REVIEW ARTICLE

Advancements in the Controlled Delivery of Nanodrugs to the Central Nervous System: Challenges and Innovations

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ABSTRACT

About 1 million of the 6.8 million deaths attributed to disorders of the central nervous system (CNS) each year are caused by neurodegenerative diseases, which include Parkinson's disease, Alzheimer's disease, tumors, and ischemic stroke. Because of the complexity of the brain, CNS issues are a major concern. To address issues with toxicity, specificity, and delivery, several drugs are available to treat illnesses of the central nervous system (CNS). Therapeutic drugs are challenged by barriers such as the blood-brain barrier (BBB), which prevents them from reaching their intended target. Scholars have been investigating pathways for pharmaceuticals to cross the blood-brain barrier and reach their intended targets. These issues show how different cellular processes must be changed or manipulated by nanotechnology to obtain the required properties. Nanoparticles are an efficient replacement for drug delivery and other methods because of their nano size, which allows them to cross the blood-brain barrier. Effective drug transfer and enhanced CNS disease treatment and diagnosis are possible using nanotechnology. Drugs could be altered via nanoengineering to carry out tasks like transferring across the blood-brain barrier, modifying signaling pathways, focusing on certain cells, facilitating efficient gene transfer, and encouraging nerve cell regeneration and preservation.

Keywords: Neurodegenerative disorders, Central nervous system, Blood-brain barrier, Nanotechnology, Drug delivery.

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INTRODUCTION

Brain cancer and other central nervous system (CNS) and peripheral nervous system (PNS) disorders are among the most common, lethal, and undertreated medical illnesses. In certain pathological conditions, such as stroke, Alzheimer's disease (AD), diabetes, Parkinson's disease (PD), seizures, and amyotrophic lateral sclerosis (ALS), the blood-brain barrier (BBB) is disrupted. To combat brain diseases, there will need to be a significant increase in drug development worldwide over the next 20 years due to the growing number of older people and teenagers with CNS issues [1]. Drug discovery for brain disorders has the lowest success rate when compared to all other pharmacological formulations. Compared to non-CNS pharmaceuticals, the development of CNS drugs takes a lot longer [2].

A group of illnesses that primarily impact individual neurons within the neural network are together referred to as "neurodegenerative diseases." The fundamental component of the nervous system, which mostly guards the spinal cord, is a network of neurons. The body cannot repair neurons because they generally do not replicate or renew on their own; therefore, when a neuron is damaged, it dies [3]. Adult neurogenesis following specific types of injury, however, still seems possible. The first indication of this was found in studies using rodent stress models. These studies showed that following a series of extremely difficult psycho-social stressors, there was a marked decrease in the emergence of neurological precursor cells inside the adult hippocampus's subgranular layer. Pharmacological therapy was able to restore this reduced cell proliferation [4-5]. Non-human primates have also been shown to benefit from antidepressants in terms of increased neurogenesis and brain progenitor cells [6]. Particular parts of the brain may become permanently dormant or die as a result of these disorders. Nerve impulses and the PNS become less effective over time in NDDs before dying. Although there are therapies available, there are unavoidable adverse effects associated with each one. The complexity of the brain, side effects, and BBB permeability make clinical research of CNS drugs difficult [7]. The most delicate and complex organ system, the brain, is shielded by the blood-brain barrier. It provides

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defense against potentially harmful and destructive substances in the bloodstream for the cerebral neurons, but it also poses a significant barrier to the delivery of drugs into the central nervous system (CNS). Ninety-five percent of the compounds are not developed into drugs because of the BBB [8-9]. "Recent studies have demonstrated that the blood-brain barrier (BBB) is a dynamic interface that controls the flow of chemicals from the bloodstream into the brain [10]. It is composed of a monolayer of polarized endothelial cells connected by intricate tight junctions, and astrocytes, neurons, and pericytes regulate its function" [11].

