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The Multifareous role of Nanomedicine in healthcare

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Abstract

Nanotechnology is an amalgamation of different disciplines of science and technology that has undergone tremendous evolution in last few years and is thought to play a significant role in revolutionizing health care sector. It can be a breakthrough in various diseases and disorders, targeted drug delivery, drug development, and discovery. Most of the applications are in clinical trials at present. Moreover, the side effects of nanoparticles are of great concern and need to research thoroughly. There are around 122 nanomedicines that are undergoing screening and clinical phase trials. However, out of these, only seventeen have been able to make it to clinical phase II and III trials. These medicines target different types of cancers, infectious diseases, and cardiovascular diseases. It is impressive to follow rapid development in nanotechnology in tune with the health industry. At the same time, it is very important to study nanoparticle-based medicines, toxicity and side effects. The goal is to provide better health care with minimal side effects. The article focuses on the applications of nanotechnology in the field of medicine highlighting the future prospects.

Keywords: Nanoparticles, Drug delivery, Tissue engineering, Antibacterial, cancer.

INTRODUCTION

Nanotechnology, as the name suggests is the technology that deals with particles in nano-range i.e. 1-100nm. Although nanotechnology and nanoparticles have been a part of nature since forever, the frontier of this technology was opened by Richard Feynman, considered the Father of Modern Nanotechnology. His lecture entitled "there's plenty of room at the bottom" seems apt as we switch from classical methods in the health industry to more sophisticated ones. At that time, the technology seemed just like a concept with no hopes of many advances in it. But after almost half a century, nanotechnology has been heralded as a major breakthrough in the field of medicine [1]. Be it treatments for strenuous diseases like cardiovascular, Alzheimer's or cancer or for drug discovery and delivery, you name it and it can be cured using nanotechnology. Since technology just picked pace in the 21st century, so most of it is still in papers or clinical trials, but it is being used in a lot of areas in the field of medicine like drug discovery, transportation, targeted therapy, tissue culture, gene therapy, antimicrobial agents and many more. The vast potential is due to its biocompatibility, specificity, rapidity, robustness, low-cost diagnostics, ease of production, and non-virulence. All in all, if we are able to use nanotechnology with minimizing its toxicity and other side effects, it will revolutionize the health industry.

Nanotechnology has provided a new platform for medical development. Nanomedicine refers to objects in the nano-range for diagnostics, treatment, and prevention of diseases. The unique properties of nanoparticles like larger surface area, quantum effect, self-assembly, etc. provide them with the quality to be used as nanomedicine. Each of these disparate properties hinges on the apparently benign relationship between nanotechnology and medicine [2].

Over the millennia, nature has perfected the art of biology at the nanoscale. In other words, the biological system is made up of building blocks on the nanoscale. Biological nanoobjects include nucleic acids, proteins, polysaccharides, extracellular matrix, receptors, intracellular signaling system, membrane channels blood plasma lipoproteins, etc. The diameter of a strand of DNA is 2nm while the diameter of hemoglobin is around 5.5nm. Protein complexes that form threads of the cytoskeleton are 7-25nm long. Viruses are the only form of living matter that exists in the nanoscale. Therefore, the biological system can be very small but are very active and perform a plethora of functions together. There is a possibility that we too can make particles as small as nanoparticles that we can control.

Nanoparticle larger than 50nm binds with great affinity to a number of receptors. The nanparticles that are smaller in size show less interaction with the receptors compared to the particles with large size. Moreover, the particles smaller than 6 nm are filtered easily by the human kidneys and can be flushed out of the body very quickly. Shape of the nanoparticles also plays an important role in defining their efficiency. Rod shaped nanoparticles show highest efficiency of uptake followed by spherical, cylindrical and cuboidal shapes. Nanoprticles with long axis can simultaneously interact with a large number of cell surface receptors while short axis nanoparticles show less interaction [3].

Not only the shape and size of nanoparticles, but also its composition plays an important role in uptake from the environment. For example, single-cell walled carbon nanotubes and gold nanoparticles, each 50 nm in diameter, possess endocytosis rates of 10^{-3} min^{-1} and 10^{-6} min^{-1} respectively. The difference in the uptake rate may be due to the variation in the intrinsic properties of carbon and gold. Electric charge on the surface of nanoparticles plays a significant role in determining its role inside a cell. It is observed that positively charged nanoparticles are uptaken at a faster rate compared to neutral or negatively charged particles. this may be due to slight negative charge present on the surface of cell membrane that drives the cellular uptake process by electrostatic attractions. Positively charged nanoparticles are quickly absorbed by serum proteins and hence cleared very quickly from blood [4].

