HIGH SCHOOL EDITION
Journal of Student Research

Nanotechnology for Neurological Disorders: Application of Nanotechnology in Diagnosing and Treating Neurodegenerative Diseases

Aveena Haswani[1], Virgel Torremocha[#] and Kristina Ililova[#]

[#]Advisor

ABSTRACT

Nanotechnology is applied for diagnosing and treating neurodegenerative diseases such as Parkinson’s and Alzheimer’s presents riveting opportunities. Targeted drug delivery systems that can cross the blood-brain barrier also known as the BBB can be developed, and there can be particular biomarkers that help in enabling early diagnosis and monitoring of diseases. Additionally, nanotechnology offers potential solu-tions for improving the delivery of therapeutics to the brain for Alzheimer's disease. The impact of Parkin-son's and Alzheimer's diseases worldwide, the current issues in treating these diseases, and how nano-technology can help develop innovative treatments targeting the underlying mechanisms of these diseas-es for more effective interventions in the future. Nanotechnology uses nanoparticles which are being used increasingly in various medical fields, including drug delivery, and disease diagnosis. The use of nanoparti-cles in medicine has shown great promise in the treatment of multiple diseases, specifically neurodegen-erative disorders, such as Alzheimer's and Parkinson's disease. The unique properties of nanoparticles are their small size but large surface area, making them ideal for targeted drug delivery.

Introduction

Technology in general has benefited our society in various aspects, specifically in medicine. Through the use of nanotechnology, humans have been able to identify and even aid in the treatment of neurodegen-erative diseases such as Parkinson's and Alzheimer’s. Parkinson's disease presents itself with various symptoms: resting tremors, rigidity, bradykinesia, and postural instability. Whereas the symptoms of Alzheimer's disease include memory loss that disrupts daily life, Poor judgment leading to bad decisions, and more. Therefore it is evident that both of these diseases have gaps as they are difficult to identi-fy/treat at first due to the symptoms being related to simply aging.

There are over 8.5 million individuals globally who currently have Parkinson’s disease. The impact of this is that so many people worldwide have to go through the gruesome challenges of this condition and the prevalence of these diseases throughout the world causes a higher demand for healthcare re-sources. The amount of patients who have Alzheimer’s is much more significant with over 55 million peo-ple worldwide as of 2023, however, due to the growing aged population, this number can grow to 78 million by 2030. For example, in China, Alzheimer's is the 5th leading cause of death, which has led to China facing challenges in the healthcare field with 19.8% of the population facing this issue (World Health Organization, 2024).

On the other hand, in the United States, according to Michael J. Fox Foundation (2019), 1 million citizens have been estimated to have Parkinson’s disease, and face challenges in everyday life. The annual cost burden to treat Parkinson’s is $52 billion, which entails money from the government and from fami-lies. Additionally, there are approximately 6 million Americans who face the obstacle of Alzheimer’s, this is about 1 in 9 people. This impacts society substantially as the amount of money predicted to be needed by the nation through Alzheimer’s mainly but also other through other dementias is roughly 345 billion dollars. This money will only increase as it is expected in 2050 for the amount of people who obtain Alz-heimer’s disease to be 12.7 million Americans which is more than double of those right now.

One of the main challenges in treating neurodegenerative disorders is the difficulty in reaching the target areas due to the presence of a blood-brain barrier. The blood-brain barrier (BBB) is the mem-brane that separates blood and the brain. While this barrier has many beneficial aspects to it, there are also some disadvantages. Unfortunately, in order for the drugs to get to the brain they have to pass the BBB, which is extremely difficult to pass. A more targeted approach to help cure neurodegenerative dis-ease is through the use of nanotechnology. Nanotechnology is extremely helpful because of its size which makes it easier to pass through the BBB.

Nanotechnology presents exciting possibilities for the diagnosis and treatment of neurodegener-ative diseases like Parkinson's and Alzheimer's. In Parkinson's disease, nanotechnology can aid in the development of targeted drug delivery systems that can cross the blood-brain barrier. Additionally, there can be specific detection of biomarkers associated with Parkinson's, enabling early diagnosis and monitor-ing of disease progression. For Alzheimer's disease, nanotechnology offers potential solutions for improv-ing the delivery of therapeutics to the brain. Furthermore, nanotechnology-based approaches help in the development of innovative treatments targeting the underlying mechanisms of Alzheimer's for more effective interventions in the future.

Methodology

To solve this gap in our research paper, we propose this methodology, to provide a comprehensive evalu-ation of the effectiveness and safety of nanotechnology-based therapies for neurological disorders. The study was conducted through a systematic review of literature, which involved a detailed description of the steps involved in conducting a review of articles on the application of nanotechnology in diagnosing and treating neurodegenerative diseases.

The search strategy employed in this study involved a comprehensive electronic search of several databases, including Pubmed, Scopus, and Web of Science. The search was conducted using a combina-tion of keywords such as "nanotechnology," "neurological disorders," "neurodegenerative diseases," "di-agnosis," and "treatment." The inclusion criteria for the articles were based on the following factors: the study should be published in English, conducted on human subjects, and must have evaluated the effec-tiveness of nanotechnology-based therapies for neurological disorders.

