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An overview of Nanorobotics Advancements in Cancer Therapeutics

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ABSTRACT:Nanorobotics is a rapidly developing field with the potential to revolutionize cancer treatment. Nanorobots are tiny machines that can be programmed to perform specific tasks inside the body. They offer a number of advantages over traditional cancer treatments, such as the ability to target tumors directly, deliver drugs more effectively, and reduce side effect.

The review paper aims to comprehensively outline the current trends and advancements in the field of nanorobotics as applied to the treatment of cancer. Nanorobotics plays a crucial role in cancer treatment by effectively locating and eliminating cancer cells. The primary functions of nanorobotics in this context include navigation, sensing, signaling, information processing, and exhibiting intelligence, all performed at the nanoscale.

KEYWORDSNanorobot, Cancer Therapy, Nanotechnology, Pharmacyte, Targeted Drug Delivery

I. BACKGROUND

One of the most serious fatal diseases in today's world which results in death of millions of peoples is the cancer. Cancer requires very complex treatment process because the process of apoptosis is greatly disappeared. It shows clinical diversity and therapeutic resistance because of the complexity in genetic and phenotypic levels due to which a diversity of approaches are being practised for the treatment which has significant restrictions and side effects. The treatment processes includes radiation therapy, chemotherapy, surgery and hormone therapy.

The key problem with current chemotherapy is not that the drugs are not particularly effective, and the existing cancer treatment drugs are not able to successfully kill growing tumor cells, and the rest of the body cannot tolerate the drug concentrations which is required to eliminate the cancer cells. The drug concentration are high enough to destroy the tumors, but it can kill the patient first because of the aggressiveness of treatment process. The mechanism of chemo-therapy treatment is usually determined by doses the patient can withstand rather than doses needed to eliminate all cancerous cells.

The main objective of nanotechnology wherein the drug is engineered in such a way that it can identify the cancerous cells from normal healthy cells to lessen their growth and proliferation. (Dubey[1] & Milesh[1], 2018)

Table 1: Worldwide cancer statistics by decade. It is estimated that 13.1 million people will die from cancer by 2030. From all these statistics, it can be concluded that cancer in men and cancer in women are the most common cancers in the world. We are talking in India. While men suffer from breast cancer and lung cancer, women are more likely to suffer from breast cancer, stomach cancer and breast cancer. Compared to white men, black men are twice as likely to die from cancer. Although white women are more likely to get breast cancer, black women have the highest deathrate.

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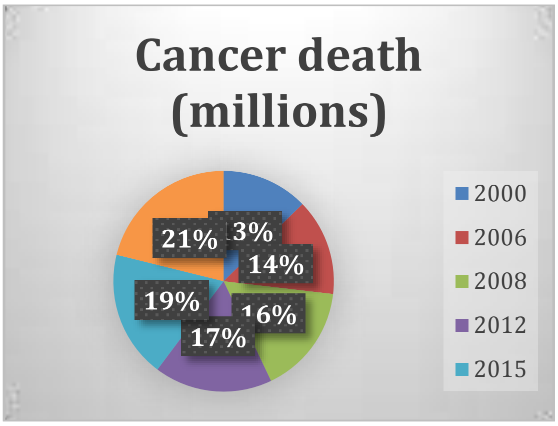

Figure 1 Global cancer death statistics

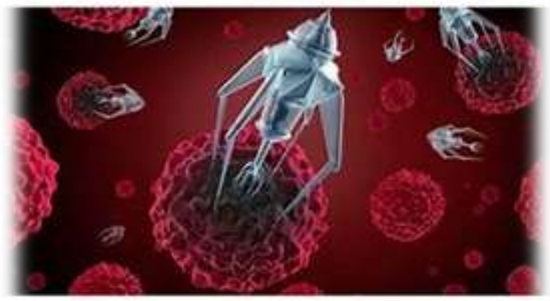

Figure 2 Nanorobotics

II. INTRODUCTION

Nanorobot

The word" nano" originates from the Greek word" dwarf" The conception of nanotechnology was first developed in 1959 by Richard Feynman.

Nanorobotics is an emerging field of science and technology that involves the design and manipulation of nanoscale robots, often referred to as nanorobots. These tiny machines, typically on the scale of nanometers (one-billionth of a meter), hold immense promise in various applications, including medicine and cancer therapy.

Nanorobots are extremely small machines built at the nanoscale, allowing them to interact with biological systems at the cellular or molecular level. They can be composed of various materials, such as carbon nanotubes or DNA strands, and are designed for specific tasks.