TYPES OF NANOPARTICLES

There are usually three kinds of nanoparticles – polymeric, inorganic, and lipid-based [5]. Polymeric NPs consist of polymersomes, dendrimers, nanospheres, and polymer micelles. They are defined as the particulate dispersions prepared from biodegradable polymers ranging in size from 10 to 1000nm. Polymers used for its preparation are polylactide, polylactide-co-glycolide, copolymers, and some natural polymers like alginate, chitosan, and albumin [6]. They possess an extensive advantage over other NPs as particle characteristics can be controlled and the surface can be easily modified but there is the possibility of aggregation and toxicity [7].

Dendrimers are among the novel class of polymeric belonging to attractive chemistry. It consists of three parts. First is the core, having the central atom or a group of atoms. The core is attached to a branch-like structure called internal voids which extends to peripheral or end groups which are the polyvalent recognition site. As dendrimers are analogous to proteins, enzymes, and viruses, modern medicine uses a variety of these materials [8]. For example, they can be used as potential blood substitutes (eg: polyamidoamine dendrimer).

Inorganic NPs comprise quantum dots, silica NP, carbon NP, iron oxide NP, and all metallic NPs like gold NP, silver NP, etc. they have a central core composed of inorganic material that defines their florescent, magnetic, and optical properties [9]. They vary in size, structure, and geometry and have theranostic applications. Although some of them may be toxic to humans and less soluble as compared to other NPs.

The third type of NPs is lipid-based NPs. Some examples are liposomes, lipid NP, and emulsion. It has an advantage over other NPs due to the simplicity of formulation with a range of physiochemical properties. Not only they are highly bioavailable, but also have payload flexibility. They have low encapsulation flexibility. A liposome is a spherical vesicle having at least one lipid layer. Researchers are mainly focusing on liposomes for targeted drug delivery. A key characteristic that differentiates liposomes from lipid nanoparticles is the presence of one or more rings of lipid bilayer surrounding an aqueous pocket [10].

APPLICATIONS

The integration of nanoparticles with the biological system has led to the development of innovative therapeutics, novel drug delivery systems, rapid and ultrasensitive diagnostic tools, etc. Here are some of the applications of nanotechnology in the field of medicine.

ANTIBACTERIAL PROPERTIES

Bacteria can be a major cause of a lot of infections and may even cause death. As bacteria evolve too and are becoming more and more resistant to conventional antibiotics, we must look for alternative ways. The large scale use of antibiotics has caused an increment in bacterial resistance that led to a decrease in antibiotic use efficiency. Nanoparticles can be considered an alternative to antibiotics. Bacterial biofilms are the major reason for their resistance to antibiotics so they must be disrupted. NPs like Au-based, Ag-based, Zn-based, and Mg-based NP can destroy or prevent the formation of these biofilms. Not only NP can substitute antibiotics but also help the delivery of antibiotics to the target site [11].

Wound dressing is very important to shield it from external contamination. But sometimes bacteria do penetrate even the dressing. Silver NP can be used as the most potent antimicrobial agent. Nanosilver was mixed with polyvinyl alcohol and chitosan to produce a fibrous mat that can be used over wounds [12]. Antibiotic resistance of microbes can be overcome by the use of metallic nanoparicles as well as their oxides.

The use of medical dressing materials containing ZnO nanoparticles will allow for avoiding microbial contamination of the wound and also aid in wound closure promoting its early healing. It may also help in delivering therapeutic agents.

TiO2 nanoparticles when mixed with a dental bonding material were found to display antibacterial properties. The mixing of nanoparticles into dental restorative materials seemed to be a good option as it provided significant antibacterial activity and promoted speedy recovery [13].

Gold nanoparticles exibit increased surface area, enhanced wide spectrum antibacterial activity and provide surface for interaction with functional groups. All these qualities make gold a promising antibacterial agent.

The ability of silver nanoparticles to interact with singlet oxygen as well as different reactive oxygen species brings about oxidative damage to membranes of bacterial cells and thus may lead to death of the bacteria. Silver nanoparticles are non-toxic to living cells and therefore can be used as effective antibacterial material [14].

Iron oxide nanoparticles also do not show any toxicity in living system but they do exhibit antifungal effect against fungi and antibacterial effect against Gram-negative and Gram-positive bacteria. Therefore, iron nanoparticles seem to be a ray of hope in management of bacterial and fungal infections. These nanoparticles hold significance as they are highly biocompatible with human body [15].

