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The Effects of Nanotechnology and Theranostic on Neurodegenerative Diseases

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ABSTRACT

Nanotechnology and nanomedicine have significantly advanced diagnostics and treatments for life-threatening and disabling diseases. Nanoparticle properties and characteristics are the most impactful force in medicine. Their size, shape, charge, surface area, solubility, and many other properties are substantial in diagnosing and treating. Their size and surface area are inversely proportional to each other. In other words, the smaller the size, the higher the surface area. Thus, their dose is less, better penetration, solubility, bioavailability, point-specific location, fewer side effects, and less toxicity.

Nanoparticles have opened new potential for diagnosis and treatment of neurodegenerative disorders. Neurodegenerative disorders affect the central nervous system (CNS) and disrupt communication between neurons vital for motor, sensory, and cognitive processes. The usage of Nanotheranostic has shown advances in the discovery of potential methods that can reduce inflammation, aggregates, and reactive oxygen species (ROS). Lastly, it is expected that there will be more usage of nanoparticles to detect and treat neurodegenerative disorders like Alzheimer's and Parkinson's.

Keywords

Neurodegenerative diseases, Nanoparticles, Nano drug delivery systems, Theronostics, Alzheimer's disease, Parkinson's disease, Diagnostics, Gold nanoparticles.

Introduction

What is nanotechnology?

Nanotechnology is any technology whose size is around the parts per billion, meaning it is in the nanometers [1]. A nanometer is equivalent to ten to the negative nine. It ranges from one nanometer to a hundred nanometers. The reactivity of a material/particle is influenced by its size. A smaller particle size increases the surface area, making it more reactive. Sensitive materials can become super durable at the nanoscale due to increased surface/volume ratio and altered properties [1]. Due to their nanoscale size and high surface area, nanoparticles (NPs) exhibit unique physical and chemical properties. Additionally, these materials or particles have optical properties depending on size [2]. The different sizes influence the different optical colors due to absorption in the visible region [2]. Their reactivity and toughness depend on the material's size, shape, and structure. Their surface charge will also be essential in how they react in the environment, the human body, and more. Moreover, their polarity, correlated with the charge, will dictate how well this material or particle interacts with other systems. Those characteristics mentioned above will affect different areas like commercial and domestic applications. Some examples include catalysis, imaging, medical applications, energy-based research, and environmental applications.

Neurodegenerative diseases

Neurodegenerative diseases are the most significant health issues in the twenty-first century [3].

What are neurodegenerative diseases?

Neurodegenerative diseases (NDs) are age-dependent disorders with different pathophysiology, and their causes and mechanisms

are not yet well understood, causing a lack of treatment options [4]. Furthermore, these illnesses appear when the nerve cells in the patient's brain or peripheral nervous system (PNS) lose function over time and eventually die [5]. Neurodegenerative disorders profoundly impact the central nervous system by disrupting the vital communication between neurons that govern sensory, motor, and cognitive functions such as vision, hearing, movement, speech and language, and memory [6].

The number of individuals who will and have neurogenerative disorders increases yearly and is expected to increase for the next four to five years. According to the National Institute of Environmental and Health Sciences, approximately 6.2 million people in the US have Alzheimer's disease (AD), and one million have Parkinson's disease (PD) [5]. Based on the Center of Disease Control and Prevention (CDC), in the United States, Alzheimer's is number seven out of the ten causes of death in 2021. Furthermore, the World Health Organization (WHO) has Alzheimer's and other neurogenerative diseases as seven of the ten leading causes of death globally [7]. Lastly, another piece of evidence that shows the exponential increase of these diseases is the market size and the projected increase of the percentage of the market in it. The market size 2023 is around 51.45 billion, projected to increase to 72.63 billion dollars [8]. In other words, the increase will be around 7.14 percent. Also, their largest market is North America, which correlates with how many deaths the US has from Alzheimer's. Hence, diseases with no cure currently have ample funding to aid treatment, but no cure has been found after discovering these diseases. That is why it is critical to continue researching nanotechnology, which has already shown significant promise in combating deadly diseases like cancer.

The following are some of the most common neurodegenerative disorders: Alzheimer's disease, Parkinson's disease, prion disease, amyotrophic lateral sclerosis, Huntington's disease, spinal muscular atrophy, and spinocerebellar ataxia [9].

This paper review focuses on two neurodegenerative disorders: Alzheimer's and Parkinson's. These illnesses are the most prevalent disorders in North America and the world. Currently, both diseases have no cure, and the number of individuals diagnosed with either of these two disorders increases yearly. Parkinson's disease is a neurodegenerative disorder that causes uncontrollable movements and difficulty with balance and coordination [10]. In comparison, Alzheimer's is a disorder that begins with mild memory loss and may progress to an inability to respond to the environment or carry on a conversation [11]. They have different ways of being diagnosed, and many of the treatments help with the symptoms but cannot prevent the disease from worsening with time.