Nanorobots are tiny devices designed for medical and manufacturing tasks at the molecular level (1-100 nm). They aim to prevent or treat diseases. Carbon, especially in diamond and fullerene forms, is a key material due to its durability. Nanorobots have a passive diamond layer to avoid immune system attacks. Being too small to see with the naked eye, they are challenging to study using techniques like scanning electron microscopy (SEM) and atomic force microscopy (AFM). (Pathan & Deshmukh, 2023)

❖ **Types of nanorobots**

Some researchers classify nanorobots in drug delivery and therapeutics according to the their applications, which are described below.

a) Pharmacyte
b) Diagnosis and Imaging
c) Respirocyte
d) Microbivores
e) Clottocytes
f) Chromallocyte

a) Pharmacyte

It is a 1-2 µm long medical nanorobot that can carry 1 µm3 of the drug administered into the tank. They are controlled by the use of the pump. It is equipped with molecular markers or chemotactic sensors that guarantee complete accuracy. Oxygen obtained from the local environment such as blood, gastric fluid, and cytoplasm is the energy of the ship. Once the nanorobot has completed its work, it can be removed or recycled via centrifugal nano separation.

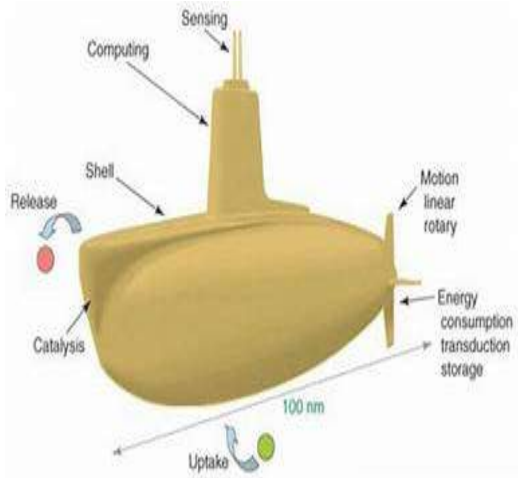

Figure 3 A Fictitious pharmacyte

b) Diagnosis and Imaging

These microchips can identify diseases by sending electrical signals when detecting specific molecules associated with the illness. For instance, special sensor nanobots can be introduced under the skin to analyze blood contents and alert about potential diseases, including monitoring blood sugar levels. These nanobots offer advantages like cost-effectiveness and ease of manipulation.

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Figure 4 Nanorobots in blood vessels for diagnosis and imaging

c) Respirocyte

It is an oxygen-carrying nanorobot that expresses red blood cells. Energy is obtained from endogenous serum glucose. Progenitor cells deliver 236 times more oxygen and acid to tissues per unit volume than RBCs (red blood cells).

d) Microbivores

It is a flat spherical device for nanomedicine applications, with a major axis diameter of 34 µm and a minor axis diameter of 2.0 m. Nanorobots can continuously use up to 200 pW of energy, which is used to digest captured bacteria. Another special report mentions the ability of phagocytic cells to approximately 80 times outnumber macrophage workers in terms of volume digested per unit volume/second.

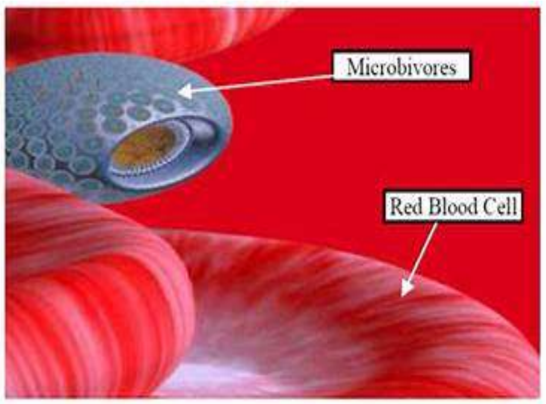

Figure 5 Microbivores

e) Clottocytes

This is a nanorobot with a unique and fun ability that can use blood clots or artificial devices to "instantly" stop bleeding. As we all know, platelets are spherical, nucleated blood cells with a diameter of 2 microns. Platelets bind to the bleeding site: here they strengthen, become sticky, and combine to form a cushion that helps close the blood vessels and stop bleeding. bleeding. They also prescribe medications that help blood clot.

