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REVIEW ON NANOROBOTS: AN INNOVATIVE APPROACH FOR CANCER TREATMENT

***Prakash B. Honrao, Sagar S. Gilda**

Department of Pharmaceutics, Dayanand Education Society, Dayanand College of Pharmacy, Latur.

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***Corresponding Author: Prakash B. Honrao**
Department of Pharmaceutics, Dayanand Education Society, Dayanand College of Pharmacy, Latur.
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ABSTRACT

The late Nobel Physicist Richard P. Feynman, in a dinner talk in 1959, very rightly said that there is enough room for the betterment of technology beyond our scope of imagination, proposing utilizing mechanical tools to make those that are relatively smaller than the others, which further can be rendered fruitful in making even more compact mechanical devices, all the way down to the level of the smallest known atom, emphasizing that this is ―aprogress which I believe cannot be avoided‖. Feynman proposed that nanomachines, nanorobots, and nanodevices may eventually be utilized to construct a huge range of atomically accurate microscopic instruments and manufacturing equipment, as well as a large number of ultra-small devices and other nanoscale and microscale robotic structures. Biotechnology, molecular biology, and molecular medicine could be used to create totally self-sufficient nanorobots/nanobots. Nanorobotics includes sophisticated submicron devices constructed of nanocomponents that are viewed as a magnificent desired future of health care. It has a promising potential in medication delivery technology for cancer, the top cause of mortality among those under the age of 85 years. Nanorobots might transport and distribute vast volumes of anticancer medications into diseased cells without hurting normal cells, decreasing the adverse effects of existing therapies such as chemotherapy damage. The ultimate development of this innovation, which will be accomplished via a close partnership among specialists in robotics, medicine, and nanotechnology, will have a significant influence on illness detection, therapy, and prophylaxis. This report includes a study on several ways to cancer therapy utilizing nanorobots. Furthermore, it offers insight into the future breadth of this area of research.

KEYWORDS: nanorobots, nanorobotics, nanogenerators, drug delivery system, chemotherapy, cancer therapy, nanotechnologyc.

INTRODUCTION AND BACKGROUND

Treating cancer is fiendishly difficult because the diseased cells have exactly the same genetic material as our own healthy cells. All that changes in a cancerous cell is the expression of those genes. In a bacterial or viral disease, the biology of the disease agents is very different to our own. In these cases scientists must simply find and attack a biological pathway in the disease agent that is not present in humans.[1]

Cancer therapies have a much more difficult time with this approach since the biology of the diseased and the healthy cells is so similar. Many cancer treatments have awful side effects because, not only do the drugs target cancerous cells, they target healthy cells too.[1]

Treatments that can selectively target cancerous cells significantly decrease the side effects of a cancer therapy. A team of researchers from ITMO University have developed a nanorobot that may be able to do just that.[1]

Ekaterina Goncharova, a co-author of the research, explained in a press release that, ―when a cell becomes cancerous, it leads to the change in the genome, after which it begins to synthesize bad' proteins, not the ones that our body needs. As a result, the cells begin to multiply uncontrollably and the tumor grows bigger and bigger.[1]

The changes in the genome of cancer cells result in the increased production of RNA strands, which tell the cell to start producing the ― bad proteins. If that RNA molecule could be selectively targeted then the disease inducing proteins would never be produced.[1]

The team's nanorobot consists of two elements: a targeting and a therapeutic. Ekaterina Goncharova elaborates: ―The therapeutic part destroys a pathogenic RNA strand: the more we destroy it, the less harmful protein is produced. The second part of our robot allows us to detect pathogenic cells: if there is an _incorrect' RNA molecule in the cell, our substance binds with a chemically modified oligonucleotide, which is artificially introduced into the cell, cleave it, and a fluorescence occurs.[1]

To date this work has been carried out in controlled conditions, testing the nanorobot's ability to destroy the RNA. The next step will be to test the system in living cells. Cost will not be a significant barrier to performing these experiments as the robots can be made for 15-25 USD.[1]

