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Unleashing the Therapeutic Applications of Nanoparticles as Drug Delivery Systems

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Review Article

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ABSTRACT

Background: The ultimate aim of nanotechnology is to revolutionize the healthcare industry through its interventions. It has a significant impact on how modern medications are formulated, targeted, and delivered with regulated dosage. Innovations in nanoparticle engineering and our knowledge of the significance of nanoparticle features like form, size, and surface quality for biological interactions are opening up new opportunities for the synthesis of therapeutic nanoparticles.

Methods and findings: With the emergence of precise drug delivery systems to treat a range of neurological diseases, nanotechnology is being used extensively in the biomedical field. It is used for the creation of extremely sensitive Nano diagnostic equipment's that make use of nano sized particles and structures. The biochemical and biophysical characteristics of the targeted drugs chosen for therapy are the primary factors considered while choosing the best nano drug delivery technology.

Conclusions: As a result, the potential of nanoparticles to enable enhanced distribution of poorly soluble drugs has started to dominate and modify the entire therapeutic paradigm of various drug delivery technologies to treat diseases, which will aid in improving the lives of a large population.

Keywords: Biomedical; Nanotechnology; Nano diagnostics; Therapeutic; Drug delivery

INTRODUCTION

The utilization of nanotechnology in various scientific domains has proven to be able to eliminate the gaps in efficient therapeutic drug delivery. Nanomaterials are used as diagnostic tools to carefully deliver therapeutic compounds to specifically targeted sites in the rapidly evolving fields of nanomedicine and nano delivery systems. The nanonization of materials is a significant aspect on both the economic and medical or pharmaceutical sides, whether they are used for medical purposes, the food sector, or the administration of drugs. Nanoparticles (NPs) are typically small nanospheres because they are made of materials that are created at the atomic or molecular level. The structural, biological, chemical, magnetic, electrical, and mechanical characteristics of nanoscale sized particles are distinctive. Their sizes, which range from 1 to 100 nm, have an impact on the forefronts of nanomedicine, from tissue engineering to microfluidics, drug delivery, and drug delivery systems to biosensors [1]. Due to their nanoscale, these structures can easily enter the tissue system, make drug administration more effective, and ensure that the medicine acts where it is intended. They can therefore move more freely inside the human body than denser, bulkier materials. They work together directly to treat sick cells more effectively and with minimal to no adverse effects. Nanoparticles have been the driving force behind the development of nanobiotechnology, drug delivery, biosensors, and tissue engineering in the biomedical industry [2].

LITERATURE REVIEW

The biochemical and biophysical characteristics of the targeted drugs chosen for therapy are the primary factors considered when choosing the best nano-drug delivery technology. When creating target specific drug delivery systems, metallic, polymeric, organic, and inorganic, nanostructures, such as micelles, dendrimers, and liposomes, are commonly taken into account. These nanoparticles are specifically added to drugs that have limited solubility and poor absorption. When analysing the use of nanomedicine, issues like the toxicity demonstrated by nanoparticles must be disregarded [3]. To reduce the toxicity issues, nanoparticles have primarily been used recently in conjunction with natural products. By facilitating drug molecule penetration across the Central Nervous System (CNS) and enhancing their bioavailability, nanodrug delivery devices show promise in addressing a number of therapeutic moieties. The bioavailability and kinetic profile of pharmaceuticals in biological systems have been improved through the use of nanotechnology in drug delivery devices. Through the development of incredibly precise reagents and instruments that enable unmatched clinical level detection and treatment, nanotechnology has the ability to significantly improve the sensitivity of diagnostics and treatments and the ensuing unfavourable side effects. This is done using tightly regulated nanofabrication techniques that produce molecularly specified nanoscale materials and devices with established physical characteristics that are special to each material in question and helpful for specific medicinal applications. The bioactivity of these nanomaterials can also be improved by modifying the size, shape, hydrophobicity, and surface properties of the nanostructures. Because nanostructures can be used as delivery agents to encapsulate or attach therapeutic pharmaceuticals and deliver them to target tissues more accurately with a controlled release, nanomedicines have gained popularity recently. A developing subject called nanomedicine applies

