INTERNATIONAL JOURNAL IN PHARMACEUTICAL SCIENCES

Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Review Article

Novel Drug Delivery System For Treating Neuropsychological Disorder

Abhay Kamble, Nakul Kathar, Gajanan Sanap

Late Bhagirathi Yashwantrao Pathrikar College Of Pharmacy

ARTICLE INFO

Received: 06 Dec 2023
Accepted: 09 Dec 2023
Published: 13 Dec 2023

Keywords:
Neuropsychological, Nanoparticles, Alzheimer's, Parkinson's, Blood Brain Barriers, Blood Cerebrospinal fluid Barrier.

DOI:
10.5281/zenodo.10370141

ABSTRACT

One of the main health issues in the world today is acknowledged to be neurological diseases (NDs). The World Health Organisation (WHO) lists neurological illnesses as one of the leading causes of death globally. Alzheimer's disease, Parkinson's disease, Huntington's disease, frontotemporal dementia, amyotrophic lateral sclerosis, Prion disease, brain tumours, spinal cord injuries, and strokes are examples of neurological illnesses. Since there are no particular treatments that can penetrate the blood-brain barrier (BBB) and significantly enter the brain to have a pharmacological effect, many conditions are regarded as incurable. The development of methods to increase medication efficacy and get around the BBB is necessary. . Using various kinds of materials at the nanoscale is one of the promising strategies. Through the use of nanotechnology and the development of nanomaterials that enhance the delivery of potent medication options. Nanoparticles can penetrate the BBB and exhibit reduced invasiveness. Also, study some drug administration approaches in brain like Delivery Intracerebrally, Delivery Intrathecally, Carbon nanotubes, liposomes, delivary via inhalation. In this review, we briefly summarized the recent literature on the use of various nanomaterials and novel Drug delivery system for the treatment of various types of neurological disorders. One of the main health issues in the world today is acknowledged to be neurological diseases (NDs). Across the world, neurological diseases (NDs) are acknowledged as a major health concern.

INTRODUCTION

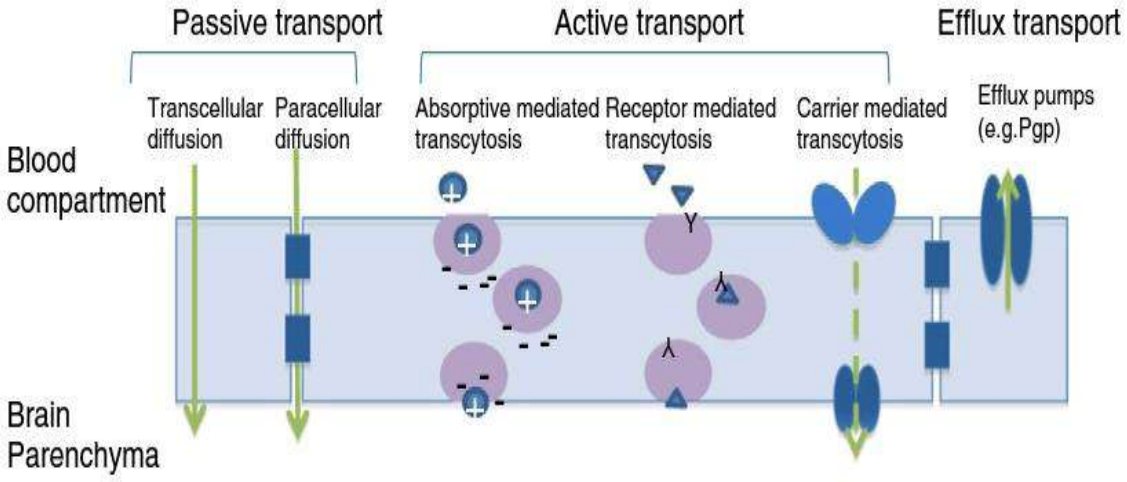
The most debilitating and difficult illnesses of the central nervous system (CNS) are known as neurodegenerative disorders (ND), and they pose a serious risk to public health [1].The term "ND" describes a neuron's loss of structure or function. There are different types of ND, including stroke, Alzheimer's, Parkinson's, Huntington's, and prion diseases. The pathophysiology of each disease is different. Some NDs lead to memory and cognitive impairment, while some affect the ability of the person to speak, move, and breathe [2].As per the World Health Organisation data, stroke ranks second globally among the top 10 major causes of

***Corresponding Author:** Abhay Kamble
Address: *Late Bhagirathi Yashwantrao Pathrikar College Of Pharmacy*
Email : abhaykamble791@gmail.com

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

diseases in 2019 and is closely followed by dementias such as Alzheimer's [3].

Numerous ailments affecting a significant portion of the global population are classified as neurological diseases, and epidemiological studies indicate that the prevalence of these conditions will rise as the population ages. Alzheimer's and Parkinson's diseases among others such as autism, traumatic brain injury, stroke, and schizophrenia are only a few of a large number of pathologies that have benefited from advances in basic neurology research in the last few decades. The selectivity of the blood brain barrier (BBB) primarily limits therapeutic success, despite the fact that the hereditary basis for many of these illnesses of the central nervous system (CNS) is recognised. The BBB is considered the most important barrier to protect the brain, constituting a rate-limiting factor in the transport of drugs and genes into the CNS [4] The BBB is a dynamic system that allows a limited diffusion of exogenous compounds into the brain with specialised transport mechanisms for essential nutrients. Absorption of molecules across the BBB occurs through two mechanisms: passive and active transport, as described in Fig.1. Passive transport includes para-cellular diffusion of hydrophilic compounds, and trans-cellular transport which is used by small lipophilic molecules (less 400–600 Da) to enter into the brain parenchyma. Active transport systems include:- i) carrier mediated transcytosis (CMT) for relatively small molecules; ii) absorptive mediated transcytosis (AMT) for positively charged peptides; and iii) receptor mediated transcytosis (RTM) for certain proteins [5].