In order to carry out these experiments, the team are currently working on developing the technology required to deliver the device to cells.[1]

Researchers have emphasised nanotechnology as an outstanding technological trend in the last few decades, and it is characterized by the fast proliferation of electronics for applications in communication, known as nanomedicine, and environmental monitoring. Studies are now being conducted on the scientific bottlenecks that affect the lifespan of the living, particularly humans. Among these constraints are illnesses with few or no alternatives for treatment and healing. A drug delivery system (DDS) refers to an alternative diagnosis and/or therapy that has been shown in the medical fraternity.[2,3]

Nanorobots are nanoelectromechanical systems (NEMS), a recently developed chapter in miniaturisation, similar to microelectromechanical systems (MEMS), which is already a multibillion-dollar business. Designing, architecting, producing, programming, and implementing such biomedical nanotechnology are all part of nanorobotics and NEMS research. Any scale of robotics includes calculations, commands, actuation and propulsion, power, data-sharing, interface, programming, and coordination. There is heavy stress on actuation, which is a key prerequisite for robotics.[2] The similarity in size of nanorobots to that of organic human cells and organelles brings up a huge variety of its possible uses in the field of health care and environmental monitoring of microorganisms. Other potential uses, such as cell healing, may be possible if nanorobots are tiny enough to reach the cells. Furthermore, it is still to be realised that the tiny sensors and actuators' square measures are necessary for the growing concept of a strongly connected ascending information technology infrastructure; the envision of artificial cells (nanorobots) that patrol the cardiovascular system, thus, detecting and destroying infections in minute quantities. This might be a programmable system with approachable ramifications in medicine, creating a revolutionary replacement from therapy to bar.[2] Chemotherapeutic substances employed in cancer treatment measure disseminates non-specifically throughout the body, where they exert an influence on both malignant and normal cells, restricting the drug quantity feasible within the growth and also resulting in unsatisfactory medication due to excessive toxic hazards of the chemotherapy drugs on normal cells of the body. It is safe to say that molecularly focused medical care has evolved as a collaborative method to overcome the lack of specificity of traditional cancer therapy drugs.[4] With the help of nanotechnology, intercellular aggregation of the drugs in cancer cells can be increased while minimising the risk of unwanted drug toxicity in normal cells by utilising various drug targeting mechanisms.[5]

Nanotechnologyis commonly referred to as small science, or scientifically, the art of developing materials And structures in the size range of 1-10 nm. Oncologists around the world are constantly researching how to Detect cancer and pinpoint the location of cancer drugs while minimizing side effects on healthy tissue. Over The past decade, rapidly expanding research in nanotechnology has presented a promising opportunity to Realize every oncologist's dream.[6]

Nano-robots are the emerging technology of this century. It Manufactures machines or robots with parts up to 1 nanometer (10-9 meters). Specifically, nanorobotics Refers to the engineering science and engineering discipline of designing and building nanorobots, devices Made of nanoscale elements or molecular. Nanomachines are mostly in the research and development phase, But some primitive molecular machines and nanomotors have already been tested. An example is a detector With a switch of about 1.5 nm capable of counting specific molecules in highly chemical samples.[7]

Nanorobots are expected to provide advances in medicine through the miniaturization from microelectronics To nanoelectronics. The aim of this article is to present the future use of nanorobots to combat cancer. Cancer Can be successfully treated with current stages of medical technologies and therapy tools. However, a Decisive factor to determine the chances for a patient with cancer to survive is: How earlier it was diagnosed; What means, if possible, cancer should be detected at least before the metastasis has begun. Another Important aspect to achieve a successful treatment for patients is the development of efficient targeted drug Delivery to decrease the sideeffects from chemotherapy. Considering the properties of nanorobots to navigate as blood-borne devices, they can help on such extremely important aspects of cancer therapy.[8]

Structure and Design of Nanorobots

Component of Nanorobots

The main component of nanorobots is surface unit carbon, due to its inertia, adaptable resistance, diamond Or C type. The other components hydrogen, oxygen, nitrogen, sulphur, silicon and fluorine, etc. For the Nanoscale.[9]

Nanobot Room

Medicine Chamber

This is a hollow part inside the Nanobot that holds small doses of medicine. The robot is able to deliver the Drug directly to the site of injury or infection. Nanorobots could also carry chemicals used in chemotherapy To treat cancer. Although the number of drugs is relatively small, applying them to cancerous tissue can also Be more convenient than older treatments, which rely on the body‘s cardiovascular system to keep chemicals Moving through the patient‘s body.