nanoscience knowledge and methods to medical biology, disease prevention, and treatment. It suggests the use of nanodimensional materials for nanosensors, nanorobots, diagnosis, delivery, and sensory functions, as well as actuating materials in living cells. The regulated release profile of loaded pharmaceuticals is improved by the prolonged release of nano-drug delivery devices, which reduces the dosing regimen. In general, failures in the safety and efficacy profiles in preclinical and clinical studies account for less than 10% of novel nanomedicine approvals. Indeed, to evaluate the safety, quality, and efficacy characteristics of a novel nanomedicine, regulatory bodies require producers to conduct precise preauthorization studies. Additionally, a significant issue that prevents the clinical translation of nanomedicines is the challenge of finding acceptable preclinical models that accurately reflect what occurs in humans. To make nanoparticle based therapeutics more viable for clinical application, cost optimization and market supply requirements must be met. Despite the relatively limited use of nanomaterials, ground breaking research is currently being conducted [4].

METHODOLOGY

Nanotechnology implementation in diseases causing morbidity across the world

The burgeoning subject of nanoscience unites the natural and engineering sciences, as well as several medical specialties. Atoms and molecules are manipulated to create nanostructures that are the same size as biomolecules for interaction with human cells, which can be used to create new therapies and enhance ones that already exist. By encouraging the body's natural mending mechanism, this terminology provides a variety of novel diagnosis and smart instrument treatments. The application of nanotechnology to medical issues has the potential to facilitate early detection and prevention and essentially improve the diagnostics, treatment, and follow-up of many life-threatening diseases, including: cancer, cardiovascular disease, brain tumours, alzheimer's disease, and any type of inflammatory and infectious diseases. Some of the application of nanoparticles in these diseases causing morbidity across the world are mentioned below [5].

Alzheimer’s disease

Dementia is currently the most prevalent cause of dependency and dysfunction in the geriatric population. In recent years, there has been a steady rise in the number of dementia sufferers. The World Health Organization (WHO) estimates that approximately 50 million people worldwide suffer from dementia. Alzheimer's Disease (AD) is the most common cause of dementia, making it a major public health concern. AD is a specific type of brain disease that accounts for 60%–80% of instances of dementia. Alzheimer’s disease is a neurodegenerative disease with a progressive memory factor, meaning that the damage to brain cells gets worse with time. Currently, FDA approved therapeutics only aim to treat AD's symptoms rather than its underlying causes. The conventional therapy for AD is limited to treating the disease's clinical symptoms. For medications to enter the brain more easily and exert a particular activity there is a great need for drug research and development [6]. When the dosage of the drug is increased, the conventional drug delivery system manifests systemic adverse effects and is unable to deliver the therapeutic dose to the target spot in the AD brain. The usage of nanotechnology for biomedical applications includes the development of precise drug delivery methods to treat a variety of neurodegenerative disorders, such as Alzheimer's disease, as well as the development of highly sensitive nanodiagnostic tools that make use of various nanoparticles and nanostructures. Designing therapeutic concoctions and diagnostic technologies that synchronously and specifically target the key molecule involved in AD could be done using a multifunctional nanotechnology

paradigm. By using engineered nanoparticles for drug delivery, it is possible to manage the ability of treatments to cross the Blood Brain Barrier (BBB) and overcome a number of other pharmacological hurdles in the treatment of neurological diseases like AD [7].

Nanocarriers are useful for making it easier to administer a particular targeted therapeutic treatment for AD. The regulated release of medications in particular brain regions is a fundamental prerequisite for AD treatments, and this can be accomplished by housing the NPs. By encapsulating nanoparticulate systems, targeted drug delivery systems can be employed to reduce the systemic side effects of medications that have already received approval. Due to the limited permeability of active medicines across the BBB, many drug delivery technologies, with the exception of nanoformulations, failed to deliver an appropriate dose of a drug to the target region in the brain. Different brain targeting nano-drug delivery methods, such as receptor mediated, adsorption mediated, and transporter mediated, have been developed over the past ten years. The selection of Nano-Drug Delivery Systems (NDDSs) is based on the size and shape of Nanoparticles, the release profile of the drug, the target and biodistribution, formulating stability and shelf life, safety, and toxicity while keeping therapeutic effects. Nanoformulations have advantages over other drug delivery systems due to their characteristics like biocompatibility, low toxicity, non-immunogenicity, high bioavailability, and enhanced drug distribution at the target site. They can deliver both lipid soluble and water soluble drugs of varying solubility across the BBB [8].

