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NANOTECHNOLOGY: A RAY OF HOPE IN MEDICAL FIELD WITH A SPECIFIC FOCUS IN CANCER

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Abstract:
The use of nanotechnology is becoming more and more prevalent in medicine as well as in our daily lives. Till date, nanoparticles are the most promising method for delivering large amounts of drugs precisely and directly to cancer cells; as a result, several of these nanomaterials have been developed. These range from basic nanoagents to complex smart devices used for imaging or medication administration. Due to their vast surface area, nanomaterials often allow for the incorporation of many moieties on the surface for either additional functions or targeting. In addition to only utilizing particles for imaging, they can also carry a therapeutic drug as a payload. A theranostic agent is produced and both are combined inside the same particle. The sophistication of highly developed nanotechnology targeting techniques offers a potential avenue for clinical applications in cancer and may enhance the utility of otherwise sub-optimal formulations. This review will cover nanotechnology in both imaging and treatment, offering a broad picture of the subject and its effects on cancer imaging and treatment.

KEYWORDS: Nanoparticles, nano-technology, cancer, chemotherapy, targeted therapeutics

Introduction:

Nanotechnology (NT) is a potent innovative force that is having an increasing effect on societies and the environment worldwide. The interdisciplinary approach is perfectly represented by the NT revolution, which is bringing scientists together from almost all fields of scientific study. Despite the evident advantages, there are increasing worries about the effects on human health and safety as well as environmental protection [1]. The NT community is striving to establish standards for nanofabrication, nanosynthesis, and waste removal for the existing nanoparticles (NPs) in order to allay these issues [2, 3]. These enhancements to the NT revolution will support the creation of products that are nontoxic, biocompatible, scalable, biodegradable, programmable or intelligent, environmentally friendly and extremely efficient [4, 5]. Further, biomedical NT (BNT), which aims to create nano-based therapies, treatments, and diagnostic procedures that will improve health care, is one of the most notable subcategories of NT [6]. By facilitating high-throughput screening capabilities, creating, *in vitro* and *in vivo* models, to track their nano-products inside living things and environment, and these breakthroughs are increasing the precision and accuracy in research [7]. The use of these models will significantly improve the process of development of nanomedicine, which will ultimately result in a more effective therapeutic product. In general, the use of BNT in its current applications is greatly improving scientific research, which is leading to the development of precise and individualized nanotechnology-based medicines and health care. The personalized treatments, which will mainly concentrate on choosing the intensity, dosage type and level based on a patient's unique illness profile, creation of complete genomic, proteomic, metabolomic, and cytomic databases

will enable researchers to choose the best therapeutic procedures [7]. Nanoformulations can be designed to express extended half-life, targeted delivery, regulated drug release and improved permeability, by altering the nanoformulations designs, to the omic-based evidence. The effectiveness of traditional medicines has been surpassed by that of nanomedicine in a short amount of time [7]. The majority of therapies in the past were successful in treating illnesses, but they usually lacked the curative potential that the BNT breakthrough is making possible.

Synthesis:

A variety of synthesis techniques [8], nanomaterials or nanostructures can be produced from both organic materials, such as, micelles, liposomes, dendrimers, inorganic sources, polymeric nanoparticles, and metal nanoparticles. With certain objectives in mind, such as connecting with particular medications, attaining accurate dispersion control, enabling targeted delivery, and making changes for therapeutic applications [9], a wide variety of nanostructures may be produced. When the function of nanoparticles (NPs) are combined drugs and other biomolecules, they can evade immune cells, stay in the body for a long time, and spread more effectively and accumulate at greater concentrations in target tissues, prevent unintentional distribution to neighbouring tissues, and release therapeutic agents in a regulated manner over time in response to particular stimuli. The production of nanomaterials with different approaches providing unique benefits and drawbacks. For instance, these physical approaches use external stimuli, in the form of thermal decomposition and laser ablation [10], and promotes nanoparticle formation. But, scalability is the limitation and requires more specialized machinery. Chemical processes: These approaches allow for customization of nanoparticle characteristics but necessitate close attention to reaction parameters and optimization. Biological techniques: These approaches offer a sustainable and environmentally responsible way to create nanoparticles by utilizing biological systems [10]. Biological approaches, on the other hand, often need more time for processing and may have difficulties producing large quantities and maintaining uniform quality. Due to their distinctive physicochemical characteristics, such as surface plasmon resonance (SPR), which enhanced therapeutic efficacy and targeted medication delivery, magnetic nanoparticles (MNPs), have been known to contribute in the field of drug design and development [11]. The biological activity, zeta potential, and interactions of metal nanoparticles with charged cell surfaces are all affected by the cooperative wavering of free electrons at their surface, which is what causes SPR. Paclitaxel has been integrated into modified iron oxide nanoparticles that exhibit both receptor-mediated targeting and superparamagnetic properties [12], demonstrating how this technique has been used to provide accurate medication delivery. Other inorganic nanoparticles, such as polymer-modified black phosphorus nanosheets and nano-ceramide-graphene oxide (GO) hybrids, have shown improved drug delivery, biodistribution, circulation, and anti-cancer properties [13,14].Due to their nanoscale characteristics, inorganic nanoparticles are being engineered in the growing area of nanobiotechnology to address the unique issues posed by unusual therapeutic candidates [15]. Silver (Ag) has stood out among these nanoparticles for its unique biological qualities and wide range of possible uses [16]. Due to its nanoscale size, silver is better able to permeate tissues, particularly through damaged skin. Additionally, biomolecule-capped silver nanoparticles (AgNPs) have a high affinity for mammalian as well as potent antibacterial capabilities **(Figure 1).** Because of their potent ability to regulate inflammatory responses and inhibit microbial growth, AgNPs have been widely employed in medical equipment to prevent infections [17]. In general, inorganic nanoparticles offer exciting prospects for the creation of novel medicines, as their versatility and distinctive characteristics provide tremendous promise for better patient outcomes, more accurate drug delivery, and improved treatment efficacy. Nanoparticles (NPs) have proven to be a promising approach for drug delivery, by the usage of materials such as chitosan (ChNPs), polyethylene glycol (PEG) and polyacrylic acid (PAA) [18]. However, these nanoparticles frequently requires the use of chemicals, which increases the environmental concerns. Furthermore, some NPs need the use of peptides or polymers like PEGylation [19], to increase their therapeutic potential and biocompatibility. However, these methods are often time-consuming and complicated. Due to their straightforward production method and inherent compatibility with living systems [20], lipid-based

nanoparticles, specifically liposomes and nanoliposomes, have garnered significant interest in addition to polymers. Using methods like the thin-film dispersion approach, researchers have successfully developed lipid-based nanoparticles (NPs) for delivering a variety of drugs. By improving the drug's ability to be absorbed in the body and its capacity to dissolve in water, improved drug delivery approach. Wang et al., study [21] showed that brinzolamide may be encapsulated using a stabilizer called hydroxypropyl-beta-cyclodextrin. The recent advances have also made it possible to create sophisticated delivery methods that make use of nanoliposomes. Further, peptide–lipid nanoparticles have a unique structure that combines the advantages of liposomes and polymers, resulting in greater water solubility, medication dispersion, sustained release, and better pharmacokinetics [22]. Because of their great versatility, liposomes stand out among organic nanoparticles and lipid molecules, enabling them to efficiently deliver a variety of therapeutic substances, including pharmaceuticals, imaging agents, bioactive compounds and photosensitizers. They are ideal for carrying hydrophobic and hydrophilic medications [23] because of their unique features. Furthermore, liposomes can be modified to fulfill particular needs by incorporating surface modifications like PEG, target ligands, or leaving them uncoated. One of the most noteworthy features of liposomes is their capacity to encapsulate a variety of medications, contrast agents, and photosensitizers within a single structure, for regulated medication release and appropriate delivery [24]. Liposomes are a promising alternative to polymeric nanoparticles because they are biodegradable and biocompatible. Lipid-based nanoparticles (NPs), notably liposomes, are an extremely promising field of study in drug delivery due to their outstanding flexibility and capacity to deliver drugs to particular targets. By focusing on these innovative approaches, we may pave the way for more effective and precise therapeutic treatments.

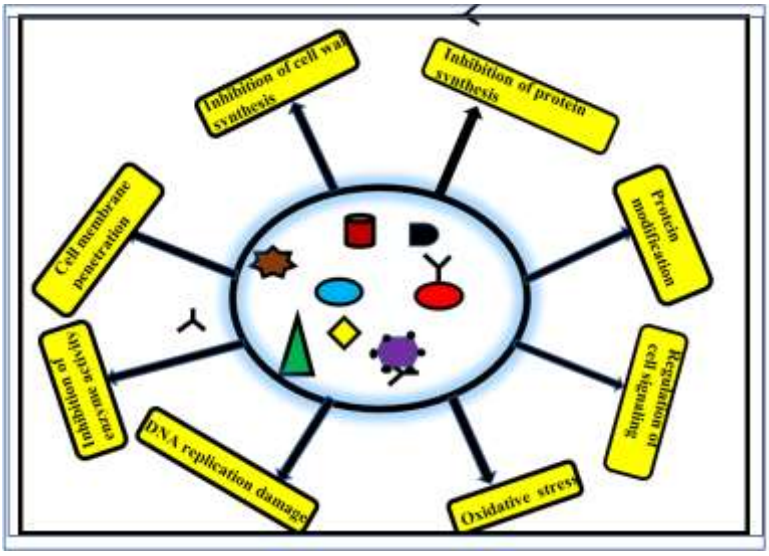

Fig 1 : Nanoparticles confering anti-microbial activities in number of ways, while using medical equipments