Probes cutters and chisels

These probes, cutters and chisels are used to remove plaque and clogs. These components help nanobots Grasp and break down matter. They may also need a tool to crush the clumpsv into very small objects. If part Of the clot breaks off and enters the bloodstream, it should cause many other problems for the cardiovascular System.[10]

Microwave Transmitterand Ultrasonic Signal Generator

Doctors need a way to destroy cancer cells without tearing them apart. Ruptured cancer cells release Chemicals that help cancer spread. By harnessing precisely tuned microwave or supersonic signals, Nanorobots can break chemical bonds inside cancer cells and kill cancer cells without disrupting cell Membranes. Alternatively, the mechanism could trigger microwave or ultrasonic signals to heat the cancer Cell enough to destroy it.

Electrodes

Nanobots use electrodes to generate an electric current that heats the cells until they are destroyed.

Laser

The power laser can burn harmful substances such as cancer cells, blood clots and plaques. These lasers Vaporize the tissues. Vaporizing cancer cells is a difficult task using a powerful laser that does not damage Surrounding tissue. Teams around the world are currently working on developing medical nanobots that are Small and enter the bloodstream. Nanorobots from a few millimetres to two centimetres long have been Developed, but they are not yet used in the health field and they are in the test phase. It can take a long time for nanobots to enter the medical market.

Power supply for nanobots

Power is available for outdoor and indoor nanobots. Harvesting energy directly from the bloodstream, the Nanorobots use the patient‘s body heat to generate electricity. It‘s like a navigation system.[11]

Nanorobots in Cancer Detection and Treatment

The development of nanorobots could bring significant advances in cancer diagnosis and treatment. Nanoparticles (NPs) play an important role in developing new methods for cancer detection. Detecting Cancer early is an important step in improving cancer treatment. Various NPs used are cantilevers, Nanopores, nanotubes, and quantum dots. These are briefly described in the literature.[12]

Nanospores

Another interesting device is the nanopore. Better ways to read the generic code can help researches spot Genetic errors that can cause cancer. The nanopore contains tiny holes that hallow deoxyribonucleic acid (DNA) to pass through her one well at a time, thus making DNA sequencing more efficient.[12]

Cantilever

When cancer cells secrete their molecular products, antibodies coated on the cantilever fingers selectively Bind to these secreted proteins. The physical properties of the cantilever change in real time, providing Information on the presence and concentration of various molecular expressions.[12]

Nanotubes

Carbon rods about half the diameter of a nanotube DNA molecule not only detect the presence of altered Genes, but also pinpoint the precise location of these alterations. A multidisciplinary team at the Massachusetts Institute of Technology has developed carbon nanotubes (CNTs) that can be used as sensors For anticancer drugs and other DNA-damaging agents in living cells.[12]

Dendrimers

These are spherical, highly branched and synthetic macromolecules with adjustable size and shape.[13] A Single dendrimer can carry a molecule that recognizes cancer cell, a therapeutic agent to kill those cells, a Molecule that recognizes the signal of cell death. Dendrimer NPs have shown promise as drug delivery Vehicles capable of targeting tumours with large doses of anti- cancer drugs.[12]

Quantum Dots

Quantum dots are tiny crystals that glow when excited by ultraviolet light. Once injected into the body, it Drifted until it encountered cancerous tissue. Deadly cells adhere to a special coating of glowing dots. Particles of light act as beacons to show doctors where the disease has spread.[12]

Nanoshells

Nanoshells have a core of silica and a metallic outer layer. By manipulating the thickness of the layer, Scientist can design beads to absorb near infra-red light, creating an intense heat that is lethal to cancer cells. The physical selectivity to cancer lesion site occurs through a phenomenon called enhanced permeation Retention.[12]

Micelles

Polymeric micelles are biodegradable spherical nanocarriers with a typical size range of 10–200 nm. Micelles are considered ideal vehicles for drug delivery because they offer many important advantages.