The US-FDA has approved five therapeutic drugs to lessen AD's clinical symptoms. This comprises non-competitive NMDAR antagonists (Memantine) and acetylcholine esterase inhibitors (Donepezil, Galantamine, Tacrine, and Rivastigmine). NPs and FDA approved alzheimer's drugs used together offer potential solutions for treating AD. Drug Delivery Systems (DDSs) might boost the effectiveness of alzheimer's drugs that the FDA had approved, but they were unable to reverse the disease or halt its progression. Only the recently authorised medication AduhelmTM is meant to address the condition. Clinical trials for the treatment of AD are being conducted on several others. For instance, the ACI-35 is a liposome based vaccination designed to stimulate an immune response against pathogenic conformers of phosphorylated tau. DDSs can thus be added to these new AD treatment candidates in the future to boost their effectiveness [9].

Due to first pass metabolism, plasma protease degradation, renal clearance, and restricted CNS access, conventional drug delivery techniques are the least effective in treating AD. Nanomedicines are becoming more and more sophisticated as advanced therapeutic approaches for avoiding the BBB and as a sustained and targeted drug delivery method. The therapeutic agent is delivered using nano-formulations such as liposomes, nanoemulsions, cubosomes, niosomes, Solid lipid NPs (SNPs), polymeric NPs, nano micelles, dendrimers, nanogels, and inorganic NPs to the target region in the CNS to treat AD. Numerous profitable uses of nanotechnology are available for AD treatments. There are now 121 different drugs being tested in clinical trials for the treatment of AD. Although there are a lot of clinical trials, none of them are particularly noteworthy for using nanoparticles to treat AD. In order to provide the least toxic, therapeutically effective, targeted drug administration with negligible cytotoxic effects for treating long term neurological diseases such as AD and dementia, major research is now being undertaken concurrently in the field of nanotechnology. These ongoing efforts would open up fresh opportunities, maybe paving the path for a highly effective therapy strategy using nanotechnology to treat AD. The drug delivery systems utilising nanoparticles enhance medication solubility and bioavailability, making them preferable options [10]. A further benefit of NPs mediated

techniques is that they enable repeated drug loading and targeted drug delivery, both of which boost drug effectiveness. However, some NPs can damage cellular and tissue architecture through acute toxicity, hence NP material should be carefully chosen. Thus, including nano-drug delivery technologies in AD therapeutics can improve the overall efficacy of drug alternatives.

Cardiovascular diseases

Cardiovascular Diseases (CVDs) are believed to be the leading cause of death worldwide. Costs associated with the diagnosis and treatment of CVDs is expected to increase during the next ten years at a faster rate. Adopting a healthy, preventative lifestyle and early identification of the diseases are the only ways to lower the prevalence and death rate of CVDs. Due to their high costs and related cardiovascular problems, conventional medicine and synthetic drugs are less commonly used. The main goals of contemporary CVD therapy are to restore regular blood flow and to prevent recurrent cardiovascular shocks. Cardiovascular disorders can be managed and treated in a number of ways. Improved medical imaging, targeted drug delivery, and targeted distribution of nanoparticles to eradicate diseased cells are some of the important functions that nanoparticles play in CVDs [11].