The blood-brain barrier (BBB) serves as a shield for the brain in a healthy individual, keeping various substances from the bloodstream out of the brain and preserving normal brain function. Because of this, the BBB is only permeable to very small particles. The diameter of the capillaries in the brain can range from 7 to 10 μm [12-13]. Only lipid-soluble, small molecules with a molecular weight of less than 400 Da can pass through the blood-brain barrier. Most macromolecules are unable to cross the brain endothelium [14]. To maintain the lowest possible ocular concentrations, the BBB also regulates the entry of potassium (K+), calcium (Ca2+), and sodium (Na+) ions at synapses. The BBB is responsible for controlling the flow of substances into and out of the brain, maintaining ionic balance, and protecting the brain from substances that can damage it, such as xenobiotics, neurotransmitter systems, and drugs that are part of the systemic circulation [15]. To successfully carry drugs over the BBB and into the central nervous system, an appropriate nanocarrier technology must be found. Brain microvascular endothelial cells (BMVECs) and certain other treatment system components (such as neurons, astrocytes, pericytes, and basal lamina) form a tight connection that protects the CNS and ensures its proper functioning. A vast array of pharmaceuticals with different structures and therapeutic purposes can be easily expelled from cells by the ATP-binding cassette (ABC) protein superfamily, which includes most BBB transporters. Our understanding of transporters' functions and contributions to the BBB has improved because of P-glycoprotein (P-gp) research [16]. Previous research focusing on BBB permeability has examined the features of transporters that dominate permeability. Extracellular calcium was first shown to be an essential part of tight junction (TJ) control in Ca2+ addition/depletion models. TJ function and assembly quickly adjust to intracellular signaling events that change TJ complexes during pathological and physiological changes.

Nanoparticles

Paul Ehrlich, the winner of the Nobel Prize, popularized the idea of the "Magic Bullet" in the early 1900s. Ehrlich claimed that certain drugs could "hit a specific target, overcoming several physiological and cellular barriers, increasing the drug bioavailability and decreasing the appearance of possible side effects." In light of this notion, DDS based on nanotechnology has developed as an alternative method to get past the BBB and achieve brain targeting. Their capacity to bypass the immune system, penetrate the blood-brain barrier, and locate target tissues determines how the DDS will behave. Various nano-delivery technologies have been developed over the past 20 years to boost the low bioavailability of particular drugs and nutraceuticals, minimize peripheral adverse effects, overcome the blood-brain barrier, and increase the therapeutic action of these molecules in the brain.

Mode of action of nanoparticles

A few physicochemical characteristics of nanoparticles facilitate their passage through brain endothelial tissue: minute size, hydrophilicity, surface charge, and the capacity to bind with ligands using nanocarriers. "The electrostatic interactions between the carrier and brain cells are a result of the positive charge on the nanoparticle surface and the negative charge on endothelial cells.The lipophilic properties of nanomaterials enhance their attributes and expedite the adsorption process. Nanoparticles are internalized through endocytosis and transcytosis when low-density lipoprotein receptors are present on brain endothelial cells, followed by desorption". Upon desorption, the particles release the drug onto the surface of the blood-brain barrier, diffusing into the brain's parenchyma. Due to their diminutive size, nanoparticles can readily traverse blood capillary endothelial cells via endocytosis and transcytosis mechanisms. Once internalized, drug-laden nanoparticles penetrate deeper into the brain's parenchyma or cells. The precise mode of drug delivery by nanoparticles involves various processes, which are yet to be fully elucidated. One plausible explanation posits that a surfactant solubilizes lipids in the endothelial cell membrane, thereby augmenting permeability across the blood-brain barrier. Nanoparticles may induce toxicity in the brain's blood vessels or disrupt tight junctions to navigate the BBB. The enhanced absorption and retention within capillary walls and brain-blood capillaries facilitate processes such as transcytosis and endocytosis across endothelial cell layers, thereby enhancing material transport. Nevertheless, drug diffusion may be effluxed out due to the presence of diverse transporters, rendering it a suboptimal pathway for pharmaceutical delivery across the blood-brain barrier.