Annually, the number of cases of neurological diseases rises in emerging nations as life expectancy continues to rise. Most neurological illnesses have a well-known cause, and several studies on their therapy have been conducted. The central nervous system is a vulnerable and complex system that creates complications in diagnosing and treating neurological diseases [6,7]. Certain barriers impede the effectiveness of therapeutic interventions. These barriers control the molecular exchange of blood with the brain. In the brain, endothelial and glial cells make up the barriers. The blood-brain barrier (BBB) is the main gateway of the system as it administers the drugs' access to the brain [8].

- Classification of neuropsychological disorders/neurodegenerative disorders

1. Parkinson disease
2. Alzheimer's disease
3. Epilepsy

4. Huntington's disease
5. Prion disease

1. Parkinson disease

Parkinson disease(PD) is the most common neurodegenerative movement disorder [9]. Parkinson disease is a chronic, progressive, and disabling disorder that is characterized by both motor and nonmotor symptoms. The disease affects millions of people worldwide and is the second most prevalent neurodegenerative condition next to Alzheimer disease [10]. The impact of Parkinson's disease on society is significant. In terms of the number of people affected, this disease is a common condition, with approximately 6·1 million people who had been affected worldwide in 2016 [11].The pathogenic characteristics of Parkinson's disease (PD) include the accumulation of misfolded α-synuclein in intra-cytoplasmic inclusions known as Lewy bodies (LBs) and the death of dopaminergic neurons in the substantia nigra (SN) pars compacta (SNpc). When patients are first diagnosed, a substantial proportion of dopaminergic neurons in the SNpc has already been lost, and neurodegeneration has spread to other central nervous system regions. The aetiology of the disease in most patients is unknown, but different genetic causes have been identified in approximately 5%–10% of cases. Replacing dopamine is the mainstay of current Parkinson's disease (PD) treatment, while deep brain stimulation (DBS) and other alternate methods are appropriate for advanced stages of the condition. The therapies that are now available effectively manage motor symptoms [12].

2. Alzheimer's disease

According to the World Health Organisation, Alzheimer's disease (AD) is a global public health priority. Despite large gains in our understanding of AD pathogenesis and how the disease is conceptualized since Alois Alzheimer reported the first case in 1907 [13]. Alzheimer's disease is the main cause of dementia and is quickly becoming one of the most expensive, lethal, and burdening diseases of this century [14]. Recent studies suggest that the incidence of dementia, particularly in men, may be declining in western countries; it is unclear which causes of dementia are declining, and this may be underpinned by better management of vascular risk [15,16]. In coming years, the largest increase in dementia prevalence is expected in low and middle income countries, which show patterns of increasing cardiovascular disease, hypertension and diabetes [17].

3. Epilepsy

Worldwide, more than 70 million people suffer with epilepsy, one of the most prevalent brain disorders. It is characterised by a lasting predisposition to generate spontaneous epileptic seizures and has numerous neurobiological, cognitive, and psychosocial consequences [18]. Nearly 80% of people with epilepsy live in low income and middleincome countries. Epilepsy is stigmatised in many parts of the world, and people may not receive treatment for it. Over 75% of those with active epilepsy are untreated and this constitutes a major treatment gap, mostly concentrated in low-income and middle-income countries' [19]. Epilepsy should be a global health priority, especially as costeffective treatments are available, which can substantially reduce morbidity, disability, and mortality [20,21]. Following the WHO, International League Against Epilepsy, and International Bureau for Epilepsy's 1997 initiation of the Global Campaign Against Epilepsy, the World Health Assembly of 2015 called on all countries to meet the special needs of people with epilepsy [22].

4. Huntington's disease

Huntington's disease is an inherited neurodegenerative condition that affects the brain. It is brought on by a mutation in the huntingtin gene, which produces a toxic protein that harms brain nerve cells. The disease is characterized by a

wide range of symptoms, including involuntary movements (chorea), cognitive decline, and psychiatric disturbances. Symptoms typically appear in mid-life, but can develop at any age. There is currently no cure for Huntington's disease, but there are treatments available to manage symptoms and improve quality of life [23].

5. Prion disease

The prion protein, a natural component of cell membranes, can be pathogenically expressed in transmissible particles that cause prion diseases, degenerative disorders of the brain system. Creutzfeldt-Jakob disease (CJD) is the most prevalent prion illness in humans .The most prevalent prion disease in humans, CJD, is sporadic, accounting for around 85% of cases; familial instances make up for 10-15% of cases, iatrogenic cases make up 1%, and variant CJD is a regional illness primarily found in the UK and France. Kuru represents the initial instance of human spongiform encephalopathy being experimentally transferred to nonhuman primates [24].

Treatment by Novel Drug delivery system

• DRUG ADMINISTRATION APPROACHES IN BRAIN

1. Delivery Intracerebrally

Direct injection/implantation into the targeted part is introduced by stereotactic coordinates and/or continuous intraventricular infusion of the drug into the brain tissue to achieve more focused and effective drug release to specific parts of the brain. This approach had positive outcomes in Parkinson's disease clinical trials. Compounds in the brain travel slowly because the white matter and grey matter microenvironments include nearly ordered cells. As a result, a greater dose is necessary to achieve the proper drug concentration [25].