Drugs can be effectively removed from blood and tissue after being delivered there by nanoparticles as well. Through the construction of effective cardiovascular molecular imaging probes based on nanotechnologies in personalised cardio medicine, quick advancements in the field of nanotechnology improve the imaging of CVDs. Invasive surgeries become a common form of treatment for heart procedures in the modern period. Vascular gene therapy is a term used to describe a promising CVD treatment. A novel, efficient, and effective method for treating different cardiac related disorders, such as hypertension, atherosclerosis, and myocardial infarction, is heart targeted nanocarrier based drug delivery. One of the standard forms of care for people with CVD is Complementary and Alternative Medicine (CAM). However, patients with hypertension have been advised to use more than 95% of CAM. To lower high blood pressure, a number of single dose, multiple dose, or fixed dose formulations are available. Recently, gene editing and gene based therapies have been used in clinics to treat patients with CVDs, while precision medicine in CVDs is evolving. Due to nanoparticles' capacity to penetrate biological barriers and assemble at the target site, cardiovascular imaging probes have a number of intriguing uses in the field of CVD medicine. Cardiology uses nanoimaging as a comprehensive method for diagnosing and real time monitoring throughout procedures and treatments. Cardiovascular imaging using nanotechnology is connected to numerous areas of treatment, surgery, and diagnostics. As theranostic agents, nanotechnology and nanomedicine provide individualised attention to the diagnostic and therapeutic spheres of cardiovascular disorders. Nanoparticles used theranostically in CVDs close the gap between experimental data and extensive clinical trials. The adoption of a nano based theranostic technique to reduce the plaque volume is an evidence of cardiovascular theranosis employing nanoimaging in the CVD detection region. It was demonstrated in that setting that iron oxide nanoparticles with rTPA tags were more effective at breaking up clots. Using fluorophores coated nanoparticles, it is possible to track the migration and eventual destiny of any clot remnants after they have been destroyed. In addition to providing opportunities for diagnosis *via* noninvasive magnetic resonance imaging for anatomic detection, the innovation of potential theranostic agents for cardiovascular disease based on High Density Lipoprotein-like Magnetic Nanostructures (HDL-MNS) also serves as efficient cholesterol efflux agents to treat atherosclerotic vascular lesions. Theranostics in cardiology enables image based therapeutic drug delivery systems, integrating medicines with imaging. Natural compound coated magnetic nanoparticles are effectively used in the imaging of CVDs. Theranostics and regenerative medicine will advance significantly owing to the multifunctional, more

intricate controlled release systems that have been made possible by recent advancements in polysaccharide based nanomaterials. These systems will also have improved therapeutic effectiveness, mechanical characteristics, and safety profiles [12-16].

In the field of CVDs, nanoscience and nanotechnology allow successful therapy, improved prognosis, and reduced side effects on tissues outside the target area. Depending on the preferred treatment agent and the severity of the disease, a variety of drug delivery systems have been utilized. Cardiology's use of nanomedicine focuses on four key areas that help treat and reduce CVDs. These nanotechnology applications include molecular imaging, targeted drug delivery, tissue engineering, and diagnostics. One of the most often employed nanocarriers for the administration of cardio protective drugs is gold. Production of metal nanoparticles is easier due to their simplicity, low toxicity rate, and stability, and they are thus widely used in gold nanocarriers. Due to features such as active and passive targeting of the heart tissues, enhanced target specificity, and sensitivity, the use of nanoparticles and nanocarriers in the field of cardiology has attracted significant attention. Several therapeutic nanocarriers have already entered the market and have started their clinical trials. According to reports, nanotechnology can be used to successfully treat more than 50% of CVDs. The future study aims to develop selective nano delivery technologies and employ peptides and antibodies to identify the markers of CVDs. Future nanocardiology is focused on assessing the clinical outcomes of cutting edge nanosystems to enhance the quality of life [17].