Types of nanoparticles delivering drugs to CNS (Figure 1)

Drug delivery for central nervous system illnesses can be accomplished with the help of nanotechnology. One benefit of nanoparticles is their ability to pass the blood-brain barrier with a site-specific drug delivery mechanism. Solid-lipid nanoparticles (SLNs), dendrimers, liposomes, micelles, and PNPs are a few examples of the various types of nanoparticles, each having a unique composition and function .

Liposomes

Liposomes are small colloidal vesicles with lipid bilayers that mimic cell membranes, used in drug delivery. They can be categorized by size and quantity of bilayers. They show promise in treating neurological diseases due to their ability to cross the blood-brain barrier. Liposomes are biocompatible and can be modified for long circulation in the body. PEG-coated

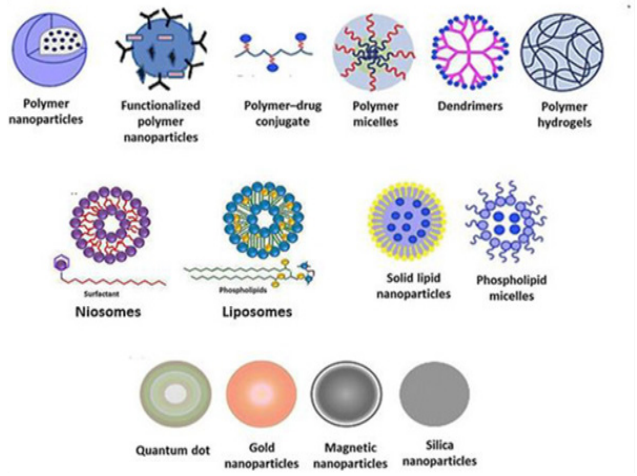

Figure 1: Schematic illustration of various types of nanoparticles

liposomes can evade detection by RES cells. Liposomes can be further modified with ligands for targeted transport to the brain. Immunoliposomes are effective against autoimmune diseases and can be used in gene therapy. Liposomes can also be used for delivering small interfering RNA for brain tumor treatment. Cell-penetrating peptides can enhance liposomes' ability to cross barriers. Liposomes can serve as an effective drug delivery system with minimal antibody activation.

Solid Lipid Nanoparticles (SLNs)

Triglycerides and fatty acids are lipids in SLNs, aqueous colloidal mixtures that solidify upon cooling. SLNs are low in cytotoxicity, stable, and used for brain drug delivery. Encapsulated drugs in SLNs have stable release profiles. SLNs prevent drug leakage and degradation, enhancing drug stability. SLNs improve bioavailability of hydrophobic drugs. SLNs are novel drug carriers with increased durability and capacity. NLCs combine solid and liquid lipids for improved drug delivery. PEG-modified SLNs enhance drug delivery across the blood-brain barrier. SLNs facilitate target-specific drug delivery across the BBB. SLNs efficiently deliver various drugs to the brain. Lipid nanoparticles show promise for Parkinson's disease treatment. Ropinirole-loaded lipid formulations improve drug bioavailability orally and topically. Lipid-based NPs may cause adverse immune reactions when administered to people.

Polymeric Nanoparticles (PNPs)

Polymeric nanoparticles are among the first and most effective methods in the field of DDS [56]. After receiving FDA approval in 1974, polylactic-co-glycolic acid (PLGA) has become the biomedical industry's most successful polymer by far. Furthermore, the possibility to employ PLGA microparticles as drug carriers of a broad range of medicinal compounds was made possible by their initial approval in 1989 with Lupron Depot®.