Hydrophobic cores can be used to carry pharmaceuticals, especially lipophilic drugs. These drugs are Solubilized and physically entrapped inside with high loading capacity. Polymeric micelles can deliver two or more therapeutic agents simultaneously and release the drugs in a controlled manner. Encapsulated drugs May be released by erosion of biodegradable polymers, drug diffusion through the polymer matrix, or Swelling of the polymer following drug diffusion. External conditions such as pH and temperature changes can also induce drug release from micelles. Furthermore, surface modification of micelles with ligands such As antibodies, peptides, or other small molecules can be used to target the delivery and uptake of these Nanocarriers, thereby reducing systemic toxicity and increasing specificity. And improve effectiveness.[14]

Polymeric NPs

These are delivery devices made from biodegradable polymers and are an attractive option as carriers of Therapeutic drugs in cancer therapy. Polymeric NPs, including nanospheres and nanocapsules, are solid Supports 10–1000 nm in diameter, made of natural or artificial polymers, are generally biodegradable, and Can adsorb, dissolve, trap, and encapsulate therapeutic agents., or covalently bonded. The polymers become Backbones via simple ester or amide linkages and are hydrolysed in vivo by pH changes. NPs are generally More stable than liposomes when administered systemically, but are hampered by poor pharmacokinetic Properties. H. Uptake, restriction of the reticuloendothelial system [RES]. Similar to liposomes, Nanoparticles can be coated with molecules on their surface, intercalated into their structure to improve Pharmacokinetics, or even targeted for delivery or imaging purposes.[15]

Applications

1) Nanorobots in blood clots.
2) Nanorobots in the diagnosis and treatment of diabetes.
3) Nanobots in kidney stones.
4) Nanorobots in cancer treatment
5) Nanorobots in arteriosclerosis
6) Nanorobots in nerve regeneration
7) Nanorobots that help in the elimination of parasites
8) Nanorobots in healing skin diseases[16]

Components of Nanorobots

Power supply, fuel buffer tank, sensors, motors, manipulators, onboard computers, pumps, pressure tanks, and structural support are the different components of a nanorobot.

A nanorobot‘s substructures include:

Fig: These tiny robots could be diseases fighting machines inside the body.