Brain tumors

A group of neoplasms in the central nervous system is collectively referred to as "brain tumours". It is a disease with a low survival rate that poses a serious threat to life. Malignant brain tumours have an abysmal prognosis, and the BBB's impermeability restricts the use of chemotherapy. For the treatment of brain tumours, numerous invasive and non-invasive techniques, as well as various kinds of nanocarriers and related hybrids, have been extensively investigated. Unfortunately, no significant clinical translations have been seen yet. The prognosis for malignant brain tumours is dismal, and treatment is constrained by BBB impermeability. For therapeutic medication targeting drugs for brain tumours, new methodologies are required. Despite the use of surgery, radiation, and chemotherapy together, patients' overall outcomes are still not favourable. Glioblastoma, commonly known as Glioblastoma Multiforme (GBM), is regarded as the adult brain tumour that is most malignant. Active or passive targeting systems are two different types of nanoscale Drug Delivery Systems (DDS). The new blood vessels have increased permeability, which is a hallmark of tumoral angiogenesis. Additionally, inadequate lymphatic drainage might passively result in NPs retention. The limits of conventional drug therapy can be solved by active targeted nanoscale drug delivery systems. Drug encapsulated NPs that were conjugated to the associated ligands on brain endothelial cells were able to considerably increase BBB permeability by using the Receptor Mediated Endocytosis (RME) process. Modified NPs delivery offers the advantages of enhanced pharmacokinetic performance and high specificity as compared to standard drug administration procedures. Reduced reticulo endothelial system absorption, prolonged half-life, and sustained drug release at tumour locations could lower the delivery dosage and lessen side effects [18].

NPs offer a flexible basis for cutting edge malignant brain tumour therapy paradigms. They are effective drugs for fighting brain tumours because of their tiny size, low toxicity, versatility, and modifiability. A unique approach to treating brain tumours is to deliver chemotherapeutics *via* NPs. Such medicinal substances can lessen systemic negative effects for patients by exclusively accumulating in the specific location of interest. NPs are often given

intravenously. However, this approach is more intrusive than intravascular delivery and is constrained by the rapid turnover of cerebrospinal fluid. Intraventricular administration can be used to enhance drug delivery and bypass the BBB. By utilising certain cancer cell surface receptors, major advances have been made in creating target specific medicines that improve cellular internalisation and site specific drug release. These active targeting techniques not only increase the drug's effectiveness but also minimise any potential negative effects. Theranostics is a method that allows NPs to simultaneously treat and image brain malignancies. Some can be attached with either imaging probes and drugs, while others may be conjugated with NPs that are employed as contrast or imaging agents. Due to the numerous functional components that NPs use to accomplish distinct roles, such as imaging, drug release, tumour targeting, and reticuloendothelial system evasion, they are regarded as multifunctional. By stimulating microglia, immune cells of CNS that function similarly to peripheral macrophages, NPs directed towards the brain can lead to neuroinflammation. Nitric oxide and reactive oxygen species are secreted by the activated microglia, which cause excitotoxicity and neuronal injury. NPs can respond to external signals such as magnetic fields to induce magnetic hyperthermia or ultrasound to produce photoacoustic treatment and can be tuned to specific stimuli in tumour microenvironments. Diagnosis, surgical treatment, and therapeutic interventions of brain cancers may be advanced by nanoparticles. Nanoparticle, based MR compounds have the potential to make tumour areas visible that would not have been seen with conventional MRI, particularly at the tumor-brain interface. The use of nanoparticles for the transport of imaging agents and diagnostic compounds is theoretically possible. Nanoparticles also serve a variety of purposes, including imaging, therapy, and diagnostics, is receiving more and more attention. The most researched nanoparticles for brain imaging and diagnosis are quantum dots and dendrimers, which have excellent structural adaptability and vast carrier capacities for accommodating numerous functional entities. In the end, nanoparticles might make the removal of brain tumours more thorough. Finally, nanoparticle based drug delivery systems are likely to improve the delivery of chemotherapy and unconventional therapies for brain malignancies. The treatment of patients with brain tumours in the future is likely to heavily rely on nanoparticles [19].

