancements in personalized medicine. This would enhance pharmacological therapies' efficacy and reduce adverse effects. Nanoparticles are a promising platform for manufacturing unique contrast agents, making it a viable technology for individualized treatment and diagnosis.

Nanorobots can cure or eliminate common diseases and improve mental and physical abilities. Research on their dynamic properties is ongoing due to their cellular interaction with the environment. Nanoscale sensors of various sorts must be created, as well as tiny motors and propulsion devices for the movement and navigation of nanorobots. Despite the challenges, further research by different groups will make this possible. If the difficulties associated with nanomanufacturing are resolved, nanorobotics could be a proper medical solution. This work aims to explore the challenges associated with creating, developing, and applying nanorobots for various purposes, ultimately transforming them into a valuable tool for treating a broad spectrum of diseases. Medical nanorobots with basic structures should develop into more advanced devices, able to carry out various medical activities and functions, eventually turning into actual bloodstream nano-submarines. It is possible to break through the barriers associated with nanomanufacturing and enter the field of medical nanorobotics. As a result, nanorobotics might become a particular medical instrument in the future and be used for the several applications covered in this analysis. This research intended to investigate a range of topics connected to the development and use of nanorobots to make them a feasible treatment for numerous diseases soon.

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