CANCER TREATMENT

Nanotechnology has the potential to restructure cancer therapy methods. One of the major advantages of using nanotechnology is due to its ability to differentiate between malignant and non-malignant cells. Once NP is targeted to the site, it can conjure cytotoxic responses either by drug release or hyperthermia, or reactive oxygen-mediated killing.

During chemotherapy, drugs are mostly given orally. So the effect of the drug outspreads the entire body leading to a lot of side effects like hair loss, weakness, body aches, etc. This can be avoided if the drug is localized only at the tumor site. Nanoparticles can be efficiently used as vectors to deliver cancer therapy drugs to the site of malignancy. A successful example of nanotechnology-mediated drug delivery is the liposome-mediated drug delivery of doxorubicin.

Lipid-based nanoparticle (LBNP) has brought about a revolution in treatment of cancer by enhancing the antitumor promoting activity of different chemotherapeutic drugs. The following features of LBNP make them a promising candidate which includes their high temporal and thermal stability. They are easy to prepare at a low cost and display high loading capacity. They can be synthesized easily using natural sources and can be up-scaled to large-scale industrial production. The combination of lipid nanoparticles with chemotherapeutic anticancer drugs brings about a large reduction in active dose, drug resistance as well as toxicity. Site directed drug delivery in tumor tissue can also be achieved via lipid nanoparticles thus safeguarding healthy tissue from anticancer drugs.

The most commonly employed LBNP drug delivery carrier are the liposomes. They represent the sole nanoparticle-based drug delivery system approved by Food and Drug Administration for treatment in cancer patients. Currently, nanostructured lipid and solid lipid NP are clinically used for anticancer drug delivery. The examples include Abraxane®, nal-IRI, Doxil® and Myocet®. Therefore, LBNPs can be thought as a potential group for cancer treatment in times to come [16]. A highly significant progress has been made in this field paving way for conducting clinical trials for multimodal treatment of cancer and other diseases in future [17]. Gold nanoparticles have revolutionized oncology research and treatment owing to their large atomic number that plays a critical role in tumor treatment.

Nanomedicine possess unique features like enhanced biocompatibility, small size, large surface area, chemical modification of surface, target specific delivery etc. It is because of these features that nanomedicine is thought to be a potential candidate for use in immune-therapy, chemo-therapy, gene-therapy, antiangiogenesis-therapy etc. [18].

It is commonly observed that the available therapies fail because a reprehensive cycle starts that establishes multiple pathways leading to recurrence of metastasis. Nanotechnology has introduced countless opportunities and possibilities in various areas of medical research including hyperthermic treatment. Tumor cells show enhanced sensitivity to heat compared to normal healthy cells. Therefore, hyperthermic treatment of tumor cells has evolved as an effective approach for treating tumor tissue. The treatment involves increasing the temperature of oncogenic tissue by 42-45^{o}C which successfully destroys the tumor cells without causing harm to the healthy cells [19]. Anaerobic metabolism is created locally due to thermotherapy by disrupting the supply of energy. The magnetic nanoparticles (MNPs) can also be utilized for treatment as they display unique properties which are not offered by conventional magnetic materials [20].

Cancer-related mortality can be reduced to a great extent by its early detection. Nanotechnology can play a significant role here as well. It is being studied for the capture of cancer biomarkers. Three nanoparticles that are being investigated are quantum dots (QD), gold NP and polymer dots. Cancer can be detected through various tumor components like proteins, circulating tumor DNA, microRNA, DNA methylation, and extracellular vesicle detection. One of the methods of detection is tagging. The metal oxide or magnetic nanoparticles are tagged with one of the components of the tumor, which generates strong signals during MRI or CT scans. These NP are concentrated around tumor cells, allowing easy detection of malignant cells. Nanotechnology can also enhance fluorescent immunoassay. Quantum dots amplify light from fluorescent labels. This allows early detection of cancer when the light would be too weak to be detected normally [21].

Usually, flavanoids are present in nature and hence thought to be safe for treatment or prevention of diseases. Flavanoids have been reported to have a great potential in treatment of different classes of cancer. However, a few limitations are associated with its widespread use like its bioavailability, non-specificiy towards targeted site, interaction with other therapeutic agents etc. Flavanoid nanoparticles are recommended for improving these shortcomings and providing effective treatment against cancer [22].

Solid malignant tumors can be effectively managed by Magnetic Induction Hyperthermia (MIH). This novel therapy brings about a small increase in temperature and directs the heat to cancer cells. Tumors that cannot be treated by other methods are effectively destroyed by this therapy [23]. This therapy offers great advantage as it specifically targets tumor cells and does not affect healthy tissues.