Cancer

A key contributor to poor health outcomes in human life is cancer. Cancer is the uncontrolled expansion and rapid invasion of tissues without normal development and differentiation. An area of intense research investment, the development of novel methods for better cancer screening, diagnosis, and therapy has led to a number of advancements that have raised the 5 year survival rates of cancer patients. The usage and application of nanoparticles in the treatment of cancer may be one of the most promising therapeutic potential areas. Researchers are looking into several nanomaterials for adaptable cancer diagnostic, imaging, and treatment options. Treatment of cancer methods based on nanotechnology may seek to increase effectiveness, lessen adverse effects, and enhance patient quality of life. There is a wide variety of diagnostic and therapeutic nanomaterial instruments. The anatomical alterations, along with the pathophysiological circumstances at the diseased site, facilitate drug delivery and imaging with nanomaterials. Compared to conventional medications, nanomaterials typically build up at the site of the disease at a higher concentration. Because of the improved drug targeting, even difficult to target disease areas like the brain are successfully treated with lessened systemic toxicity. Nano formulations with good biocompatibility and pharmacokinetic features have shown tremendous promise for the administration of new anticancer medicines. According to predictions, nanoscale biomaterials made of biocompatible lipids, polymers, or inorganic materials combined with targeting groups will offer enormous potential for delivering pharmaceutical active ingredients to their

precise target areas for enhanced therapeutic objectives. Such adaptable tailored nanoparticles will have more potential applications and support the development of precision medicine. The delivery of cytotoxic drugs to cancer cells in the body has been extensively researched using particles of different material origins. Among them are genuine nanoparticles like dendrimers and quantum dots, along with nanoparticulate mixtures of nanoparticles like lipoproteins, solid lipids, micelles, and microcapsules. By extending the blood circulation period of therapeutic drugs for greater tumour accumulation and addressing the poor water solubility and undesirable adverse effects frequently noticed after their administration, nanoparticles significantly simplify their employment as therapeutic agents for tumour therapies. Importantly, these innovative nanomedicines created by encapsulating certain therapeutic compounds in nanocarriers can successfully target tumours by exploiting the passive targeting technique mediated by the EPR phenomenon. Thus, these innovative therapies play a major part in driving healthcare expenditures.

Numerous studies, both *in vitro* and *in vivo*, demonstrate that nanomedicine treatments are effective in the treatment of cancer. However, relatively few cancer therapies based on nanocarriers have managed to enter clinical trials. Numerous studies have been conducted on nanoparticles to determine their efficacy in the treatment of various cancers. To effectively treat primary and systemic cancers, some of these nanoparticles have started clinical trials, such as SGT-53 nanoparticles, which are made of cationic liposomes loaded with the plasmid expressing the p53 gene. Currently undergoing clinical phase I, the nanocomplex is believed to provide promising results as observed in human subjects with various cancers. With a similar aim of treating metastatic breast cancer, pancreatic ductal adenocarcinoma, and urothelial carcinoma, nanoparticle albumin bound paclitaxel is under clinical phase II/III trials. By integrating more sophisticated or even predictive diagnostic technologies with cutting edge targeted strategies, risks in clinical development may be reduced. The broad use of cancer nanomedicine therapies is hampered by problems with production, nanomaterial characterisation, and safety considerations. It is necessary to characterise nanomedicine products thoroughly and repeatedly to forecast their effectiveness and safety in people. To forecast how nanomedicine therapies will work in the clinic, standards for *in vitro* and *in vivo* models are necessary. Furthermore, there is an urgent need for clear standards and thorough rules for both regulatory approval and massive industrial output. As a result, this might help find safe and better responders, and personalised cancer therapy may be achieved [20].

RESULTS

Rendering solutions through nanotechnology

Nanotechnology has a multitude of applications in the biomedical industry and can alter the dimensions of therapeutics and materials. This allows for easier control over the varied properties of drugs and materials. Nanotechnology exploits medicinal compounds at the nanoscale to make nanomedicines. The incorporation of nanotechnology can make it easier to overcome the challenges that medications use to treat neurodegenerative diseases. Recent advances in nanotechnology make it simpler to safely deliver drugs to specific sites of action and direct pharmaceuticals toward specific molecular targets. For the cure of cancer and infectious diseases, various therapies based on nanoparticles with a size range of 1-1,000 nm have been effectively introduced over the past few years. In the field of synthetic nanoparticles, achieving targeted triggered, dispersion of particles still poses a significant challenge. Biomaterials that are enzymatically degradable, reductively labile, or pH sensitive and that enable bond breakage between drug and carrier, or destabilisation of the carrier upon reaching the desired site of

action, are currently used in the majority of techniques. While using nanomaterials for drug delivery, the physicochemical characteristics of the drug are taken into consideration when choosing the nanoparticle. The utilisation of bioactive natural chemicals in conjunction with nanoscience is highly appealing and has grown significantly in recent years. Whenever it pertains to the administration of natural therapies for the treatment of cancer and various other diseases, it offers a number of benefits. As a result of their numerous distinctive properties, including their ability to induce tumor suppressing autophagy and function as antimicrobial agents, natural chemicals have been thoroughly researched in the treatment of diseases.