Nanoparticles used in the field of medical:

Nanoparticles have a high surface-area-to-volume ratio, because of their nanoscale size, which enables them to absorb large amounts of drugs and travel quickly throughout the bloodstream. Based on their chemical constitution, nanoparticles are divided into three groups: organic, inorganic, and carbon-based [25]. Some of the major classifications of nanoparticles are shown in **Figure 2**. Organic nanoparticles, such as those with a radius of less than 100 nm, are created from the synthesis of carbohydrates, proteins, lipids and other organic molecules. In comparison to organic compounds, inorganic nanoparticles have superior biocompatibility, hydrophilic properties, non-toxicity, and high stability. Elemental metals, metal oxides, and metal salts are examples of inorganic nanoparticles. Carbon-based nanomaterials include graphene, its derivatives, carbon nanotubes, and fullerenes [25].

Due to their unique structural dimensions, these materials have attracted the attention in a variety of domains, including biomedical applications. In response to the light, the nanoparticles heat up to the point where they can kill cancer cells. In the future, nanoparticles might be injected straight into the bloodstream and develop into cancerous tumors, according to researchers. Smart pills are drug releases that include digestible sensors that can be adjusted to regulate a medicine dosage throughout the body. As with any novel and revolutionary technology, nanomedicine encounters intrinsic barriers, the most notable of which is that it has been widely adopted in clinical practice. Nanotechnology's environmental effects build up in living tissues and organs and can be produced at a reasonable cost [25].

Nano-theranostics are nanoformulations, combine the delivery of a payload and luminescent molecular tag, to a targeted location in order to track bioactivity, enhance therapeutics, decrease the toxicity of imaging agents, and improve the abilities of nano-imaging instruments, for example, a nanoformulation is being created that can specifically target pancreatic cancer cells to deliver gemcitabine, (an anti-cancer medicine), tagged with gadolimium [26]. The main benefit is that these two chemicals are harmful in their unbound forms and can lead to a number of problems, but, here the toxicity is removed [27]. The nanoformulation may be tracked using MRI, thanks to the gadolinimum, which guarantees its delivery to the intended site during systemic circulation [26,27]. However, in recent years, manganese (Mn) has taken the place of gadolinium as a less hazardous T1 MRI contrast agent. In addition to its paramagnetic characteristics, Mn has a longer plasma half-life, which significantly increases its targeting potential for theranostic administration [28]. Further, excellent T1 MRI formulation was given to mice (intranasally) which was found to be a potent vehicle for lung cancer theranostics [28]. Using novel biomimetic NCs called leukosomes, another theranostic approach now under development aims at the endothelial cells of inflammatory sites [29]. In order for NPs to carry out theranostic functions, chitosan has also been used to functionalize a large number of NPs. The ability to use an external magnetic field to draw nanoparticles (NPs) to a particular region of the body is known as magnetofection [30]. Furthermore, chitosan combined with graphene oxide creates the best gene delivery vehicles, which are the promising for chemo, gene and phototherapies for cancer treatment [30]. The primary benefit of these chitosan-graphene oxide nanoparticles (NPs) is that they may aid in the simultaneous delivery of MRI contrast agents, DOX, and anti-cancer plasmid DNA [31]. This combination strategy resulted into a potent platform for cancer treatment as well as *in vivo* tumor imaging [31]