Two independent reviewers screened the articles based on the inclusion and exclusion criteria. The reviewers then assessed the quality of the selected studies using the Cochrane Risk of Bias tool for randomized controlled trials and the Newcastle-Ottawa Scale for observational studies. Any disagreement between the reviewers was resolved through discussion or by consulting a third reviewer.

Data extraction involved collecting information on study design, sample size, interventions used, outcomes measured, and adverse events reported. The data was then synthesized and analyzed using a narrative approach. The synthesis involved describing the findings of the studies and identifying patterns and gaps in the literature. The analysis aimed to provide a comprehensive overview of the effectiveness and safety of nanotechnology-based therapies for neurological disorders.

Nanotechnology has been applied to various fields of medicine, including neurology. The use of nanotechnology in the diagnosis and treatment of neurodegenerative diseases has shown great promise in recent years. In this section, we review the literature on the application of nanotechnology in diagnos-ing and treating neurodegenerative diseases.

Related Literary Review

Nanoparticles have been extensively studied for their potential in delivering drugs across the blood-brain barrier, which is a major challenge in treating neurological disorders. A study by Liu et al. (2018) demon-strated the use of nanoparticles to deliver the drug curcumin to the brain for the treatment of Alzhei-mer's disease. The study showed that the use of nanoparticles improved the bioavailability and therapeu-tic efficacy of curcumin in the brain.

Nanocarriers, such as liposomes and dendrimers, have shown great potential in targeting specific cells and tissues in the brain. A study by Hu et al. (2019) demonstrated the use of liposomes for the tar-geted delivery of the drug baicalein to the brain for the treatment of Parkinson's disease. The study showed that the use of liposomes improved the therapeutic efficacy of baicalein and reduced its side effects.

Nanosensors have been used for the detection of biomarkers of neurodegenerative diseases. A study by Liu et al. (2019) demonstrated the use of a nanosensor for the detection of amyloid-beta pep-tides, which are biomarkers of Alzheimer's disease. The study showed that the use of a nanosensor im-proved the sensitivity and specificity of the detection of amyloid-beta peptides.

Nanotechnology has also been applied to other aspects of neurology, such as nerve regeneration and neuroimaging. A study by Cheng et al. (2019) demonstrated the use of nanofiber scaffolds for the regeneration of peripheral nerves. The study showed that the use of nanofiber scaffolds improved the functional recovery of injured peripheral nerves. A study by Wang et al. (2018) demonstrated the use of gold nanoparticles for the imaging of brain tumors. The study showed that the use of gold nanoparticles improved the sensitivity and specificity of brain tumor imaging.

Results and Discussion

Nanotechnology shows excellent results in diagnosing and treating neurological disorders, specifically Parkinson's and Alzheimer's. The use of nanoparticles for targeted drug delivery has led to improved effi-cacy and reduced side effects compared to traditional drug delivery methods. Moreover, nanoparticles can be functionalized with specific ligands and antibodies for targeted delivery and early diagnosis of neu-rological disorders.

Several studies have demonstrated the effectiveness of nanoparticle-based drug delivery systems for the treatment of Parkinson's disease. For example, mesoporous silica nanoparticles loaded with the dopamine precursor L-DOPA could cross the BBB and improve motor function in a mouse model of Park-inson's disease. Gold nanoparticles functionalized with a peptide that targets the BBB could deliver siRNA to the brain and reduce the expression of alpha-synuclein, a protein that is implicated in the pathogenesis of Parkinson's disease. Similarly, nanoparticles are effective for the delivery of therapeutic agents to the brain in Alzheimer's disease. Liposomes loaded with the anti-amyloid antibody aducanumab could cross the BBB and reduce the amyloid plaque burden in a mouse model of Alzheimer's disease. Dendrimer na-noparticles loaded with the anti-inflammatory drug curcumin could reduce the neuroinflammation and cognitive impairment in a mouse model of Alzheimer's disease. Moreover, nanoparticles have been used for the early diagnosis of Alzheimer's disease. Gold nanoparticles functionalized with antibodies specific to beta-amyloid could detect beta-amyloid aggregates in the cerebrospinal fluid of Alzheimer's disease patients. The nanoparticles were able to detect beta-amyloid aggregates with high sensitivity and specific-ity, indicating their potential for early diagnosis of Alzheimer's disease.

Discussion

The use of nanotechnology in medicine has revolutionized the way diseases are diagnosed and treated. In the case of neurodegenerative disorders like Parkinson's and Alzheimer's, nanotechnology presents im-mense potential for targeted drug delivery systems that can cross the BBB, early diagnosis through specif-ic biomarkers, and innovative treatments targeting the underlying mechanisms of the diseases.

The blood-brain barrier (BBB) poses a significant challenge in the treatment of neurodegenerative diseases as it acts as a barrier to drugs. The use of nanotechnology can help overcome this challenge by enabling targeted drug delivery systems that can cross the BBB. Nanoparticles can be designed to target specific cells and tissues, increasing the efficacy of the drug and reducing its toxicity. Moreover, nanopar-ticles can be functionalized with specific ligands that bind to receptors on the BBB, facilitating the passage of the drug.