https://images.app.goo.gl/UnoW6UDGweUki7AFA

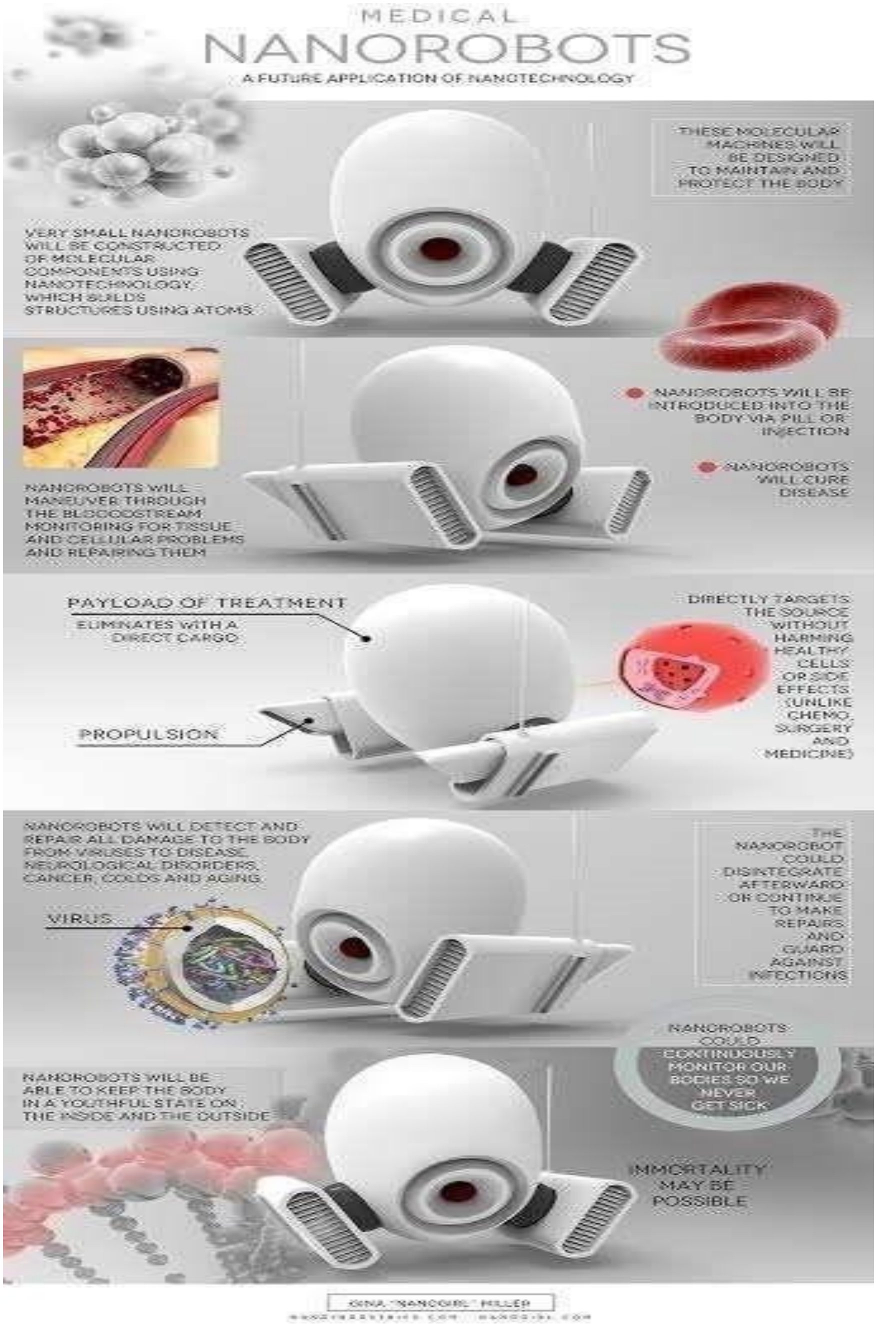

Fig: Nanorobots https://images.app.goo.gl/BTejzgfAyEKqvMyX7

Payload: This hollow region contains a little amount of drug. The nanorobots will move through the blood and deliver the drug to the preferred site.

Micro camera: It helps the operator in directing the nanorobot through the body.

Electrodes: Using the electrolytes in the blood, the electrodes on the nanorobot can form a battery. These electrodes are also able to destroy cancer cells. It is done by creating an electric current and heating the cells to death.

Lasers: They have the ability to burn artery plaque, blood clots, or cancer cells.

Ultrasonic signal generators: They are used when nanobots are used to locate and destroy kidney stones.

Swimming tail: In order to enter the body and travel against the blood flow, nanorobots will require a form of propulsion. They will have motors for movement and manipulator arms or mechanical legs for mobility.

Types of Nanorobots

Basically, there are two types of nanorobots: assemblers and self-replicators.

1) **Assemblers:** They have the shape of cells. They can interpret various types of molecules or atoms.
2) **Replicators:** These are nanobots with the ability to multiply themselves fast. However, some researchers categorisenanorobots in drug delivery and treatment based on their uses. They are listed below.

Respirocyte: It is an artificial oxygen carrier nanorobot. They act similarly to red blood cells in human bodies, but with a relatively larger oxygen load.

Chromallocyte: They are cell-repair robots. They will replace entire chromosomes in individual cells. As a result, they will be able to cure the effects of genetic disease as well as other forms of accumulated damage to our genetic material.