Traditional AD drugs, such as rivastigmine, have been encapsulated in PLGA NPs to improve brain penetration, reduce frequent dosage, and minimize cholinergic side effects. An acetylcholinesterase (AchE) inhibitor that has FDA approval is donepezil. "More NPs were able to breach the blood-brain barrier as a result of the surface modification with Tween 80, enabling brain targeting after IV injection. The addition of surfactant to NPs caused the BBB's tight junctions to open via an endocytosis or transcytosis mechanism, releasing the drugs inside brain endothelial cells and delivering them to the brain". Furthermore, Tween-80 surface coating suppressed P-glycoprotein and the efflux mechanism, which improved drug transport to the brain through the blood-brain barrier. The results using gamma scintigraphy images demonstrated increased brain accumulation of donepezil-loaded NPs, despite accumulation in off-target organs. To boost brain concentration, PEG has been utilized to alter the NPs' surface to give them stealth characteristics and immune system evasion. Galantamine-loaded NPs were made in this manner to treat AD. The potential of this innovative nanoformulation to raise drug concentration in the brain was reported by the intravenous injection of PEG-PLGA NPs combined with ascorbic acid. The commercial drugs as well as other treatments under investigation, like growth factors and neurotrophic factors, have been encapsulated to enhance their biodistribution. This has resulted in higher therapeutic levels of these treatments in the brain and a lower chance of systemic side effects. Despite its potential for treating diseases, NTFs are not yet fully translated to the clinic due to several factors, including their short half-life and limited bioavailability. To overcome these drawbacks, a novel therapeutic strategy for AD has been developed: PLGA NPs encapsulating basic fibroblast growth factor (bFGF). To boost GF brain levels following intranasal treatment, these PLGA-NPs were further conjugated with Solanum tuberosum lectin (STL) and surface-modified with PEG.

The most effective therapy for Parkinson's disease (PD) available today is dopaminergic therapy. Although the clinical standard treatment is levodopa, or L-DOPA, a DA prodrug, only 1% of given L-DOPA may enter the brain intact. Furthermore, the short half-life of L-DOPA means that large doses must be administered frequently, which can have several negative consequences, such as dyskinesia or the wearing-off and on-off phenomenon brought on by repeated administration. Drug release control and biodistribution can be altered with NPs-based DDS, minimizing adverse effects and optimizing therapeutic benefits while mitigating these disadvantages.

Magnetic Particles

New nanomaterials for targeted therapies, magnetic nanoparticles are superparamagnetic, making them attractive for targeted remedies. The right amount of drug at the right location limits the effectiveness of conventional methods. Magnetic particles can be manipulated with an external magnetic field for CNS illnesses. Superparamagnetic iron oxide nanoparticles are ideal for targeted therapies. Improved dispersibility observed in recent years with functionalized iron oxide nanoparticles. Oligosaccharide-coated magnetic

particles enable noninvasive imaging of cancer cells. Polymeric encapsulation may improve colloidal stability and BBB crossing. Polymeric coverings prevent drug breakdown and increase bioavailability. Carnosine and dexamethasone added to functionalized iron oxide nanoparticles for ischemic stroke treatment. Brain cells may react differently to magnetic nanoparticles based on various factors. Larger particles trigger a stronger immune response compared to smaller ones. Positive surface charge may elicit a greater immunological response. Several approaches are used to address immunological responses in brain drug delivery. Magnetic nanoparticles should preferably be coated with a biocompatible polymer.

Dendrimers

Polymeric macromolecules called dendrimers have hyperbranched network architectures and can be modified in terms of surface functions. Biological molecules (antigens, antibodies, and oligonucleotides) and drug molecules are effectively transported throughout biological systems by dendrimers, which function as nanocarriers. As dendrimers have so many benefits, including pH stability, adjustable solubility, drug-loading capacity, surface functionalization ability, and biocompatibility, they have been extensively studied as nanocarrier technologies.