The intended implanted devices are based on polymeric matrixes with drugs encapsulated inside that are biodegradable and biocompatible. At the intended delivery site, where the reservoir is to be implanted, the skull is opened. The drug's physicochemical behaviour has a significant impact on how well it penetrates the body, and in most cases, only a little amount of the molecule is given. For instance, treating quadriplegic patients with a nerve growth factor implant after inserting it into the brain produced better results [26]

2. Delivery Intrathecally

Here, the neurotherapeutic medications are administered intrathecally directly into the cisterna magna of the brain. In cases of spinal disorders and diffuse meningeal diseases, this is the best route for drug delivery. The key benefit of this strategy is that it does not necessitate the extensive use of therapeutic medications because it enables the transport of a bigger number of enzymes to the brain. In addition, this strategy manages the problems associated with the short blood half-lives of drugs while avoiding the problems of systemic exposure and toxicity. However, the potential for drug diffusion in the distal portion of the spinal canal is the primary disadvantage of this technique [27].

3. Carbon nanotubes

Are allotropes of carbon with a nanostructure that is cylindrical. Nanotubes and other members of the fullerene family have long, hollow structures made of sheets that are only one atom thick. Single-wall and multiwall CNTs are present in one or more layers within them [28]. These carbon-based nanoparticles are helpful for routine medical treatments. The mechanical, chemical, and electrical properties of the CNTs are distinct [29]. Both the pure and modified (by different polymers) versions of CNTs are evaluated. Hybrid networks between neurons and nanotubes can promote brain activity, network connection, and synapse formation. Future efforts to promote the functional recovery of neurons following brain damage are likely to benefit greatly from CNT-

based technologies, given their exceptional physical properties and their recently found ability to interface with neuronal circuits, synapses, and membranes [30].

4. Liposomes

Lipid bilayers make up liposomes, which are spherical vesicles in shape. Liposomes have the advantage of being exceedingly biocompatible, having minimal toxicity, and having no negative impacts on the drug delivery mechanism. Phosphatidylcholine and cholesterol comprise liposomes [31, 32]. GABA, which comprises liposomes, needs to take into account two obstacles in order to target the brain system: the BBB and microglia reactivity. Osmotic shock enhances drug distribution via liposomes by momentarily opening the blood-brain barrier. GABA-based liposomes have the ability to target physiological conditions such as hypertension and heart failure, as well as neurological diseases such as anxiety, stress, and epilepsy [33, 34]. Several strategies have been put forth to deliver medications to the brain. Transporters fall into two families: irreversible nanoparticles and reversible nanoparticles. Reversible nanoparticles include liposomes and micelles [35]. Theranostics is a new field of medicine that combines diagnostic and therapeutic functions in one. Theranostic agents are molecules that can be administered drugs in a safe and controlled way, like liposomes and micelles. By concentrating on the activity of the problematic tissues and minimising needless delivery and overabundance of the drug, magnetic targeting of cells and tissues improves efficiency [33, 36].Theranostic approaches, which target the brain, are based on the multitasking nature of building complex nanostructures, such as drug delivery vehicles that can pass the blood-brain barrier. It has been demonstrated that a theranostic molecule such as heat shock protein [HSP]-72 targeted liposomes can improve the effectiveness of treating neurological illnesses [37].

5. Delivery Via Inhalation

For systemic pharmacological action, the intranasal route has been used to deliver drugs directly into the bloodstream through the nasal mucosa. This eats the trigeminal nerves that connect the nasal mucosa and trigeminal nerves in the brain, takes a little dose, is self-administered, and does not use sterile procedures. Bypassing gastrointestinal breakdown and protein binding in the circulation, this enables rapid absorption and the commencement of action, the absence of hepatic, simple administration, and all of the above. This lowers systemic side effects and improves drug absorption. Intranasal administration is used to administer cytokines, neurotrophins, neuropeptides, genes, and chemotherapy drugs, to name a few. The mucosal enzymes that break down pharmaceuticals, the fact that this procedure is not delivered by a medical professional, the short hold time in the nasal cavity, and the constraints imposed by the nasal anatomy are the obvious drawbacks of this approach. Consequently, these come after short dosages of medication that enter the central nervous system[38, 39].

6. A chemistry-based strategy

The right molecules for medication material distribution via BBB are considered in this technique. There are two ways in which the drug can be lapidated using this procedure. First, by conjugating the drug's water-soluble molecules with lipid-soluble molecules, the polar functional groups on those molecules can be concealed. Secondly, it is possible to conjugate a water-soluble drug with a lipid-soluble drug carrier. While several delivery routes for neurotherapeutics have been developed, throughout the past 20 years, these approaches have been the focus of extensive investigation. Two such are chimeric peptides and cationic proteins [40].