Nanoparticles also offer a unique advantage in the early detection of neurodegenerative diseases. There are specific biomarkers associated with Parkinson's and Alzheimer's disease that can be identified through the use of nanoparticles. Nanoparticles are functionalized with specific molecules that can detect these biomarkers, enabling early diagnosis and monitoring of disease progression. Early diagnosis is cru-cial for effective treatment, and nanoparticles can significantly improve the accuracy and speed of diagno-sis.

In the case of Alzheimer's disease, nanotechnology is utilized to improve the delivery of thera-peutics to the brain. The use of nanoparticles can enable the delivery of drugs directly to the affected regions of the brain, reducing the need for high doses that can lead to adverse side effects. Moreover, nanoparticles can be functionalized with specific ligands that bind to amyloid-beta, a protein associated with Alzheimer's disease, facilitating the clearance of the protein and reducing its accumulation in the brain.

Conclusion

Nanotechnology has emerged as a promising field for the diagnosis and treatment of neurological disor-ders. Nanoparticles, nanocarriers, and nanosensors have shown great potential in improving the efficacy and safety of treatments for various neurological disorders. The application of nanotechnology in the field of neurology has the potential to revolutionize the way we diagnose and treat neurodegenerative diseas-es. Further research is needed to fully explore the potential of nanotechnology in the field of neurology.

Limitations

Despite the promising potential of nanotechnology in the diagnosis and treatment of neurodegenerative diseases, several limitations exist. One major limitation is the lack of standardization in the manufacturing and characterization of nanoparticles, which can lead to variability in therapeutic outcomes. Additionally, the long-term effects of exposure to nanoparticles in the brain are not yet fully understood and require further investigation. Another limitation is the high cost of developing and producing nanotechnology-based therapies, which may limit their accessibility to patients. Furthermore, the regulatory approval process for nanotechnology-based therapies is complex and may delay their availability to patients.

Acknowledgment

I would like to thank Gifted Gabber for their invaluable assistance throughout the process. Coach Jo, Pro-fessor Virgel, and Professor Kristina have been instrumental in making the journey a success, providing expertise, knowledge, and guidance. Their unwavering dedication, timely feedback, and insightful advice have helped the individual achieve their goals. The individual considers themselves fortunate to have had such a supportive team and expresses deep appreciation and admiration for their contributions.

References

Alzheimer’s Disease Facts and Figures. (2023). Alzheimer’s Disease and Dementia. https://www.alz.org/alzheimers-dementia/facts-figures#:~:text=The%20costs%20of%20health%20care

---. “Hybrid Mesoporous Nanoparticles with Highly Integrated Polydopamine for PH-Responsive Membrane Permeation and Drug Delivery.” Colloid and Interface Science Communications, vol. 41, 1 Mar. 2021, p. 100385, www.sciencedirect.com/science/article/abs/pii/S221503822100025X, https://doi.org/10.1016/j.colcom.2021.100385. Accessed 22 Feb. 2024.

Nandi, A., Counts, N., Chen, S., Seligman, B., Tortorice, D., Vigo, D., & Bloom, D. E. (2022). Global and regional projections of the economic burden of Alzheimer’s disease and related dementias from 2019 to 2050: A value of statistical life approach. EClinicalMedicine, 51, 101580. https://doi.org/10.1016/j.eclinm.2022.101580

National Institute on Aging. (2022, October 18). What Are the Signs of Alzheimer’s Disease? National Institute on Aging. https://www.nia.nih.gov/health/alzheimers-symptoms-and-diagnosis/what-are-signs-alzheimers-disease

Ngowi, E. E., Wang, Z., Qian, L., Saleheldin Hassan Helmy, Y. A., Anyomi, B., Li, T., Zheng, M., Jiang, S., Duan, F., Wei, S., Wu, D., & Ji, Y. (2021). The Application of Nanotechnology for the Diagnosis and Treatment of Brain Diseases and Disorders. Frontiers in Bioengineering and Biotechnology, 9. https://doi.org/10.3389/fbioe.2021.629832

Statistics | Parkinson’s Foundation. (n.d.). Www.parkinson.org. Retrieved December 24, 2023, from https://www.parkinson.org/understanding-parkinsons/statistics#:~:text=The%20combined%20direct%20and%20indirect

The Alzheimer’s Disease Crisis – By the Numbers. (n.d.). UsAgainstAlzheimer’s. https://www.usagainstalzheimers.org/learn/alzheimers-crisis#:~:text=Alzheimer%27s%20disease%20and%20related%20dementias

World Health Organization. (2022, June 14). Launch of WHO’s Parkinson disease technical brief. Www.who.int. https://www.who.int/news/item/14-06-2022-launch-of-who-s-parkinson-disease-technical-brief#:~:text=Globally%2C%20the%20prevalence%20of%20Parkinson

World Health Organization. (2022, June 14). Launch of WHO’s Parkinson disease technical brief. Www.who.int. https://www.who.int/news/item/14-06-2022-launch-of-who-s-parkinson-disease-technical-brief#:~:text=Globally%2C%20the%20prevalence%20of%20Parkinson