Poly(amidoamine) (PAMAM) is the most studied drug delivery agent for oral administration due to its water solubility and ability to cross epithelial tissue, which enhances the drug's transfer via the paracellular pathway. "Dendrimers are classified into several types based on their functionalization moieties: PAMAM, PPI, liquid crystalline, core-shell, chiral, peptide, glycodendrimers, and radially layered poly(amidoamine-organosilicon) (PAMAMOS). Due to the presence of amine groups, dendrimers have restricted therapeutic applicability". The drug is delivered by dendrimers in two ways: first, through the covalent bonding of the drug being broken down in vivo by available enzymes or by a favorable environment that can break the bonds; second, through the drug being released because of changes in the physical environment, such as pH, temperature, etc.

Micelles

Micelles are vesicles composed of amphiphilic surfactants, which are non-polymeric, or amphiphilic copolymers, which are polymeric, and they have recently caught the interest of scientists due to their potential application in the delivery of drugs to the central nervous system. Micelles remain stable in an aqueous environment because of the hydrophilic coating on the outside. Furthermore, it increases their accumulation in leaky vascular regions and shields them from the reticuloendothelial system (RES) by prolonging their blood circulation. The poloxamer, or pluronic copolymer class, is of particular interest since it has the potential to block drug efflux transporters. Due to its widespread expression on the BBB, the P-gp efflux carrier facilitates drug delivery to the central nervous system.

Nanogels

Hydrogel technology has advanced thanks to nanotechnology, which has created smart nanogels with more sophisticated capabilities than bulk three-dimensional cross-linked hydrogels. Hydrogels with a size range of 1–100 nm are known as nanogels. There are still concerns regarding the toxicity and biodegradability of inorganic nanocarriers, and drug burst release problems are associated with polymer particles of poly(lactic-glycolic acid) copolymer (PLGA).

According to studies, the brain's absorption of insulin is improved when nanogels are taken orally. To covalently bind insulin, poly(N-vinylpyrrolidone)-based nanogels were created and evaluated for brain administration via electron beam irradiation. The investigation indicated that when nanogel was administered intranasally, the nasal mucosa did not react immunologically. This study demonstrates the therapeutic potential of nanogels against certain neurodegenerative diseases. Strong nasal drug absorption was shown by olanzapine loaded in chitosan-based nanogels. Using intriguing research, a hydrogen bond-enhanced nanogel system with antioxidant and anti-inflammatory capabilities was developed: glycyrrhizic acid−zinc alginate nanogel, or GA-NG. Selective brain accumulation and distribution were demonstrated by this nano-hydrogel. Enhancing stability, this nano-hydrogel system made use of hydrogen bonding sites for small molecules that were active. Such investigations validate the promise of nanogels as noninvasive drug delivery systems and sustained release carriers for Parkinson's disease.

Quantum dots

QDs are semiconductor nanocrystals that have a diameter of 2 to 10 nm. The QDs have garnered significant interest in the field of nanomedicine because, in contrast to traditional organic dyes, they exhibit emission in the near-infrared (650 nm) range, which is highly desirable for biomedical imaging because of the low tissue absorption and decreased light scattering. QDs are thought to be the most effective for treating CNS diseases because of these characteristics. For the diagnosis and brain disease imaging, several conjugated QDs are employed. The BBB is unaffected by these semiconductors' chemo-electric characteristics or size. The primary factor for QD transport over the BBB is their surface. According to Lien et al.'s research, graphene QDs can prevent the accumulation of Aβ1-42 peptides and have numerous therapeutic uses for this issue. There are several ways to make QDs traverse the blood-brain barrier (BBB), and one of the ways they do so is by binding with certain molecules.