Nanoformulations have the ability to reduce toxicity while also improving the drug's pharmacokinetic and pharmacodynamic profiles. Through improved permeability, nanocarriers help medications flow through biological membranes safely, boosting their effectiveness even at low doses. Bypassing phagocytic opsonization, nanocarriers deliver higher medication concentrations at the targeted region in the brain. The surface properties of the nanocarriers are being modified in order to improve localisation, minimise first pass metabolism, boost permeability, and enable controlled medication release in the central nervous system, particularly in neurodegenerative illnesses. In order to overcome the BBB barrier and other obstacles to targeted medication delivery in the brain, conventional and innovative nanocarriers are primarily being investigated. To overcome the cytotoxicity and effectively treat a variety of CNS disorders, such as neurodegenerative diseases, modifications on the basis of materials, form, and design are necessary. Nanoparticles have been discovered to help gather information at all phases of clinical procedures due to their application in several innovative tests to diagnose and treat diseases. The main advantages of these nanoparticles are linked to their surface characteristics because different proteins can attach to the surface. For example, gold nanoparticles are used as tumour labels and biomarkers in a variety of biomolecule detection procedures. Recently, doxorubicin and imaging agents such as Gd^{3+} contrast agents were delivered to mice brain tumour tissues using Tat peptide modified gold nanoparticles as a platform. Compared to mice treated with free doxorubicin, those administered with nanoparticle complexed doxorubicin had a higher survival rate.

Advanced drug development is now more apparent owing to nanocrystal formulation. Clearly, drugs with solubility issues are best suited for nanocrystal technology. Important factors include the reduction in particle size, which increases particle surface, saturation solubility, and subsequently increases the dissolution velocity. Formulations can be created using the nanocrystal technology without the inclusion of troublesome surfactants that could increase side effects or unpleasant reactions. Additionally, because the nanoparticles dissolve quickly, nanocrystals enable an early start to the action of the medicine. This is advantageous, especially for medicines that need to start working quickly. The nanocrystal technique enables lesser doses and hence decreased side effects if a big dosage is required to obtain tolerable blood levels for poorly soluble medicines, resulting in increased adverse effects. A prolonged or focused release can be achieved by altering the nanocrystal surface.

DISCUSSION

Since nanotechnology offers a myriad of excellent options, the therapeutic approach would continue to be provided in a more focused and specialised way. By enabling the targeted and site specific administration of medications, nanotechnology has many advantages in the treatment of chronic human diseases. The effectiveness of the medicine is driven by the drug delivery of the more recent or older molecules. Targeting ligands like antibodies or peptides may

be included in the next generation of nanoparticle systems, which could further increase their efficacy or lessen their toxicity. Targeted drug delivery is made possible by the efficient sequestration of pharmaceuticals with nanoparticles and their modification with certain ligands. As a result, the intended drug molecule's therapeutic effectiveness is substantially increased. Pharmaceutical drugs can be made more stable and more effective at the target site by being encapsulated or loaded inside nanoparticles. This reduces the need for higher drug dosages and the toxicity that follows. However, the lack of knowledge regarding the toxicity of nanostructures is a significant concern and unquestionably calls for more study to increase the efficacy while maintaining improved safety to facilitate safer actual implementation of these drugs. Future research will focus on more complicated systems such as multifunctional nanoparticles that can be used for therapy, imaging, and targeting all at once. It is necessary to precisely construct nanoparticles with the physicochemical and biological characteristics to carry out each desired function as the functionality of nanoparticles grows more complex. A rapid increase in the number of multifunctional nanoparticles entering the clinic could be seen in the future due to the use of safer nanomaterials as well as cutting-edge engineering methodologies that produce nanoparticles that are ideally constructed.