Nanotechnology bestows a novel forward march for cancer therapy. It put forwards immense hopes of reducing systemic toxicity by producing nanoparticles modified with different functional groups for target directed treatment. It may also provide unique way of overcoming multiple drug resistance, a feature generally associated with cancers. Apart from cancer treatment, nanoparticles may be developed as useful diagnostic systems.

DRUG DELIVERY AND DIAGNOSTICS

Nanocrystals (quantum dots) and nanoparticles (like nanoshells, Dendrimers, gold NP, and magnetic NP) have unique advantages like surface properties and multifunctional nature for the development, delivery, and diagnostics of drug [24].

Drugs based on nanoparticles find great use not only in diagnosis but also in treatment of many diseases because of different modifications possible with nanoparticles like variation in size, shape, surface chemistry, nanomaterial employed etc. Nanostructures can be used for site directed drug delivery and also ensure controlled release of the drug for effective therapy. Sustained and site targeted release of drug lessens the toxic side effects of the drug. Moreover, nanostructures find use in diagnosis and treatment of diseases. There are positive reports of treatment of various diseases using this technology like AIDS, cancer etc.

Novel techniques for nanotechnology-based diagnostics such as biosensors are being developed that would be cost-effective and sensitive. For example, Nanomix (California) developed carbon nanotube-based biosensors for monitoring respiratory functions.

Two NPs are being widely used for bioimaging- luminescent nanoprobe and magnetic NP. A luminescent nanoprobe is generally used for optical imaging whereas magnetic NP is used for MRI. Magnetic NP can alter the T1 and T2 relaxation time of MRI which greatly enhances the efficiency of MRI [25].

We can now encapsulate the drug inside a nanoparticle and send it to the target site. This leads to the usage of lower concentrations and high efficiency of the drug. Different nanovesicles used are liposomes, dendritic polymers, micelles, nanocapsules, nanospheres, and liquid crystals. The size and shape of micelles can be manipulated. This unique quality makes it an interesting vehicle for delivering various drugs. The drug can be loaded inside the core of the micelle. Liposomes are polar in nature, consisting of a phospholipid bilayer. So the drug is encapsulated inside a nanocage- functionalized with channel proteins that protect it from proteolytic enzyme degradation. There exist a concentration gradient between nanocage and external environment, therefore there is a possibility that the drug can move out from the cavities in nanocage. Nanocapsules comprise of vesicular membrane surrounding a cavity into which a drug is entrapped. Nanospheres are matrix systems filled with uniformly dispersed drug. Apart from efficient drug delivery, drug release can also be controlled after the advancement of microelectro –mechanical systems (MEMS). Even the administration of drugs becomes less invasive and painful as mostly they are administered through the oral route.

Colorectal cancer is considered as a fatal disease because of unavailability of methods for its early detection as well as lack of suitable strategies for efficient drug delivery. Detection of the cancer is difficult and often misleading using imaging techniques. Moreover, the recommended chemo and radio therapy for treatment of the cancer produce negative side effects. It further adds to the already high death rate of the disease. The tremendous progress made in the field of nanotechnology has potential to offer superior solution for early detection and treatment of colorectal cancer. Potent formulations based on nanoparticles not only help in cancer detection at early stage but also enhance water solubility of drug and its availability to cancer cells. It also checks the non-specific distribution of the drug in the body thus ensuring efficient treatment of the disease [26].

The term 'theranostics' contains two words 'therapeutics and diagnostic'. Theranostics is used to denote the combination of radioactive drugs in which one radioactive drug identifies (diagnosis) and the second drug is delivered to the cancer cells for cure.

Iron oxide nanoparticles find great use in diagnosis, cure and theranostic treatments. Main application of the particles in diagnostics includes liver and lymph node inflammation, vascular imaging, magnetic resonance imaging, magnetic particle imaging etc. Iron nanoparticles can be used as iron supplements in anemia, cancer treatment and theranostic therapy. Drugs in combination with iron oxide nanoparticlesare used for image guided targeted drug delivery, clearing of blood brain barrier, theranostic mediated tissue engineering etc. These applications describe the highly versatile nature of iron oxide nanoparticles containing materials and their potential use in medical science [27].