f) Chromallocyte

The Chromallocyte is a revolutionary technology designed to substitute entire chromosomes within individual cells, effectively reversing the impact of genetic diseases and mitigating damage accumulated over time. To initiate the repair process, the repair machine assesses the cell's contents and activity. It then proceeds to meticulously repair the cell on a molecular and structural level. This repair capability enables the restoration of entire cells, offering a comprehensive solution to genetic ailments and aging. (Pathan & Deshmukh, 2023)

III. IDEAL CHARACTERISTICS OF NANOROBOTS

- Nanorobots can be easily incorporated into human bodies.
- Nanorobots must have size in between 0.5 to 3 microns large with 10 nm parts.
- Nanorobots of larger size than the above will block capillary flow.
- It will prevent itself, from being attacked by the immune system by have passive, diamond exterior.
- It will communicate with the doctor by encoding messages to acoustic signals at carrier wave frequencies of 1-100 MHz.
- It might produce multiple copies of it to replace worn-out units, a process called self-replication. (Dr.Mehra & Nabhi, 2016)

IV. ADVANCEMENTS IN NANOROBOTICS

a. Drug Delivery

One of the most significant advancements in nanorobotics lies in their ability to enhance drug delivery. Nanorobots can navigate through the bloodstream, locate tumor sites, and deliver precise doses of drugs directly to cancer cells, minimizing systemic exposure and reducing side effects on healthy tissues. This targeted approach can significantly improve the efficacy of chemotherapy and reduce its associated toxicities.

b. Tumor Detection and Diagnosis

Nanorobots equipped with biosensors can act as intelligent probes, detecting and identifying cancer cells with high sensitivity and specificity. They can patrol the body, seeking out tumor cells and sending signals back to a monitoring device. This early detection capability can enable timely intervention and improve the chances of successful treatment.

c. Targeted Therapy

Nanorobots can be programmed to interact with specific molecules on the surface of cancer cells, allowing for targeted therapy. By attaching therapeutic agents directly to tumor cells, nanorobots can deliver localized treatment, minimizing damage to healthy tissues and enhancing treatment efficacy.

d. **Remote Sensing and Imaging**

Nanorobots equipped with imaging technologies can provide real-time feedback on the location and status of tumors. This enables precise monitoring of the treatment progress and allows for adjustments in therapy as needed.

e. Hyperthermia Therapy

Some nanorobots can generate heat when exposed to specific stimuli, such as light or magnetic fields. This property is exploited in hyperthermia therapy, where nanorobots are used to heat and destroy cancer cells while sparing surrounding healthy tissue.

f. Microsurgery at the Cellular Level

Advanced nanorobots have the potential to perform precise surgical tasks at the cellular or molecular level. This can include cutting off blood supply to tumors, removing abnormal cells, or repairing damaged cellular structures.

g. Smart Nanorobots

Incorporating artificial intelligence (AI) and machine learning into nanorobots enhances their ability to adapt to the complex and dynamic nature of cancer. Smart nanorobots can make decisions based on real-time data and optimize treatment strategies for individual patients.

h. Minimally Invasive Surgery

Nanorobots can perform delicate surgical procedures with precision and minimal invasiveness. They can navigate through blood vessels and reach tumors in hard-to-access areas, removing or destroying cancerous tissue without the need for large incisions. This minimally invasive approach can reduce patient recovery time and improve surgical outcomes. (Mehta, Borkhataria, & Tejura, 2023)

❖ **Current therapy of cancer**

Among the problems of cancer, resistance to drugs and their delivery systems is the biggest problem in treating and reducing the signs and symptoms of cancer, but many recommendations and medications are now available. The effectiveness of cancer treatment decreases due to abnormal tumor pathology and tumor vascular pattern.

The following are the advanced and innovative cancer therapy types with their benefits and challenge.

- Stem cells therapy
- Pluripotent stem cells
- Adult stem cells
- cancer stem cells

a) Stem cells therapy

Bone marrow (BM) contains undifferentiated cells called stem cells, which possess the ability to differentiate into any kind of body. Strategies utilizing stem cells are also thought to be secure and efficient in the treatment of cancer. Clinical trials are still being conducted for stem cell uses. For instance, its application in the restoration of more injured tissues is being looked into. Trials using mesenchymal stem cells (MSCs) for bone marrow delivery are presently underway. Fat tissue and connective tissue.