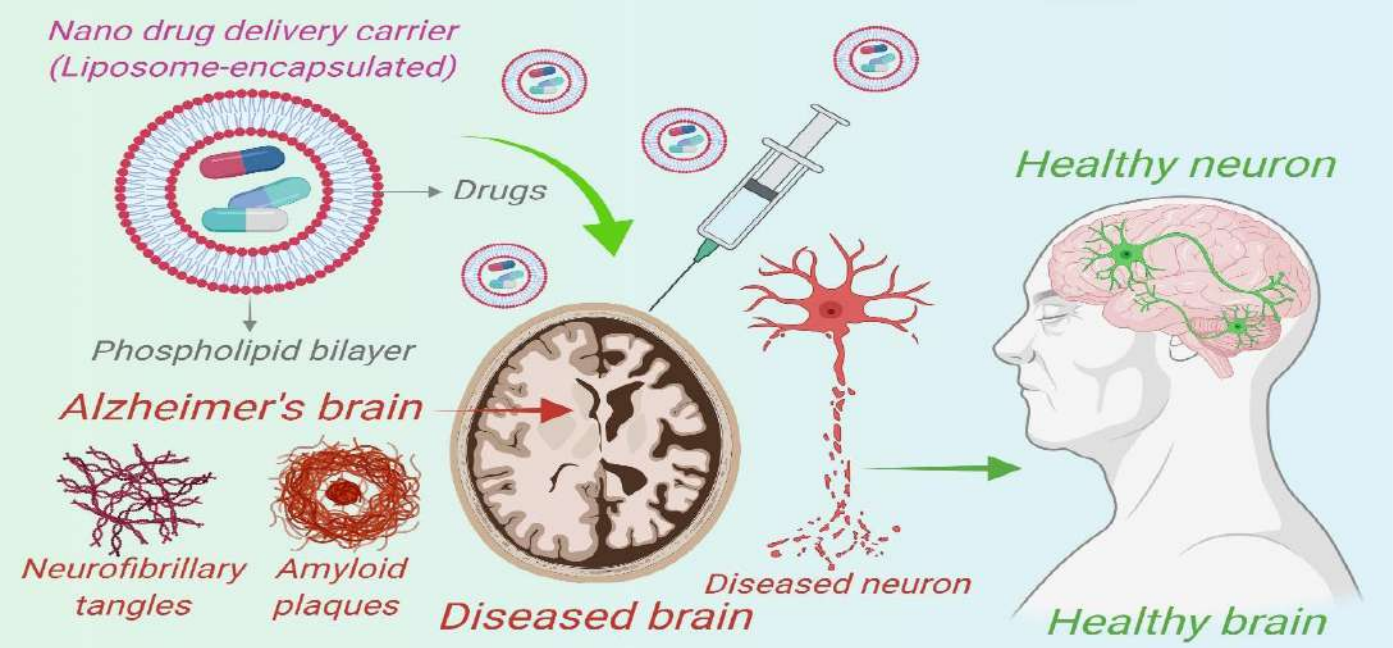
- **ADVANTAGES AND DISADVANTAGE OF ABOVE APPROACHES**

Sr.no.	**1**	**2**	**3.**	**4.**
Approach	**Delivery intracerebrally**	**Delivery intracerebrally**	**Liposomes**	**Delivery Via Inhalation**
Advantages	1.Targeted delivery 2.Sustained release, favourable results are obtained with High level of drug concentration. 3.Overcoming blood-brain barrier challenges 4.Fastest onset of Action 5.Increased Bioavailability 6.Enhanced therapeutic efficacy	1.cost effective with the least side effects. 2.direct access to the central nervous system. 3.Prolonged Drug Exposure 4.Minimized Metabolism and Elimination	1.Blood-Brain Barrier (BBB) Penetration 2.Encapsulation of a Variety of Drugs 3.Protection of Drugs 4.Biocompatibility 5.Reduced Systemic Side Effects. 6.Flexibility in Formulation.	1.Rapid Onset of Action 2.Avoidance of First-Pass Metabolism 3.Non-Invasive Administration: 4.Improved Patient Compliance: 5.Improved Drug Stability 6.Potential for Targeted Delivery
Disadvantage	1.**Invasive Nature:-** Intracerebral treatments typically involve invasive procedures, such as surgery. 2.Costs and Accessibility: 3.Individual Variability: 4.Risk of Complications: Invasive procedures always carry a risk of complications, such as adverse reactions to anesthesia.	1.Highly invasive, poor patient consent. 2.Risk of Infection 3.Limited Drug Selection 4.Potential for Neurotoxicity 5.Cost and Accessibility: 6.Limited Distribution within the CNS:	1.Complex Manufacturing. 2.limited stability 3.Risk of Drug Leakage 4.Variability in Response 5.Challenges in Surface Modification 6.expensive	1.Challenges in Formulation Stability: 2.Limited Bioavailability for Some Compounds: 3.Difficulty in Targeting Specific Brain Regions 4.Potential for Drug Interactions: 5.Risk of Systemic Absorption

- **Nanomaterials for the Treatment of Neurodegenerative Diseases**

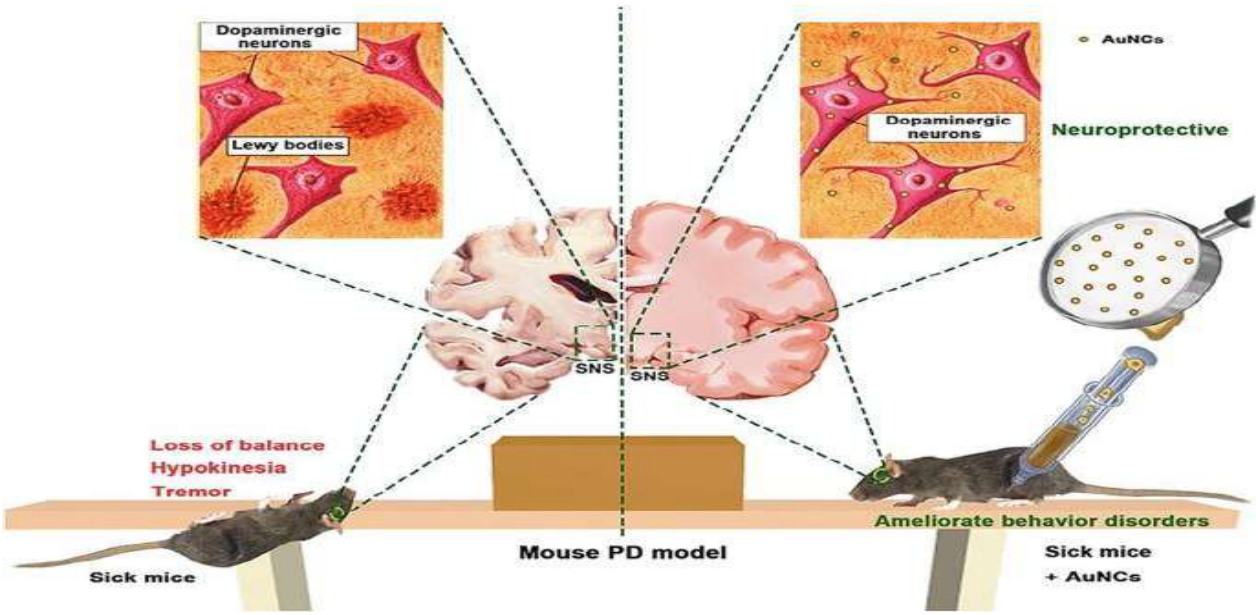
1. Alzheimer's Disease (AD)