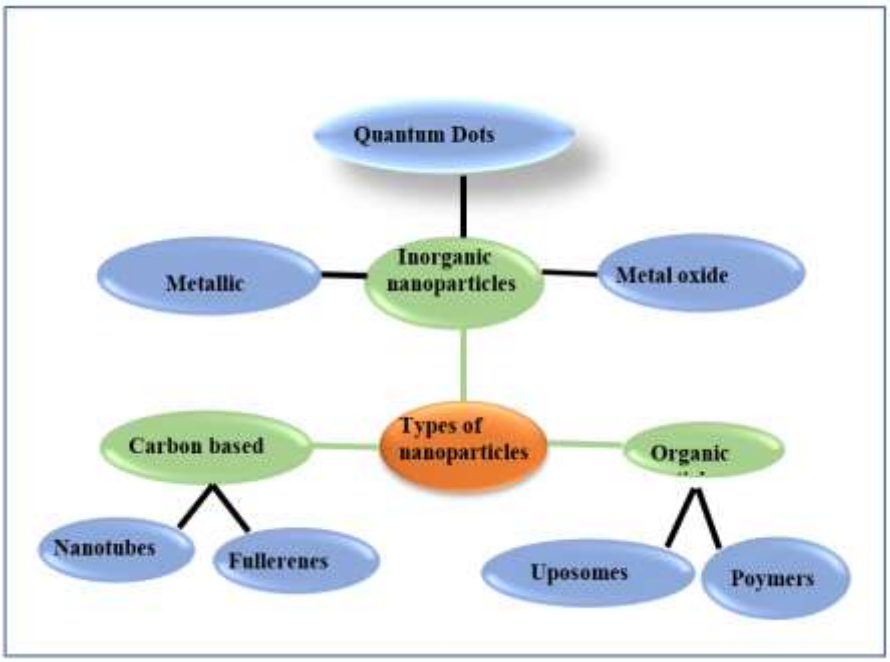

Fig 2 : Types of nanoparticles used in the medical field

Nanotheranostics for Cancer Patients

Nanoparticles that respond to stimuli are being added to nanoformulations that are designed to target tumor cells, and they can cause full cancer cell ablation and improved tumor theranostics when exposed to radiation, photonics, heat, or magnetic stimulation and avoid the cytotoxic effects on healthy cells, for example, radiotherapy is a highly successful cancer treatment method, but it has historically been associated with significant negative side effects [32]. However, it is now possible to perform safe and highly effective radiotherapy *in vivo,* using tumor-targeted NCs containing metal-based nano-enhancers [32]. These NCs at the tumor sites, are activated by X-rays, and gamma rays and cause cancer cell death via cell cycle arrest, induction of oxidative stress, inhibition of DNA repair or mitochondrial failure [32]. When magnetic NPs that have reached the tumor site are subjected to a very rapid alternating external magnetic field, their magnetic moments produces sufficient heat to kill the cancer cells (33). Additionally, magnetic NPs provide theranostic capabilities which allows NPs for *in vivo* precise targeting of tumor cells to avoid any cytotoxic effects on healthy cells [34]. In addition, photo-sensitive nanoparticles, another agent that serves as an anti-cancer drug to achieve full tumor ablation [35]. Photothermal therapy (PTT) is what this is called, and it has been demonstrated to have higher, non-invasive anti-cancer benefits than traditional surgical and chemotherapeutic procedures [35]. Furthermore, a patient's recovery time is brief, the incidence of negative side effects is greatly reduced, and the rate of cancer recurrence is low [35] after PTT. In mice infected with breast cancer, complete tumor ablation was shown to be successful when this theranostic nanomedicine was administered in mice [35]. In a study where photosensitizing chemicals were loaded into hollow silica NPs and surface-functionalized for increased retention, photosensitizing agents were utilized to induce tumor ablation through photodynamic therapy (PDT), active agent for tumor ablation induction, was this PDT agent, which produces hydrogen peroxide, ROS, which causes mitochondrial failure. PDT is an oxygen-dependent process [36]. Surprisingly, another study found that by altering the amount of ATP, induced ROS production to prevent multidrug resistance in cancer cells [37]. This was made possible by targeting the pyruvate molecule in the mitochondria with lipid membrane-coated silica-carbon (LSC) hybrid nanoparticles [37]. The production of ROS starts with NIR radiation, which oxidizes NADH and causes an increase in the amount of NAD+ [37]. The possibility that multidrug-resistant cancer cells may arise poses a serious threat and an increasing problem that this treatment could help solve. Redox-responsive NCs are used to facilitate the last form of stimuli-responsive cancer treatment, which is now gaining traction. When these NCs are internalized into cells, which have a far higher concentration of glutathione (GSH) than the extracellular environment, they respond to the shift in glutathione levels [38]. The gradient of reduction potential that the NCs are exposed to is used as stimulus that can induce intracellular release [38]. The higher concentration of GSH in tumor cells compared to healthy cells [38] makes this mechanism particularly useful for cancer treatments. The co-delivery of gemcitabine and DOX [39] was achieved by functionalizing these polymersomes for folate-targeting. The model demonstrated to express augmented intracellular release induced via GSH in pancreatic and breast cancer cells [39]. Nevertheless, this model may be adapted to an *in vivo* environment and have significant anti-cancer benefits.