This paper will delve into the history and challenges surrounding Alzheimer's and Parkinson's diseases. This analysis aims to comprehensively understand both diseases and the applications available for theragnostic with nanoparticles. Nanoparticles have many benefits for many diseases and illnesses, including diagnostics, therapeutic, and treatment. The goal is to look at the diagnostics and therapy done in the past, what they do currently, and the potential diagnostics and therapies that are in development.

Neurodegenerative Diseases

Parkinson disease

Parkinson's disease is a neurodegenerative disorder that causes uncontrollable movements and makes it challenging to balance and coordinate. Some examples of uncontrollable movements are shaking and stiffness [10]. This disease progresses over time, and as it goes, it hinders their movement control; walking and talking are significantly affected. Individuals with Parkinson's may also experience mental and behavioral changes, insomnia, depression, memory issues, and fatigue. Moreover, most people develop the disease after age sixty, but around five to ten percent of the population have symptoms before age fifty [10].

One of the most noticeable signs and symptoms of Parkinson's disease occurs when nerve cells in the basal ganglia degenerate or die [10]. The basal ganglia is a region of the brain that is responsible for regulating movement. It is important to note that when a patient's neuron dies or degenerates, their ability to produce dopamine is reduced. The low dopamine production level correlates to Lewy bodies' accumulation [12]. These proteins, Lewy bodies, can block dopamine's production and transmission [12,13].

This reduction in dopamine levels is associated with movement problems typical of Parkinson's disease, as explained by the National Institute on Aging [10]. In other words, individuals who develop Parkinson's disease lose their nerve endings, which causes impairment in the production of norepinephrine [10]. Also, Norepinephrine is the primary chemical messenger of the sympathetic nervous system [10]. However, the actual cause of neuron death concerning Parkinson's disease is still unknown. Moreover, PD progresses in five stages, with symptoms worsening over time. In the first stage, the patient has mild symptoms that do not interfere with their daily tasks. Typically, their symptoms consist of tremors and movement symptoms in one part of their body [14]. For the second stage, the symptoms of the patient will get worse. This includes tremors, rigidity, and other movement symptoms that affect the neck and trunk part of the body [14].

Additionally, they can start having walking problems, and their posture could improve, making it challenging to work on their daily tasks. During the mid-stage, the third stage, individuals may experience symptoms such as loss of balance, increased falls, motor impairment, and limited functionality [14].

Likewise, the disability can range from mild to moderate in this third stage. In stage four, symptoms are fully developed and severely impair the functioning and movement of the patient. This means the person will need tremendous assistance with daily activities and tasks. At this point, the person cannot live alone [14]. At stage five, the person experiences extreme stiffness in their legs, making it impossible to stand or walk and often leading to wheelchair usage. This stage requires around-the-clock care for the person's daily

activities and tasks. Lastly, Patients seek medical attention when they notice physical symptoms like resting tremors, bradykinesia, rigidity, and postural instability [12]. Doctors perform a thorough assessment that includes a review of medical history, current and previous medications, and a neurological examination. Similarly, one way to diagnose Parkinson's is through an FDA-approved imaging scan that provides detailed images of the brain's dopamine levels [12].

Alzheimer disease

Like Parkinson's, Alzheimer's is also a progressive neurogenerative disease with no cure. Alzheimer's is a progressive memory loss disease that can also lead to losing the ability to respond and continue a conversation [11].

Alzheimer's disease affects brain regions responsible for thinking, memory, and language. The causes of the disease are complex but involve the accumulation of two proteins, amyloid, and tau, in the brain [15]. The protein amyloid forms plaques around the brain cells, whereas tau forms tangles within brain cells [16]. Moreover, when the brain cells become impaired, neurotransmitters decrease, which means the signals that send the messages between brain cells become affected and unable to send the message correctly [16].

The proteins amyloid and tau damage the brain neurons, which leads to brain damage. The initial harm occurs in the hippocampus and entorhinal cortex regions. These regions are parts of the brain that are vital in forming memories. Moreover, as the progression of Alzheimer's continues, the neurons will keep dying, and therefore, more areas of the brain will be affected and shrinking. At the final stage of Alzheimer's, the damage will spread throughout the brain, and the brain tissue will shrink significantly [17].

Some signs and symptoms of Alzheimer's are cognitive impairment. The first signs of impairment will vary from patient to patient, but some of the most common are memory loss, movement difficulty, and problems with the sense of smell [17]. Alzheimer's disease manifests in various stages, with the symptoms becoming more pronounced as the condition advances. The condition begins with mild symptoms and then progresses to moderate, eventually becoming severe [18]. The mild stage starts with memory loss and cognitive difficulties. Some examples include wandering and getting lost, repeating questions, and taking longer to complete daily tasks. The moderate stage is where damage occurs in areas of the brain. Some of the affected controls are language, reasoning, conscious thought, and sensory processing. Moreover, the patient may be unable to learn new things and carry out multi-step tasks. Lastly, the severe stage is when the brain shrinks significantly because the plaques and tangles spread throughout the brain. The person in this stage can usually be in bed until death [17].