Over 80% of instances of dementia globally are caused by Alzheimer's disease (AD), one of the most prevalent neurodegenerative illnesses in the aged population. It results in loss of learning capacity as well as gradual mental, behavioural, and functional deterioration [41]. One example of how NPS may enhance the effectiveness of AD therapy is lipoic acid, a substance found naturally in the mitochondria that has strong anti-inflammatory and antioxidant properties that can lower oxidative stress [42]. Their design ensures that they are safe, biodegradable, and tailored to a specific target [43]. These nanosystems have the potential to efficiently distribute and maintain medications and other neuroprotective substances in the brain during the treatment of Alzheimer's disease [44].Bypassing the blood-brain barrier, the intranasal technique facilitates the delivery of drugs straight to the brain. The most common method for transporting nanoparticles is endocytosis, which includes receptor-mediated endocytosis, phagocytosis, and pinocytosis Receptor-mediated endocytosis is the most desirable method[45]



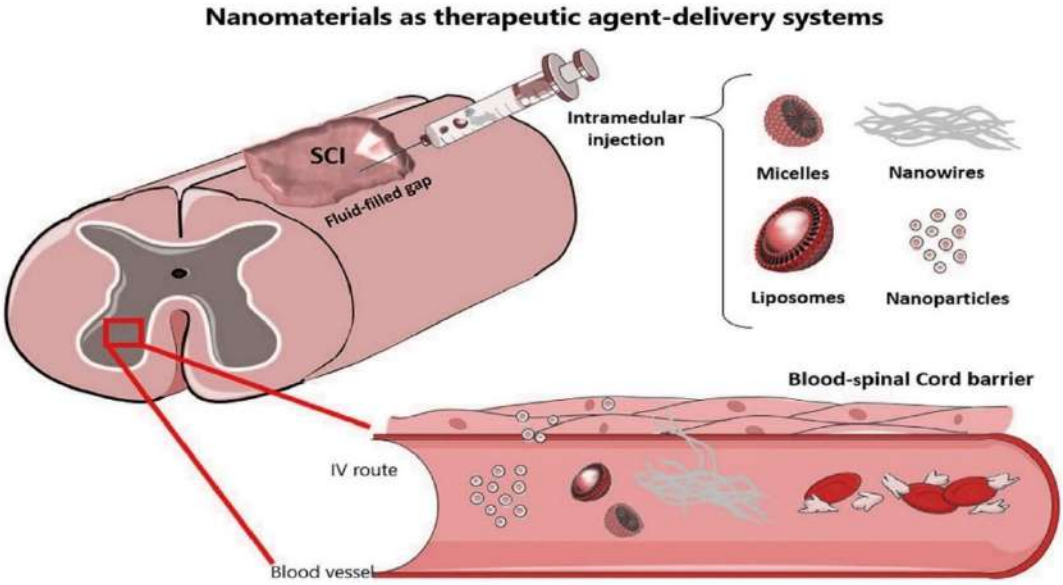
2. Parkinson disease

In addition to Alzheimer's disease, Parkinson's disease (PD) is a common neurodegenerative illness [46]. In patients with Parkinson's disease (PD), dopamine-producing neurons in the substantia nigra and basal ganglia are lost [47]. Parkinson's disease (PD) is characterised by stiffness and tremors in the muscles, slow movements, and postural instability. A loss of motor coordination, altered gait patterns, and freezing of gait are other common motor signs [48]. Traditional drugs are not as bioavailable in the brain and have a lot of side effects. Therefore, in order to address the therapeutic limitations of Parkinson's disease, critical measurements are needed. The field of nanotechnology has significantly advanced our knowledge of the pathophysiology of Parkinson's disease. Effective medications with fewer adverse effects and higher brain bioavailability could be produced thanks to nanotechnology [49].