CONCLUSION

Nanotechnology is truly a multidisciplinary science where chemists, physicist, biologists and pharmaceutical scientist all have played major roles to develop novel treatment and diagnosing modalities. It is evident through this review that application of nontechnology in drug delivery and medicine has paved new pathways and opened many doors for providing customizable and safer treatment option. The treatment of cancer and HIV/AIDS, non-invasive imaging as well as nutraceutical delivery have all progressed with the application of nanotechnology. Ultimately, through the manipulation of molecular size and surface properties, researchers are able to deliver drugs for longer period of time with less frequent dosing (sustained release) and with greater precision and penetration in difficult to access tissues.

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COMPETING INTERESTS

The authors declare that there are no competing interests.

REFERENCES

1. Martins P, et al. Nanoparticle drug delivery systems: Recent patents and applications in nanomedicine. Recent Pat Nanomed. 2013;3:105-118.
2. Akgol S, et al. The usage of composite nanomaterials in biomedical engineering applications. Biotechnol Bioeng. 2021;118:2906-2922.

3. Hasan A, et al. Nanoparticles in tissue engineering: Applications, challenges and prospects. Int J Nanomedicine. 2018;13:5637.
4. Goldberg M, et al. Nanostructured materials for applications in drug delivery and tissue engineering. J Biomater Sci Polym Ed. 2007;18:241-268.
5. Patra JK, et al. Nano based drug delivery systems: Recent developments and future prospects. J Nanobiotechnology. 2018;16:1-33.
6. Sahu T, et al. Nanotechnology based drug delivery system: Current strategies and emerging therapeutic potential for medical science. J Drug Deliv Sci Technol. 2021;63:102487.
7. Watkins R, et al. Natural product based nanomedicine: Recent advances and issues. Int J Nanomedicine. 2015;10:6055.
8. Gaur PK, et al. Enhanced oral bioavailability of efavirenz by solid lipid nanoparticles: *In vitro* drug release and pharmacokinetics studies. Biomed Res Int. 2014.
9. Biswas A, et al. Advances in top down and bottom up surface nanofabrication: Techniques, applications and future prospects. Adv Colloid Interface Sci. 2012;170:2-27.
10. Campuzano S, et al. Nano/microvehicles for efficient delivery and (bio) sensing at the cellular level. Chem sci. 2017;8:6750-6763.
11. He H, et al. Survey of clinical translation of cancer nanomedicines lessons learned from successes and failures. Acc Chem Res. 2019;52:2445-2461.
12. Aguero-Torres H, et al. Dementia is the major cause of functional dependence in the elderly: 3 year follow-up data from a population based study. Am J Public Health. 88:1452-1456.
13. Maiese K, et al. Impacting dementia and cognitive loss with innovative strategies: mechanistic target of rapamycin, clock genes, circular non-coding ribonucleic acids, and Rho/Rock. Neural Regen Res. 2019;14:773.
14. Larson EB, et al. Cognitive impairment: Dementia and alzheimer's disease. Annu Rev Public Health. 1992;13:431-449.
15. Khachaturian ZS, et al. Diagnosis of alzheimer's disease. Arch Neurol. 1985;42:1097-1105.
16. Rahman MM, et al. Recent advancements of nanoparticles application in cancer and neurodegenerative disorders: At a glance. Biomed Pharmacother. 2022;153:113305.
17. Tosi G, et al. Nanoparticles as carriers for drug delivery of macromolecules across the blood brain barrier. Expert Opin Drug Deliv. 2020;17:23-32.
18. Martin-Rapun R, et al. Targeted nanoparticles for the treatment of alzheimer's disease. Curr Pharm Des. 2017;23:1927-1952.
19. Ouyang Q, et al. New advances in brain targeting nano drug delivery systems for alzheimer's disease. J Drug Target. 2022;30:61–81.
20. George A, et al. Natural biodegradable polymers based nano-formulations for drug delivery: A review. Int J Pharm. 2019;561:244-264.