b) **Pluripotent stem cells**

Separated from the embryo's homogenous core cell mass, embryonic stem cells (ESCs) has the ability to differentiate into any or all cell types, with the exception of placental cells. A revolution in cell biology occurred in 2006 when Yamanaka discovered qualities that could induce pluripotent stem cells (iPSCs) from human cells in culture. 17 To stay away from ethical problems with coculturing iPSCs and ESCs that result from embryo injury. embryonic stem cells with hematopoiesis (hESCs) and iPSCs are being employed in the production of antibodies as well as the stimulation of effector T cells and natural killer (NK) cells 18**.**

c) Adult stem cells

Hematopoietic stem cells (HSC), mesenchymal stem cells (MSC), and neural stem cells (NSC) are three adult stem cell (ASC) types that are frequently employed in cancer therapy. body. At the moment, leukemia and multiple myeloma can only be treated using cord blood hematopoietic stem cell injections authorized by the FDA in the United States. 20 Numerous tissues and organs include mesenchymal stem cells, which are crucial for tissue regeneration and repair. comprises cells like chondrocytes, adipocytes, and bone cells. The distinct biological characteristics of MSCs might be utilized as an as an addition to existing tumor treatments. 21 NSCS have the ability to self-renew, produce new glial and neuronal cells, and be employed in the therapy for metastatic breast cancer as well as other cancers.

d) cancer stem cells

Normal stem cells or precursor/progenitor cells undergo epigenetic alteration in order to produce cancer stem cells (CSCs). It may be promising for the treatment of cancer because of its functions in the growth, metastasis, and recurrence of cancer. 23 The use of stem cells in tumor treatment is multifaceted. The process of "homing" is whereby HSCs quickly move to BM stem cell niches, where they engraft the graft and go on to produce specialized cells. Stem cell CXCR4 receptors are essential for this process, since they connect with endothelial cells through LFA-1, VLA-4/5, CD44, and the release of matrix-degrading enzymes (MMP-2/92). The second pathway involves the migration of mesenchymal stem cells into the tumor and their subsequent migration into the Tumor cells release CXCL16, SDF-1, CCL-25, and IL-6, which attract the tumor microenvironment (TM). TM) induces differentiation, which leads to the formation of tumor stroma. several types of blood. (Dubey[1] & Milesh[1], 2018)

❖ Application of Nanorobots

- **Dentistry**

The dental treatment, utilizes the nanorobots as dentirobots which induce straighten irregular set of teeth, oral analgesia and desensitise tooth.

- **Treatment & Diagnosis of Diabetes**

This branch involves the determination of need for injecting insulin inside the body for maintaining the blood sugar level in the human metabolism, monitoring glucose level in the body using nanorobots which generally uses the chemosensors. (Pathan & Deshmukh, 2023)

- **Deliver the drug**

Nanorobots can transport drugs to the site of action using the drug delivery carriers known as Pharmacytes which will deliver the drug to the targeted point. The dosage of the drug in the carrier is loaded depending upon the haul of the pharmacyte. (Dr.Mehra & Nabhi, 2016)

- **Surgery**

Surgical nanorobots are one of the tools which performs the functions such as diagnosing, spotting of pathological site, befitting injuries by nanomanipulation etc.

- **Gene Therapy**

Nanorobots are used to treat the genetic disorders by studying the molecular structure of both nucleic acids and proteins found in the cell.

- **Targeted Treatment**

Nanorobots can be designed to selectively target and destroy cancer cells, offering a more localized and effective treatment approach.

- **Imaging**

Nanorobots with imaging capabilities can provide real-time feedback on the status of tumors, aiding in diagnosis and treatment monitoring.

- **Cancer Detection and treatment**

Nanorobots are capable of detecting tumour cells which is composed of protein and a polymer known as transferrin which blocks the natural functions of cellular iron uptake directly leading to the death of cancer cells. These robots kill the cancer cells without damaging the healthy cells without any side effects.

- **Microsurgery**

Nanorobots can perform precise surgical tasks at the microscopic level, allowing for minimally invasive procedures and highly accurate interventions (Sivasankar & Durairaj, 2012)

III. CONCLUSION

Nanorobotics is a rapidly developing field with the potential to revolutionize cancer treatment, offering advantages such as targeted tumor delivery, effective drug delivery, and reduced side effects.

Nanorobots in cancer therapy can be controlled by pumps and equipped with molecular markers or chemotactic sensors for accuracy. They can obtain energy from the local environment and be easily incorporated into the human body.

Nanorobots have the potential for self-replication and can communicate with doctors through encoded messages in acoustic signals. They can also identify diseases by sending electrical signals when detecting specific molecules associated with the illness.

Nanorobotics holds immense promise in various applications, including medicine and cancer therapy, and involves the design and manipulation of nanoscale robots.

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