TISSUE ENGINEERING

Nanotechnology is also providing a helping hand in the field of regenerative medicine and synthetic artificial organs. To date, a lot of nano-based constructs have been made. For example, the successful transplantation of the trachea which was made from a nanocomposite polymer seeded with the patient's stem cell. For the development of synthetic hollow organs like blood vessels and airways, a nanomaterial called POSS has played a significant role. It is found that only a 2% incorporation of POSS into the polymeric formulation has resulted in enhanced mechanical properties and better suture retention. Orthopedic implants are one of the largest areas benefiting from the integration of nanotechnology with tissue engineering. Nanoceramics like alumina, titania, and hydroxyapatite were used. Osteoblast proliferation and long-term functions were seen in *vitro.* POSS-PCU scaffolds of auricular and nasal have been successfully implanted subcutaneously in mouse models and human arms as well [28].

Dermal grafts are a financial burden to date which is mainly due to the extensive *in vitro* cell culture time required before the graft fully matures and can be used clinically. Nanostructured tissue-engineered scaffolds can reduce the culturing time hence reducing production costs. Human dermal fibroblasts have been successfully produced in *vitro* by using poly (eta-caprolactone) grafted with nanostructure chitosan.

Nanoparticles are at the position of greatest importance in nanotechnology and their typical size-dependent properties have shown promise in overcoming many of the obstacles faced by TE today.

Recent progress in nanoparticle research and production techniques and regulation of size in nanoscale systems has cast a significant effect on tissue engineering and regenerative medicine (TERM). The different materials like polymers, metals, magnetic/paramagnetic materials, ceramics etc. can be modulated and modified for tissue-engineering and artificial organ functionalization [29].

CARDIOVASCULAR DISEASES

There is a huge gap between in this area of cardiovascular therapeutics as it is limited to oral medicines and invasive surgeries. A diverse range of nanoparticles is being used for research in cardiovascular therapies like Dendrimers, liposomes, micelles, and nanocoating. Liposome has the potential to carry out treatment of peripheral artery disease and intermitted claudication. At present, research is being carried out to study the delivery of prostaglandin E- 1 (PGE-1) using liposome as delivery vehicle. The trade name of the drug is Liprostin that is undergoing phase III clinical trials. PGE-1 is a potential clinical molecule displaying a wide range of pharmaceutical properties like inhibition of platelet aggregation and leukocyte adhesion, vasodilatation and anti-inflammatory properties. Liposomes are also being designed for site directed action on thrombosis (blockage of blood vessels) which is the major cause of myocardial infarction [30]. In the mouse thrombosis model, Urokinase (a thrombosis drug) was in liposome for targeted drug delivery. 75% less drug was required for the same. Co-polymer micelle formed from polyethylene glycol may be employed as a carrier for gene delivery to bring about effective treatment of vascular diseases through efficient expression of gene as well as reduced cytotoxicity in vascular smooth muscle cells. Nitric oxide (NO) is a potent vasodilator and vascular homeostasis which helps in preventing atherosclerosis (build-up of fats and cholestrerol inside the walls of arteries). It is encapsulated within a dendrimer and used in targeted therapy [31].

Nanoparticles as well as nanocarriers find a great use in the field of cardiology too. Nanoparticle based drugs or nanocarrier entrapped drugs can be passively or actively targeted to cardiac tissues ensuring efficacy of the drug. It is reflected that greater than 50% of CVDs can be managed successfully via the usage of nanoparticle based drugs.

Coating on cell membrane has been thought to be a helpful way of introducing biomimetic functionality to produce novel synthetic nanoparticles. Nanoparticles overlaying cellular membranes can effectively interact with their environment and explore the complexity existing inside a cell. Our improved understanding of the different phenotypic alterations during progression of a disease, will facilitate development of novel nano-delivery vehicles displaying target specificity at different stages of the disease. Novel nano-delivery vehicles in combination with specific nanoparticles can be tailor made to treat a particular disease. Recently isolated bioactive molecules as well as diagnostic markers can be amalgamated with biomimetic nanotechnology to escalate their effectiveness and usefulness. For instance, therapies based on miRNA are reported to be effective against many diseases. The potential of such therapies could further be enhanced by nano-encapsulation.

NANOBOTS

Although this is just concept nanobots or nanorobots can be the future of medicine as minimally invasive medicine is the current buzz. Nanorobotic models can be built by nanoscale particles using molecular self-assembly. There is two possible accesses for the same. First is the "bottom-up" approach i.e. assembling the nanorobot, piece by piece. The second approach is "top-down" which deals with micro electromechanical systems (MEMS) and scaling them down to the nano level. The plan is to defend the body from the inside. The major advantages are minimal or no tissue trauma, less recovery time required, continuous monitoring and diagnosis from inside, and rapid response to sudden changes. There are no clinical trials available as this technology still possesses some considerable challenges like deformed nanobots needing to re-learn how to move. Apart from developing engineering materials, the generation and storage of power for nanobots hold another vital challenge [32].