Theranostic nanoparticles: In surgical application

The improvement of cancer imaging techniques is a major focus for identification of cancer cells, now a days. *In vivo* fluorescent guided therapy, uses fluorescence to highlight, every malignant cell in the patient, in-order to guarantee accurate surgical excision [40]. This method even makes cancer cells into visible tumors visible, lowering the chance of the cancer returning after surgery [40]. Certain biomarkers are used by theranostic NCs to fluorescently label cancer cells. By combining bioinformatics with diagnostic approaches, it is possible to identify the most distinctive and unique biomarkers for each cancer type for usage as the target molecule, guaranteeing that only malignant cells are targeted. In mouse models, this method has been effective, and it is becoming more and more popular for improving the accuracy of surgery [41]. Optical Tomography, another distinctive diagnostic technique that uses multimodal *in vivo* imaging technology, creates 3D optical images

using multimodal imaging using μCT and MRI [42]. Using fluorescent nanoparticles, NIR fluorescence-enhanced diffuse optical tomography (fDOT) has previously been employed to identify malignancies in mice. This kind of technology will advance our understanding and ability to diagnose illnesses in their earliest stages by identifying issues and their underlying causes [42].

Organic nanoparticles in cancer therapy

The use of organic nanoparticles (NPs) in targeted cancer therapy has undergone a surge in research in recent years, transforming medication delivery systems. For the delivery of bioactive compounds and therapeutic drugs, PEG-PLA and PEG-PLGA nanostructures are especially promising [43]. The efficacy of these materials in cancer treatment is largely due to their outstanding stability and regulated release. Furthermore, because of their distinctive dimensional characteristics and potential anticancer properties [44], carbon-based compounds such graphene oxide (GO) have attracted attention in order to develop creative therapeutic strategies and targeted medication delivery in cancer care. Formulations, such as PEG-platinum and PEGAg nanostructures, are among the PEG-based NPs that include both hydrophilic and hydrophobic moieties, for drug delivery [45]. Furthermore, PEG-PLA copolymer-based NPs, are used for the targeted delivery of anticancer medicines, like hydrophobic platinum and Capecitabine. PEG conjugated with beta-Cyclodextrin, has shown improved capacity for delivering anticancer medicines like Sorafenib and Doxorubicin [46]. Furthermore, the remarkable potential of these nanocarriers has been demonstrated in applications in immunotherapy and diabetic treatment using a flexible modified PEG–Cyclodextrin complex [47]. Additionally, the PEG-PCL copolymer, created in combination with PEG and beta-Caprolactone, can target the delivery of hydrophobic medicines such cytokines against a variety of cancer [48]. The persistent attempts to customize nanoparticle formulations for certain therapeutic uses are highlighted by this continuous study. Further, the advantages and disadvantages for the use of NPs are listed below, **(Table- 1).**

Advantages of nanotechnology	**Disadvantages of nanotechnology**
Plays a role in targeted drug delivery	Can result in carcinogenesis
Drugs are released in a sustained and controlled way	The process of metabolism varies with the type of material used in nanoparticle, during its synthesis
The solubility of lipophilic drugs is highly increased	There is lack of knowledge about the adverse effects of nanoparticles in human body especially the bio-chemical pathways
Physical and chemical properties are appropriate	Genotoxicity is unpredictable, due to the lack of knowledge of assessment studies
The nanoparticles have good bioavailability, biocompatibility and biodegradability	Its highly expensive
The toxicity and side effects are reduced	The shelf life is short

Table 1: Various advantages and disadvantages of the nanotechnology in medical field

Conclusion:

The revolutionary influence of nanobiotechnology on healthcare is undeniable, ultimately providing unheard-of possibilities for targeted and successful treatment delivery. Researchers can optimize the size, form, and surface characteristics of nanocarriers at the molecular level by using nanoscale manipulation, which improves therapeutic results. Polymer nanocarriers stand out as attractive choices due to their structural adaptability and distinctive qualities, enabling effective and adaptable delivery systems. The accuracy of targeted and triggered release techniques is increased, allowing therapeutic substances to reach certain tissues while minimizing adverse effects. Additionally, nanobiotechnology addresses issues of inadequate solubility by means of regulated delivery, thereby unlocking the therapeutic promise of phytochemicals. Looking ahead, nanobiotechnology offers a vast horizon of possibilities, with ongoing research set to transform healthcare by creating more effective, focused, and tailored therapeutic strategies. Continued investigation of innovative

methodologies, nanomaterials, and technologies will advance nanobiotechnology into new domains, overcoming obstacles in the future of healthcare.

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Declarations
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