Pharmacyte: They can carry drugs in their tanks. So, they act as drug delivery devices.

Microbivores: They can destroy certain types of bacteria.

Clottocyte: They play a role comparable to platelets in human blood. Platelets have the unique property of aggregating in a wound to form a clot, blocking blood flow.

BiomedicalApplications of Nanorobots

The major area of application of nanorobots is in the medical industry. They are likely to offer novel therapies for people suffering from a variety of diseases. Medical nanobots can help in diagnosis, and treatment of a wide range of diseases. Nanorobots are so small that they interact on the same level as bacteria and viruses do. As a result, they are capable of merging with tiniest particles of our body, such as atoms and molecules. The development of perfect nanobot has not yet been possible. But, the development of such a nanorobot will mark a significant step in the history of science. Because, they can have unique applications in diagnosis and treatment. In the next part, we will discuss the various biomedical applications of nanorobots. Furthermore, you will see the challenges in practical application of them.

Drug Delivery

The limited release of drugs selectively to diseased cells has been a major restraint in traditional drug-delivery systems. To obtain precise drug delivery to specific disease sites, drug carriers must have certain particular qualities. It consists of a pushing force, regulated navigation and release, and tissue penetration. These are still unmet limitations of existing drug delivery systems. However, nanorobots offer a novel and exciting class of delivery vehicles that can satisfy the above requirements.

Therapeutic drugs

A sensing agent and a payload are the two main components of most nanobots. The sensing agent might be one or more chemical strands. The targeted cell has some features that can activate each strand of the sensing agent. When the sensing agents are activated, the nanobots deliver the payload to the desired cell. Furthermore, the payload contains a drug for treatment. Moreover, these molecular delivery vehicles may be programmed to release their payload only when the targeted cell is ill.

Nanomotors (motor- like nanobots) can quickly transport and deliver therapeutic payloads directly to disease sites. As a result, they increase therapeutic efficacy and decrease the side effects of toxic drugs. To prove the delivery function and performance of these nanorobots, several investigations have been conducted in test tubes and in vitro conditions. Although most of these researches have been done in vitro, basic in vivo trials are currently ongoing. For example, magnetically directed nanorobots were used to deliver fluorouracil medicine to a mice model to reduce tumor growth.

Precision Surgery

Robotic systems are used to minimize the challenges involved with complex surgical procedures. They also help to expand the capabilities of human surgeons. This type of robot-assisted surgery is a fast expanding area. It enables doctors to conduct a wide range of minimally invasive surgeries with high precision, flexibility, and control. These tiny robots can travel throughout the human body. Moreover, they can function in numerous difficult-to-reach tissue areas. As a result, they can address many health issues. We can expect these tiny surgeons in near future.

Nanorobots in Biosensing

Nanomotors can detect and separate biological organisms from a mixture of materials. It is possible through an antigen-antibody, complementary pairing, or donor-receptor mechanism. The nanomotors will be functionalized with distinct bioreceptors for this purpose. These receptor- functionalized nanomotors provide strong binding with their complementary system. As a result, sensing is possible. For instance, tubular microrockets loaded with targeting ligands, such as antibodies, aid in the detection of specific cancer cells.

Cancer Diagnosis and Treatment

Early diagnosis of cancer will help to cure it. Nanorobots with a chemical biosensor (nanosensor) help to identify cancer cells in the early stages of development. This nanosensor will detect cancerous cells in the body. Thus, certain nanobots can help in the early diagnosis of cancer in the future.

Although early diagnosis is important, the more important thing is the treatment. There are various types of cancer treatments. But, they all have some serious drawbacks. Firstly, the anticancer drugs may cause damage to the normal cells. Similarly, we are aware of the side effects of chemotherapy. Because of the ability of nanorobots to move within human bodies, they may be useful in cancer therapy. We have already discussed the use of nanobots in targeted drug delivery. We can use this in cancer therapy too.