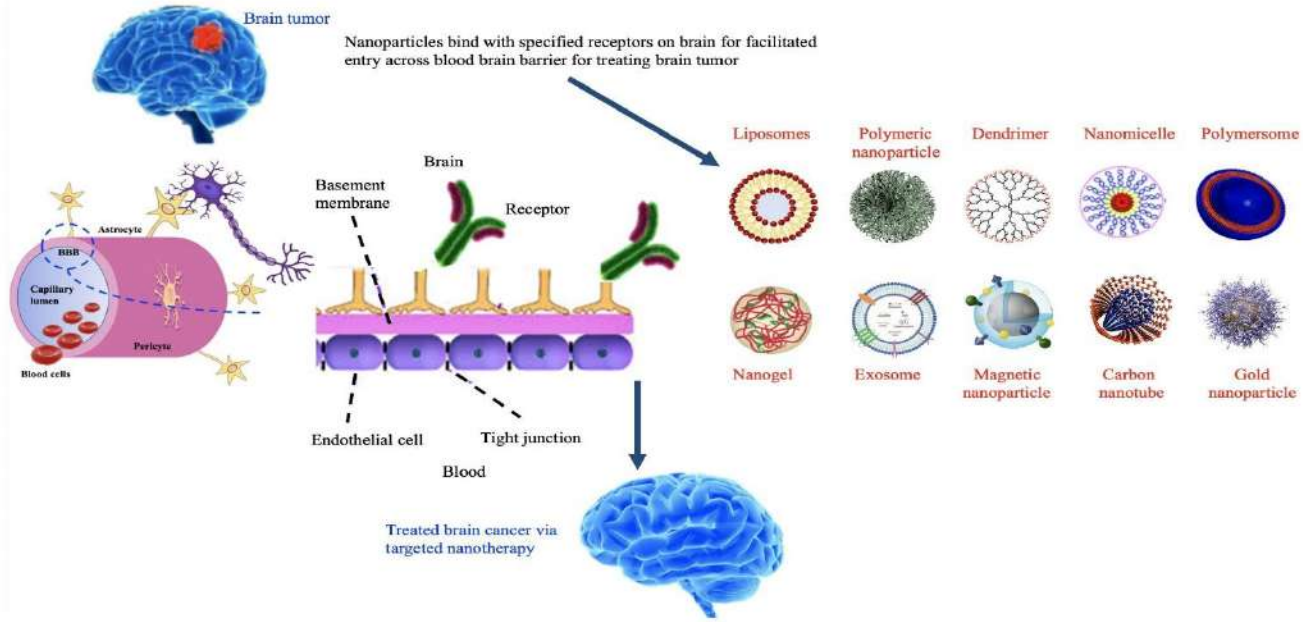
3. Spinal cord injury

spinal cord injury Damage to the Spinal Cord A traumatic injury or illness can result in spinal cord damage (SCI), a neurological disorder that impairs voluntary motor control, sensory function, and the autonomic nerve system. It can also have an influence on cognitive, cardiovascular, bladder, and stool functions. In addition to relationship stress and breakup, societal prejudice, and less career opportunities, common psychological difficulties for SCIs include changes in sexuality, weight gain, poor sleep, impaired cognitive function, and chronic pain [50].



4. Brain Tumors

Different cell types can give rise to tumours with variable degrees of malignancy and invasiveness, causing brain tumours to affect both adults and children[51,52]. A broad category of neoplasms known as brain tumours are usually categorised as benign or malignant. It is believed that unchecked cell proliferation and tissue invasion of dedifferentiated cells brought on by hazardous chemical, physical, and biological exposures are the main causes of brain tumour malignancy [53]. With a frequency of 1 to 5 occurrences per 100,000 individuals, CNS tumours are the most prevalent solid tumour and the primary cause of cancer-related deaths in children, adolescents, and young adults [54]. Brain tumours are frequently treated with surgery, radiation, and systemic chemotherapy; however, these approaches have a poor prognosis and a high recurrence rate. In recent decades, intravenous and oral delivery of anti-cancer medications have been deemed unfeasible in comparison to intra-arterial administration [53]. Among these tactics are liposomes, nanoparticles, drug-loaded microbubbles, and magnetic attraction of cells [54].



REFERENCES

1. Re, F.; Gregori, M.; Masserini, M. Nanotechnology for neurodegenerative disorders. Maturitas 2012, 73, 45–51. [CrossRef] [PubMed]
2. Gitler, A.D.; Dhillon, P.; Shorter, J. Neurodegenerative Disease: Models, Mechanisms, and a New Hope; The Company of Biologists Ltd.: Cambridge, UK, 2017; Volume 10, pp. 499–502.
3. WHO.TheTop10Causes of Death-WHO|World Health Organization; WHO: Geneva, Switzerland, 2020. Available online: https: //www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death (accessed on 12 January 2022).
4. W.M.Pardridge, The blood–brain barrier: bottleneck in brain drug development, NeuroRx 2 (2005) 3–14.
5. D.J. Begley, Delivery of therapeutic agents to the central nervous system: the problems and the possibilities, Pharmacol. Ther. 104 (2004) 29–45.
6. Ramos-Cabrer, P.; Agulla, J.; Argibay, B.; Pérez-Mato, M.; Castillo, J. Serial MRI study of the enhanced therapeutic effects of liposome-encapsulated citicoline in cerebral ischemia. Int. J. Pharm. 2011, 405, 228–233. [CrossRef] [PubMed]
7. El-aziz, E.A.E.-d.A.; Elgayar, S.F.; Mady, F.M.; Abourehab, M.A.; Hasan, O.A.; Reda, L.M.; Alaaeldin, E. The Potential of Optimized Liposomes in Enhancement of Cytotoxicity and Apoptosis of Encapsulated Egyptian Propolis on Hep-2 Cell Line. Pharmaceutics 2021, 13, 2184. [CrossRef]
8. Abbott, N.J.; Patabendige, A.A.; Dolman, D.E.; Yusof, S.R.; Begley, D.J. Structure and function of the blood–brain barrier. Neurobiol. Dis. 2010, 37, 13–25. [CrossRef] [PubMed]
9. De Rijk MC, Rocca WA, Anderson DW, et al. A population perspective on diagnostic criteria for Parkinson's disease. Neurology 1997; 48: 1277–81.
10. Hirtz D, Thurman DJ, Gwinn-Hardy K, et al. Howcommonarethe"common" neurologic disorders? Neurology 2007:68(5):326–327. Doi:10.1212/01.wnl.0000252807.38124.a3.