Owing to untiring research in last decades, nanobots have been established as agents that can be targeted to a particular location under physiological conditions utilizing the energy derived from either different biochemical pathways or from moving microorganisms. Thus nanobots have not only tremendously enhanced the efficacy of drugs but also reduced their toxicity. It is because of these unique features that nanobots hold tremendous potential in healthcare sector [33].

VACCINE DEVELOPMENT

Nanotechnology can also be put to use in development of vaccines. Nanoparticles are easily synthesized and offer unique physico-chemical properties. They also have the potential to boost innate immunity as well as work like an adjuvant. Entrapment of antigen or drug inside a nano-delivery vehicle ensures its regulated release and protects it from degradative activity of proteases, the protein digesting enzymes. This feature becomes advantageous in case of orally administered nano-encapsulated drug that remains safe in gastro-intestinal tract. The proliferation and differentiation of T cells is greatly affected by nanoparticles. For instance T cell proliferation is enhanced by hydro-carbonised as well as oxidized silica nanoparticles. A few magnetic nanoparticles are also reported to increase Th1 multiplication [34].

As the globe continues through the trenches of the SARS-CoV-2 pandemic, nanotechnology came as a savior in the form of a major component in the most efficacious COVID vaccine developed to date. Pfizer/BioNTech and Moderna have created an mRNA-based vaccine that uses lipid nanoparticle technology. They are using the application of self-replicating mRNA which includes replicase enzyme to self-propagate. mRNA is loaded in lipid nanoparticles which is similar to liposomes. This is done to protect naked mRNA from degradation by ribosomes. The intake of mRNA inside a cell is sensed by intra-cellular

RNA sensors like cytoplasmic nucleic acid sensors and endosomal toll-like receptors [35]. The interaction of mRNA to the defense receptors of the host stimulates the innate immunity pathway by up-regulating the expression of numerous downstream genes. Lipid nanoparticles utilized in production of mRNA vaccine is made up of phospholipid along with cholesterol and PEG- lipid and an ionizable cationic lipid. The particle size of m RNA vaccine is maintained at 60-100 nm by continuous stirring.

Some other vaccines are currently under clinical trials which are using nanotechnology for vaccine development. Novavax has developed a protein subunit vaccine that relies on a virus-like nanoparticle drug delivery system. ARCoV vaccine developed by the Academy of Military Medical Sciences also uses lipid nanoparticles for drug delivery but is under phase 1 trial [36].

Nanotechnology is playing a significant role in expansion of vaccine technology by developing delivery vehicles based on nanocarriers to improve cell mediated as well as antibody mediated immunity. Vaccine formulations utilizing nanoparticles display high stability of antigens. They also show increased immunogenicity as they can be targeted to specific site with slow release of antigen. Research on nanomaterials has focused our attention on lipid based liposomes, polymers, emulsions, virus like particles etc. for use in design of nanocarriers for vaccine delivery. The material should effectively encapsulate the vaccine antigen, stabilize it as well as work as an adjuvant. Moreover, the carrier needs to retain nanosize so that it can easily be taken up by antigen presenting cells ensuring effective antigen presentataion and regognition. The surface of nanocarriers can modified using target specific groups that help them deliver the antigen load to receptors on target cells leading to specific and heightened immune response[37].

CHALLENGES

Even though *in vivo* studies of nanotechnology hold promising results, most of them a still confined to laboratory research, and very few of them are applied in clinics. We are still not much aware of the toxicity as well as side effects, efficacy and internal metabolic conversion of nanoparticles. Nanomaterials need to assess differently than the conventional method due to their smaller size, and new routes of exposure emerge to enter new cellular portals. Also, this technology is still in its initial stages, creating new biological interactions therefore undiscovered toxicities. Nanotoxicology is also a serious matter of concern because there is no internationally accepted standard protocol for toxicity testing of nanomaterials. Researchers use their protocol which makes it very difficult to establish nanotoxicity results. Apart from toxicity, some other issues are not given much attention like the local supply chain of nanotechnology-based products or account for the possibility of local invention or fabrication. Along with a lot of benefits, monodispersity, unregulated size, and cumbersome production procedure has limited its use commercially.