Moreover, we can all use them to kill cancer cells. For instance, researchers from Arizona State University showed how nanobots can destroy cancer cells using a mouse tumor model. DNA nanostructures (DNA folded to a size of 90nm) and the blood-clotting enzyme thrombin were used to create them. They attack a protein called nucleolin. This protein is only found on the surface of cancer cells. The nanobots release thrombin into the cancer cell after attaching to it. Then, this prevents the blood supply to the cancer cells. Hence, kills the cancer cells. As a result, the experiment was a success, leaving the normal cells unaffected.

Artificial Oxygen Carrier (Respirocyte)

You have already seen the respirocyte in the classification of nanorobots. Let us discuss them in detail. We know that they act as red blood cells. It is an imaginary nanorobot that floats in the bloodstream. It is basically a tiny pressure tank that can be filled with oxygen and carbon dioxide molecules. Moreover, a controlled release of these gases from the tank is possible.

Gas concentration sensors are located outside each nanorobot. The oxygen partial pressure is high and the carbon dioxide partial pressure is low in the lung capillaries. As a result, the nanobots will load it with oxygen and discharge the carbon dioxide. When the partial pressure of carbon dioxide is very high and the partial pressure of oxygen is relatively low, this will reverse. As a result, respirocytes mimic the activity of normal hemoglobin- filled red blood cells. They can, however, provide 236 times more oxygen per unit volume than a genuine red blood cell.

Respirocytenanorobots and red blood cells in bloodstream

Illustration of respirocytes in blood stream

Hype vs. Reality

There are lots of hypes and claims related to the applications of nanorobots. According to some researchers, tiny nanorobots might be flowing through your bloodstream within the next ten years. A vast number of suggestions for the possible use of nanorobots in medicine are arising. Furthermore, nanotechnologists expect that these tiny robots will be commercialised in the near future. Actually, DNA robots are already being tested in animals to identify and destroy cancer cells.

However, commercialisingnanorobots is not as simple as that. Because there are several challenges in using nanorobots in the human body. In the next part, we will look at these challenges. As we all know, new drugs take up to 15 years of testing before they get approval. As a result, nanorobots, as an external device injected into human bodies, will require significantly longer time to obtain approval for use. Furthermore, people‘s readiness to accept the usage of a new treatment method should be considered.

Meanwhile, expectations for nanomedicine remain high. Over the last decade, the expected commercial potential has not declined or even stayed constant. But it has only increased. As a result, it is fair to assume that the expectations and predictions for nanorobotics will likewise come true in the future.

Challenges and Future Scope in Nanorobotics

Nanorobots might be a new, supporting, and hopeful machine technology for patients in the treatment and diagnosis of life-threatening illnesses. The focus in the medical field will move from medical science to medical engineering in the future, with nanorobotics as the revolution. Future efforts will be necessary to move nanorobots from test tubes to living organisms. Nanorobots have already been shown to work well in viscous biological fluids such as gastric juice and whole blood. Because of the foreign nature of nanobots in humans, operating them in human tissues and organs requires careful examination.

The nanomotors for in vivo applications should be much smaller in order to allow their transport into cells and capillaries with narrow dimensions. Furthermore, it is critical to address biocompatibility concerns. Therefore, nanobots that can self-decompose into harmless compounds after completing a task would be incredibly useful. Moreover, the human body will resist any foreign material. Anyone interested in this field should be aware of the challenges. Because understanding the difficulties will allow you to contribute to research in nanorobots. As a result, they can fill gaps in the research.

Solving these special demands will result in a faster translation of nanorobot research into medical applications. We believe that with close collaboration between the nanorobotic and medical communities, these problems may be solved progressively, eventually broadening the range of nanorobots in medicine.[17]

CONCLUSION

In this review, the main focus was on the importance, function, types, and application of nanorobots, especially for cancer treatment. The nanorobots can support or improve treatment efficiency by performing advanced biomedical therapies using minimally invasive operations. Chemotherapy‘s harsh side effects and untargeted drug distribution necessitate new cancer treatment trials. The key advantage of nanorobots is their speed and durability.

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