11. GBD 2016 Neurology Collaborators. Global, regional, and national burden of neurological disorders, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol 2019; 18: 459–80.
12. Lee A, Gilbert RM. Epidemiology of Parkinson disease. Neurol Clin 2016; 34: 955–65.
13. Alzheimer A. Uber eine eigenartige Erkrankung der Hirnrinde. Allg Zeitschrift Psychiatr 1907; 64: 146–148.
14. Alzheimer Europe. Dementia in Europe Yearbook 2019: estimating the prevalence of dementia in Europe. 2020. https://www.alzheimereurope.org/content/download/195515/1457520/file/FINAL%2005707%20Alzheimer%20Europe%20yearbook%202019.pdf (accessed Jan 24, 2021).
15. Wu Y-T, Fratiglioni L, Matthews FE, et al. Dementia in western Europe: epidemiological evidence and implications for policy making. Lancet Neurol 2016; 15: 116124.
16. Matthews FE, Stephan BCM, Robinson L, et al. A two decade dementia incidence comparison from the Cognitive Function and Ageing Studies I and II. Nat Commun 2016; 7: 11398.
17. Prince M, Albanese E, Guerchet M, et al. World Alzheimer Report 2014: Dementia and Risk Reduction an Analysis of Protective and Modifiable Factors, 2014.
18. Fisher RS, Acevedo C, Arzimanoglou A, et al. ILAE official report: a practical clinical definition of epilepsy. Epilepsia 2014; 55: 475–82.
19. Saxena S, Li S. Defeating epilepsy: A global public health commitment. Epilepsia Open 2017; 2: 153–55.
20. Megiddo I, Colson A, Chisholm D, Dua T, Nandi A, Laxminarayan R. Health and economic benefits of public financing of epilepsy treatment in India: An agentbased simulation model. Epilepsia 2016; 57: 464–74.
21. Ding D, Hong Z, Chen GS, et al. Primary care treatment of epilepsy with phenobarbital in rural China: costoutcome analysis from the WHO/ILAE/IBE global campaign against epilepsy demonstration project. Epilepsia 2008; 49: 535–39.
22. WHO. Global burden of epilepsy and the need for coordinated action at the country level to address its health, social and public knowledge implications. 2015: Resolution WHA68·20.
23. Lancet 2007; 369: 218–28 Department of Neurology, Wake Forest University, Medical Center Blvd, Winston Salem, NC 27157, USA (Prof F O Walker MD) fwalker@wfubmc.edu
24. Lancet Neurol 2005; 4: 635–42 Pathology 627, The Johns Hopkins University School of Medicine & Bloomberg School of Public Health, Baltimore, MD21287, USA (R TJohnsonMD) rtj@jhmi.edu
25. Marianecci, C., Rinaldi, F., Hanieh, P. N., Di Marzio, L., Paolino, D., & Carafa, M. (2017). Drug delivery in overcoming the blood–brain barrier: role of nasal mucosal grafting. Drug Design, Development and Therapy, Volume11, 325–335. https://doi.org/10.2147/DDDT.S100075
26. Bors, L., & Erdő, F. (2019). Overcoming the Blood–Brain Barrier. Challenges and Tricks for CNS Drug Delivery. Scientia Pharmaceutica, 87(1), 6. https://doi.org/10.3390/scipharm87010006

27. Denora, N., Trapani, A., Laquintana, V., Lopedota, A., & Trapani, G. (2009). Recent Advances in Medicinal Chemistry and Pharmaceutical Technology-Strategies for Drug Delivery to the Brain. Current Topics in Medicinal Chemistry, 9(2), 182–196. https://doi.org/10.2174/156802609787521571
28. De Pablo, F., & de la Rosa, E. J. (1995). The developing CNS: a scenario for the action of proinsulin, insulin and insulin-like growth factors. Trends in Neurosciences, 18(3), 143–150. https://doi.org/10.1016/01662236(95)93892-2
29. Kola, I., & Landis, J. (2004). Can the pharmaceutical industry reduce attrition rates? Nature Reviews Drug Discovery, 3(8), 711–716. https://doi.org/10.1038/nrd1470
30. Akhtar, A., Andleeb, A., Waris, T. S., Bazzar, M., Moradi, A.-R., Awan, N. R., & Yar, M. (2021). Neurodegenerative diseases and effective drug delivery: A review of challenges and novel therapeutics. Journal of Controlled Release, 330, 1152–1167. https://doi.org/10.1016/j.jconrel.2020.11.021
31. Wang,L.-S.; Chuang, M.-C.; Ho, J.-a.A. Nanotheranostics—A review of recent publications. Int. J. Nanomed. 2012, 7, 4679.
32. Shim, M.S.; Kwon, Y.J. Stimuli-responsive polymers and nanomaterials for gene delivery and imaging applications. Adv. Drug Deliv. Rev. 2012, 64, 1046–1059. [CrossRef]
33. Ramos-Cabrer, P.; Agulla, J.; Argibay, B.; Pérez-Mato, M.; Castillo, J. Serial MRI study of the enhanced therapeutic effects of liposome-encapsulated citicoline in cerebral ischemia. Int. J. Pharm. 2011, 405, 228–233. [CrossRef] [PubMed]
34. Fontes, M.A.P.; Vaz, G.C.; Cardoso, T.Z.D.; de Oliveira, M.F.; Campagnole-Santos, M.J.; Dos Santos, R.A.S.; Sharma, N.M.; Patel, K.P.; Frézard, F. GABA-containing liposomes: Neuroscience applications and translational perspectives for targeting neurological diseases. Nanomed. Nanotechnol. Biol. Med. 2018, 14, 781–788. [CrossRef]
35. Frézard, F.; dos Santos, R.A.; Fontes, M.A. Liposome-encapsulated neuropeptides for site-specific microinjection. In Neuropeptides; Springer: Berlin/Heidelberg, Germany, 2011; pp. 343–355.
36. Ulrich, A.S. Biophysical aspects of using liposomes as delivery vehicles. Biosci. Rep. 2002, 22, 129–150. [CrossRef]
37. Spuch, C.; Navarro, C. Liposomes for targeted delivery of active agents against neurodegenerative diseases (Alzheimer's disease and Parkinson's disease). J. Drug Deliv. 2011, 2011, 469679. [CrossRef]
38. Hanson, L. R., & Frey, W. H. (2008). Intranasal delivery bypasses the blood-brain barrier to target therapeutic agents to the central nervous system and treat neurodegenerative disease. BMC Neuroscience, 9(S3), S5. https://doi.org/10.1186/1471-2202-9-S3-S5
39. Lochhead, J. J., & Thorne, R. G. (2012). Intranasal delivery of biologics to the central nervous system. Advanced Drug Delivery Reviews, 64(7), 614–628. https://doi.org/10.1016/j.addr.2011.11.002
40. Denora, N., Trapani, A., Laquintana, V., Lopedota, A., & Trapani, G. (2009). Recent Advances in Medicinal Chemistry