CONCLUSION

The advancement of nanotechnology and nanoscience has given us new hopes for better health care. Applications of nanotechnology have outspread immensely in the field of medicine. Before nanotechnology can create a mark in the health industry, it is important to elucidate the effects of nanotechnology in biological systems. The foremost requirement is to study the interaction between the physiochemical features of nanomaterials and the surfaces and spaces offered by different organelles, live cells and tissues and organisms as a whole. Despite the positive aspects of nanotechnology, the number of unanswered questions and safety concerns cannot be ignored. If we can tackle these challenges, the future of nanotechnology in medicine holds a very bright future and can dominate the health industry completely owing to its prodigious merits.

Conflict of interest

None declared.

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REFERENCES

1. Zajtchuk R. New technologies in medicine: biotechnology and nanotechnology. Disease-a-month. 1999;45(11):453-95.
2. Nasrollahzadeh M, Sajadi SM, Sajjadi M, Issaabadi Z. An introduction to nanotechnology. InInterface science and technology 2019; 28(1-27). Elsevier.
3. Albanese A, Tang PS, Chan WC. The effect of nanoparticle size, shape, and surface chemistry on biological systems. Annual review of biomedical engineering. 2012;14(1):1-6.
4. Albanese A, Tang PS, Chan WC. The effect of nanoparticle size, shape, and surface chemistry on biological systems. Annual review of biomedical engineering. 2012;14(1):1-6.
5. Yang J, Jia C, Yang J. Designing nanoparticle-based drug delivery systems for precision medicine. International Journal of Medical Sciences. 2021;18(13):2943.
6. Ram Prasad RP, Rishikesh Pandey RP, Ajit Varma AV, Ishan Barman IB. Polymer-based nanoparticles for drug delivery systems and cancer therapeutics. InNatural polymers for drug delivery Wallingford UK: CABI. 2017, 53-70.
7. Jahanshahi M, Babaei Z. Protein nanoparticle: a unique system as drug delivery vehicles. African journal of Biotechnology. 2008; 7(25).
8. Noriega-Luna B, Godínez LA, Rodríguez FJ, Rodríguez A, Zaldívar-Lelo de Larrea G, Sosa-Ferreyra CF, Mercado-Curiel RF, Manríquez J, Bustos E. Applications of dendrimers in drug delivery agents, diagnosis, therapy, and detection. Journal of Nanomaterials. 2014, 2014.
9. Guo T, Lin M, Huang J, Zhou C, Tian W, Yu H, Jiang X, Ye J, Shi Y, Xiao Y, Bian X. The recent advances of magnetic nanoparticles in medicine. Journal of Nanomaterials. 2018, 2018.
10. Guterres SS, Alves MP, Pohlmann AR. Polymeric nanoparticles, nanospheres and nanocapsules, for cutaneous applications. Drug target insights. 2007; 2:117739280700200002.
11. Chauhan M, Kaur G, Sharma B, Chaudhary GR. Antimicrobial Applications of Engineered Metal-Based Nanomaterials. InBiomedical Translational Research 2022, (495-521). Springer, Singapore.
12. Singh M, Singh S, Prasad S, Gambhir IS. Nanotechnology in medicine and antibacterial effect of silver nanoparticles. Digest Journal of Nanomaterials and Biostructures. 2008; 3(3):115-22.
13. García-Pinel B, Porras-Alcalá C, Ortega-Rodríguez A, Sarabia F, Prados J, Melguizo C, López-Romero JM. Lipid-based nanoparticles: application and recent advances in cancer treatment. Nanomaterials. 2019;9(4):638.
14. Cao X, Zhu L, Bai Y, Li F, Yu X. Green one-step synthesis of silver nanoparticles and their biosafety and antibacterial properties. Green Chemistry Letters and Reviews. 2022;15(1):28-34.
15. Gudkov SV, Burmistrov DE, Serov DA, Rebezov MB, Semenova AA, Lisitsyn AB. Do iron oxide nanoparticles have significant antibacterial properties?. Antibiotics. 2021;10(7):884.
16. García-Pinel B, Porras-Alcalá C, Ortega-Rodríguez A, Sarabia F, Prados J, Melguizo C, López-Romero JM. Lipid-based nanoparticles: application and recent advances in cancer treatment. Nanomaterials. 2019; 9(4):638.
17. Almeida B, Nag OK, Rogers KE, Delehanty JB. Recent progress in bioconjugation strategies for liposome-mediated drug delivery. Molecules. 2020;25(23):5672.
18. Dan L, Hongwei Z. Application of nanotechnology in the treatment of ovarian cancer. Journal of International Oncology. 2018;45(4):253.
19. Emerich DF, Thanos CG. Nanotechnology and medicine. Expert opinion on biological therapy. 2003;3(4):655-63.
20. Jose J, Kumar R, Harilal S, Mathew GE, Parambi DG, Prabhu A, Uddin M, Aleya L, Kim H, Mathew B. Magnetic nanoparticles for hyperthermia in cancer treatment: an emerging tool. Environmental Science and Pollution Research. 2020;27(16):19214-25.
21. Wagner MK, Li F, Li J, Li XF, Le XC. Use of quantum dots in the development of assays for cancer biomarkers. Analytical and bioanalytical chemistry. 2010;397(8):3213-24.