Exosomes

Most nucleated eukaryotic and prokaryotic cells release exosomes, which are extracellular vesicles that can function as endogenous nanoparticles. The components of exosomes might comprise proteins, lipids, metabolites, DNA, and RNA, depending on the origin and functional state of the cell. Exosomes are primarily involved in intercellular communication and can control inflammation, autoimmune,

and T-cell-mediated immune responses. Nonetheless, native exosomes derived from mesenchymal stem cells (MSCs) continue to be able to support immunological regulation, migration, homing, and neurite remodeling. Current studies have shown that in PD39 and AD40 illness models, engineered MSC-derived exosomes, or MSC-exos, moved to specific brain regions that were affected. It was demonstrated during stroke that exosomes generated from dendritic cells (DC) were immunomodulatory and exosomes derived from macrophages were neuroinflammatory. Exosomes can carry drugs into the brain through the blood-brain barrier because of their small size and endogenous characteristics. Naturally occurring exosomes can cross the blood-brain barrier by binding to receptors on brain endothelial cells. Exosomes have been investigated for carrying neurotransmitters (dopamine) across the blood-brain barrier in the hopes of treating Parkinson's disease, based on their interaction with transferrin receptors. In addition to influencing immunological responses, exosomes are involved in cell-to-cell communication. Macrophages and dendritic cells, for instance, are immune cells that produce exosomes, which, depending on their contents, can either stimulate or dampen immunological responses.

Use of Prodrugs

Prodrugs are more frequently used to deliver drugs that are unable to cross the blood-brain barrier into the brain without damaging the structural barrier. Most of these are used to treat disorders of the nervous system. To transfer drugs into the brain, a variety of prodrug systems are employed, including gene-directed enzyme prodrug systems, receptor-mediated prodrug delivery systems, and lipophilic carrier systems. Moreover, pharmacologically active agents are added to prodrugs—which lack or have minimal biological activity—through chemical modification. These prodrugs then undergo an in vivo transformation to release the active drug. Therefore, without ever releasing the drug in its active state, active prodrugs might be able to cross the barrier and then be activated. Prodrugs are bio-reversible drug compounds that alter chemically or enzymatically in vivo to liberate the active parent compound. These substances circumvent obstacles to a drug's utility by acting pharmacologically. Prodrugs have the intended pharmacological action after being delivered to the target site. More precisely, the inclusion of lipophilic groups renders medicinal substances or drugs lipophilic. Using the most prevalent functional groups that could permit drug permeability through any type of structural or physical barrier, these are created.

Peptide Masking

Furthermore, different barriers hinder the use of brain-targeting therapies like P/P (Protein Peptide) drugs. Lipophilicity, achieved by adding a cholesteryl group, is crucial for successful P/P permeability. Non-invasive techniques like intraventricular delivery can be used. Disguising drugs by altering their chemical makeup to make them lipid-soluble is another helpful method for safe transportation. A lipophilic group increases the chance of a peptide passing through the blood-brain barrier, but its basic properties may be obscured. Cholesteryl is used instead of cholesterol due to its lipophilic nature. Masking helps the drug pass through the barrier by hiding its water solubility. Therapeutic peptides are also hidden from degrading enzymes in the brain. Larger molecules may not pass through, but shorter peptides with a high surface charge can attach to receptors on one side. Coupling the drug to a target molecule can facilitate crossing the blood-brain barrier. C-terminal peptide thioesters aid in peptide masking. Their synthesis involves the BAL (Backbone amide linkage) approach, which improves drug efficacy and delivery. Despite their potential, many P/P drugs on the market fail to treat conditions effectively. Masking molecules with low molecular weights are ideal for high accessibility as they can easily cross the blood-brain barrier and deliver the drug effectively.

Current Approaches and Challenges

Considerable efforts are made to investigate nanodrug strategies for CNS disorders. Advancements are in early phases and need more preclinical testing. Development of nanodrugs for CNS disorders is hindered by safety concerns. BBB can be opened non-invasively with external stimulation. This approach may cause neurobehavioral disorders. Blood circulation is how CNS regulators access the brain. Protein-corona formation hinders development of nanoparticles. The efficiency of nanoparticles' targeting can be hampered by serum proteins. The size of the protein corona is influenced by the nanoparticle surface charge. The impact on the protein corona has been thoroughly examined. Prospective regulators may be developed by assessing nanoparticles through clinical trials. Nanotechnology may improve neutron capture therapy cure and boron delivery to brain tumors. Boron neutron capture therapy initiates nuclear reactions with boron-10 and low-energy thermal neutrons. Treatment of neutron capture involves low molecular weight substances. Promising results have been shown with boron-containing nanocarriers.