and Pharmaceutical Technology-Strategies for Drug Delivery to the Brain. Current Topics in Medicinal Chemistry, 9(2), 182–196. https://doi.org/10.2174/156802609787521571

41. Kumar,A.; Singh, A. A review on Alzheimer's disease pathophysiology and its management: An update. Pharmacol. Rep. 2015, 67, 195–203. [CrossRef]
42. Furtado, D.; Björnmalm, M.; Ayton, S.; Bush, A.I.; Kempe, K.; Caruso, F. Overcoming the blood–brain barrier: The role of nanomaterials in treating neurological diseases. Adv. Mater. 2018, 30, 1801362. [CrossRef] [PubMed]
43. Li, A.; Tyson, J.; Patel, S.; Patel, M.; Katakam, S.; Mao, X.; He, W. Emerging Nanotechnology for Treatment of Alzheimer's and Parkinson's Disease. Front. Bioeng. Biotechnol. 2021, 9, 672594. [CrossRef] [PubMed]
44. Sood, S.; Jain, K.; Gowthamarajan, K. Intranasal therapeutic strategies for management of Alzheimer's disease. J. Drug Target. 2014, 22, 279–294. [CrossRef] [PubMed]
45. Agarwal, M.; Alam, M.R.; Haider, M.K.; Malik, M.; Kim, D.-K. Alzheimer's Disease: An Overview of Major Hypotheses and Therapeutic Options in Nanotechnology. Nanomaterials 2021, 11, 59. [CrossRef
46. American Psychiatric Association, A. Diagnostic and Statistical Manual of Mental Disorders; American Psychiatric Association: Washington, DC, USA, 1980; Volume 3.
47. Colvert, E.; Tick, B.; McEwen, F.; Stewart, C.; Curran, S.R.; Woodhouse, E.; Gillan, N.; Hallett, V.; Lietz, S.; Garnett, T. Heritability of autism spectrum disorder in a UK population-based twin sample. JAMA Psychiatry 2015, 72, 415–423. [CrossRef]
48. Hua, X.; Thompson, P.M.; Leow, A.D.; Madsen, S.K.; Caplan, R.; Alger, J.R.; O'Neill, J.; Joshi, K.; Smalley, S.L.; Toga, A.W. Brain growth rate abnormalities visualized in adolescents with autism. Hum. Brain Mapp. 2013, 34, 425–436. [CrossRef]
49. Moni, M.; Rahman, M.; Begum, M.; Uddin, M.; Ashraf, G.M. Deciphering the Role of Nanoparticle-Based Treatment for Parkinson's Disease. Curr. Drug Metab. 2021, 22, 550–560. [CrossRef]
50. Li, J.; Cai, S.; Zeng, C.; Chen, L.; Zhao, C.; Huang, Y.; Cai, W. Urinary exosomal vitronectin predicts vesicoureteral reflux in patients with neurogenic bladders and spinal cord injuries. Exp. Ther. Med. 2022, 23, 65. [CrossRef]
51. Huang, R.; Boltze, J.; Li, S. Strategies for improved intra-arterial treatments targeting brain tumors: A systematic review. Front. Oncol. 2020, 10, 1443. [CrossRef]
52. Beccaria, K.; Canney, M.; Bouchoux, G.; Puget, S.; Grill, J.; Carpentier, A. Blood-brain barrier disruption with low-intensity pulsed ultrasound for the treatment of pediatric brain tumors: A review and perspectives. Neurosurg. Focus 2020, 48, E10. [CrossRef]
53. Huang, R.; Boltze, J.; Li, S. Strategies for improved intra-arterial treatments targeting brain tumors: A systematic review. Front. Oncol. 2020, 10, 1443. [CrossRef]
54. Chen, E.M.; Quijano, A.R.; Seo, Y.-E.; Jackson, C.; Josowitz, A.D.; Noorbakhsh, S.; Merlettini, A.; Sundaram, R.K.; Focarete, M.L.; Jiang, Z. Biodegradable

PEG-poly (ω-pentadecalactone-co-p-dioxanone) nanoparticles for enhanced and sustained drug delivery to treat brain tumors. Biomaterials 2018, 178, 193–203. [CrossRef]

HOW TO CITE: Abhay Kamble, Nakul Kathar, Gajanan Sanap, Novel Drug Delivery System For Treating Neuropsychological Disorder, Int. J. in Pharm. Sci., 2023, Vol 1, Issue 12, 317- 329. https://doi.org/10.5281/zenodo.10370141