22. Khan H, Ullah H, Martorell M, Valdes SE, Belwal T, Tejada S, Sureda A, Kamal MA. Flavonoids nanoparticles in cancer: Treatment, prevention and clinical prospects. InSeminars in cancer biology 2021;69:200-211. Academic Press.
23. Jose J, Kumar R, Harilal S, Mathew GE, Parambi DG, Prabhu A, Uddin M, Aleya L, Kim H, Mathew B. Magnetic nanoparticles for hyperthermia in cancer treatment: an emerging tool. Environmental Science and Pollution Research. 2020;27(16):19214-25.
24. Lombardo D, Kiselev MA, Caccamo MT. Smart nanoparticles for drug delivery application: development of versatile nanocarrier platforms in biotechnology and nanomedicine. Journal of Nanomaterials. 2019, 2019.
25. Guo T, Lin M, Huang J, Zhou C, Tian W, Yu H, Jiang X, Ye J, Shi Y, Xiao Y, Bian X. The recent advances of magnetic nanoparticles in medicine. Journal of Nanomaterials. 2018.
26. Pavitra E, Dariya B, Srivani G, Kang SM, Alam A, Sudhir PR, Kamal MA, Raju GS, Han YK, Lakkakula BV, Nagaraju GP. Engineered nanoparticles for imaging and drug delivery in colorectal cancer. InSeminars in cancer Biology 2021;69:293-306. Academic Press.
27. Dadfar SM, Roemhild K, Drude NI, von Stillfried S, Knüchel R, Kiessling F, Lammers T. Iron oxide nanoparticles: Diagnostic, therapeutic and theranostic applications. Advanced drug delivery reviews. 2019;138:302-25.
28. Teoh GZ, Klanrit P, Kasimatis M, Seifalian AM. in development of artificial organs. Minerva medica. 2015;106:17-33.
29. Fathi-Achachelouei M, Knopf-Marques H, Ribeiro da Silva CE, Barthès J, Bat E, Tezcaner A, Vrana NE. Use of nanoparticles in tissue engineering and regenerative medicine. Frontiers in bioengineering and biotechnology. 2019;7:113.
30. Chandarana M, Curtis A, Hoskins C. The use of nanotechnology in cardiovascular disease. Applied Nanoscience. 2018;8(7):1607-19.
31. Noriega-Luna B, Godínez LA, Rodríguez FJ, Rodríguez A, Zaldívar-Lelo de Larrea G, Sosa-Ferreyra CF, Mercado-Curiel RF, Manríquez J, Bustos E. Applications of dendrimers in drug delivery agents, diagnosis, therapy, and detection. Journal of Nanomaterials. 2014.
32. Bhat AS. Nanobots: the future of medicine. International Journal of Management and Engineering Sciences. 2014;5(1):44-9.
33. Luo M, Feng Y, Wang T, Guan J. Micro-/nanorobots at work in active drug delivery. Advanced Functional Materials. 2018;28(25):1706100.
34. Albanese A, Tang PS, Chan WC. The effect of nanoparticle size, shape, and surface chemistry on biological systems. Annual review of biomedical engineering. 2012;14(1):1-6.
35. Milane L, Amiji M. Clinical approval of nanotechnology-based SARS-CoV-2 mRNA vaccines: impact on translational nanomedicine. Drug delivery and translational research. 2021;11(4):1309-15.
36. Zhang NN, Li XF, Deng YQ, Zhao H, Huang YJ, Yang G, Huang WJ, Gao P, Zhou C, Zhang RR, Guo Y. A thermostable mRNA vaccine against COVID-19. Cell. 2020;182(5):1271-83.
37. Kheirollahpour M, Mehrabi M, Dounighi NM, Mohammadi M, Masoudi A. Nanoparticles and vaccine development. Pharmaceutical Nanotechnology. 2020;8(1):6-21.