Limitations and future directions

Nanodrugs have recently led to the development of customized drugs as well as intriguing new ways to treat CNS diseases. It is necessary to consider them as a successful way of delivering drugs across the blood-brain barrier. Therapeutic drug carriers have the potential to diffuse across brain tissue, penetrate the blood-brain barrier, and target specific cells via signaling mechanisms.

Nanotechnology-based pharmaceutical delivery systems have been continually investigated and emphasized in the vast majority of nanodrug therapies being utilized to treat CNS diseases. Furthermore, several nanodrugs are presently undergoing clinical trials; nevertheless, little is known about their pharmacokinetics and safety currently. Instability within the BBB, oxidative stress, and amino acid breakdown could all be caused by the characteristics and content of nanoparticles, increasing their neurotoxic effects on the brain. Drug loading may be restricted by functionalized nanoparticles' large surface area and compact form, which may lead to particle aggregation despite their successful therapeutic localization.

The amount of nanodrug and the method of pharmaceutical delivery may both contribute to increased neuroinflammation, which can result in oxidative stress, DNA damage, and allergic reactions. Therefore, it is essential to understand the biodegradability and biocompatibility of nanodrugs. Developing and implementing standardized techniques to assess the toxicity of nanoformulations in both in vitro and in vivo research is indeed critically needed to provide complete information on the toxicity of nanoformulations in humans.

Successful applications of nanodrugs must interact with neurons on a systemic level. Because of the intricate cellular connections and limited anatomical accessibility at the neuronal level, drug transport may be more problematic. It is a major issue to keep the central nervous system's vital functions intact during drug delivery. Several multifunctional nanomaterials have been the subject of research, and the results have shown remarkable challenges that need to be quickly overcome. "For example, some of the nanomaterials have properties like biological reasonableness, effectiveness, biocompatibility, and toxic effects in the living organism classifications." "Among the many challenging issues being worked on are the modification and control of nanotechnology, pharmaceutical cargo packing, drug delivery to the brain, deep brain stimulation (DBS), implantation stimulation, and even brain cell activity". The creation and characterization of nanoparticles appear to be crucial for their use in drug delivery to prevent unintentional harm to healthy cells. Depending on the degree of neurodegeneration a patient experiences, these advancements should make it simpler to develop drugs in the future.

CONCLUSION

The number of people with CNS diseases and brain tumors is continuously increasing as a result of the environment's and lifestyle's ongoing decline. Because of these conditions' distinct surroundings, sensitivity to outside substances, and intricate structures, which make it challenging to administer drugs through them, the primary treatment problem is the BBB's impermeability. A robust and efficient carrier that could deliver the drugs to the target place effectively and with little to no adverse effects needs to be developed. When it comes to treating CNS illnesses, nanoparticles have demonstrated to be powerful and effective carriers when compared to traditional therapy.

As theranostics for neuroprotection, nanoparticles such as liposomes, polymeric nanoparticles, dendrimers, and micelles are much sought after. There is a lot of interest in nerve growth factors and nanoformulations for neurological illnesses, but little information is known about their side effects. Nevertheless, nanotechnology has unequivocally shown itself to be a creative and inspiring source of scientific knowledge, allowing for the accurate and simple administration of drugs to the central nervous system. There is an urgent need to investigate novel therapeutic options with promising outcomes due to the increasing number of brain illnesses and the growing population. Utilising nanotechnology in neuroscience could solve unmet clinical needs and offer better results to patients. Pharmacological delivery to a specific target and sustained drug release may be regulated via a new wave of nanodrugs. It is predicted that the existing accepted technique of pharmaceutical distribution may be greatly outperformed by the nanotechnology-based delivery system, which might also yield significantly more productive customized drugs.

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