Alzheimer's disease can cause the brain to compress and, therefore, the brain cells to die [19] eventually. One of the most common causes of dementia is caused by Alzheimer's disease. This disease gradually affects the individual's ability to function, hence showing a declination of memory, thought, behavior, and social skills [19]. Lastly, Alzheimer's has different ways to be diagnosed. A doctor must conduct tests on memory, problem-solving, attention, counting, and language. Also, the doctor uses brain scans such as computed tomography (CT), Magnetic Resonance Imaging (MRI), or Positron Emission Tomography (PET). Also, doctors can order blood and urine to determine possible causes of the problem. Tests must be repeated to determine possible disorders. The way that Alzheimer's is treated is by having help from caregivers and having physical activities that provide physical and emotional benefits [17].

Past Treatments and Challenges with Neurodegenerative Diseases

History of the neurodegenerative diseases: Parkinson's and Alzheimer's

The first time Parkinson's disease was described was in 1817 by James Parkinson. This neurological disorder has been extensively researched. Milestones include clinical and pathological characteristics, neuroanatomy and neurochemistry, environmental and genetic factors, peripheral to central spread hypothesis, and technological and therapeutic approaches [20]. This disease has existed for thousands of years and was identified through written records or other evidence. Before James Parkinson described and defined the illness today known as Parkinson's disease, there were many other written records about the disease since the early ages. Throughout history, there have been several instances where the symptoms of Parkinson's Disease (PD) were described. For instance, between 2000 BC and 425 BC, the known symptoms of PD were presented [20]. In 169, Galen, an anatomist and experimental physiologist, distinguished between resting and intentional tremors. There are also records of possible instances of PD in 1228. Lastly, the closest known PD symptoms description before James Parkinson was 1690 by Ferenc Papai Pariz. After James Parkinson, many others also tried to understand this illness that causes tremors. The historical overview of Parkinson's disease after James Parkinson is remarkable. Many individuals attempted to find solutions for this incurable disease. In early 1899, there was a general description of PD but no knowledge and understanding of the anatomical, pathological, and neurochemical features. Then later that year, Brissaud suggested that PD originated from damage to the substantia nigra. Later in 1912, Frederick Lewy observed aggregated inclusions named Lewy bodies. These aggregated inclusions were in the substantia nigra, which provided a vital pathological marker. In the 60s, it was found that Dopamine levels were reduced in PD patients. Later, in the 70s, George Cotzias and Donald Brian Calne discovered that dopamine receptor agonists like bromocriptine and apomorphine were potent for PD therapy. In the 90s, it was used in cell therapy, and alpha-synuclein was identified as a significant component of Lewy bodies. Then, in 2000, they worked on blind clinical trials. Despite significant progress, there is still no cure for Parkinson's disease. Further research is needed in areas such as environmental factors, the spread of pathology, early diagnosis, and understanding why dopamine neurons are specifically affected [20].

In contrast, the definition of Alzheimer's disease was first established in 1968, and it was regarded as presenile dementia instead of Alzheimer's [21]. Later, in the early 1980s, Alzheimer's was used to refer to cognitive impairment. In 1984, the term AD was introduced to describe a clinical diagnosis of dementia. Around the 90s, neuropathologists defined AD as an abundant burden of neuritic plaques and neurofibrillary tangles. Lastly, over the past ten years, the development of fluid and imaging biomarkers to measure β-amyloid and tau abnormalities has made it possible to diagnose pathobiological conditions before death [21].

Challenges

Many of the challenges of these neurodegenerative disorders come from pre-diagnostics, prevention, and cure. The symptoms of diseases like Alzheimer's and Parkinson's are only shown physically after many decades of brain impairment. In other words, many people may not realize they have these diseases until physical or apparent symptoms appear due to significant brain impairment. For instance, Parkinson's disease manifests symptoms of tremors and movement impairment resulting from the loss of thirty to fifty percent of dopaminergic neurons in the nigrostriatal region [22]. Moreover, the most challenging aspect of developing treatments for neurodegenerative diseases is identifying early pathological events that could lead to cell death and targeting them to rescue afflicted neurons [23]. Furthermore, the challenges lie in that there is no cure, and the only therapy available can slow the progression or treat symptoms like tremors. The real challenge is to answer what causes these proteins and aggregates to form in the first place and how this can be prevented.

Like Parkinson's, Alzheimer's is difficult to identify and diagnose without a few details of information first. To identify AD without the symptoms, one must know if family members had the disorder. Other ways to identify possible risk factors that influence neurodegenerative disorders include age, genetics, environment, medical history, habits, routines, and choices [6]. After researching the many categories of other factors, these are the most prominent risk factors [24].

Age is one of the most significant factors that can cause mutations and aggregations in a patient's brain, and the older the patient, the greater the chances of these occurrences. Genetics and family history of the illness can also be good indicators of potential illness in next-generation family members. For instance, it has been documented that cases of family history are increasing. Around 2019, a Harvard Health Publishing article found a 30% chance of a family member developing an illness. These two diseases have targeted proteins that are the reason for degradation. Currently, there are experiments, *in vivo* and *in vitro*, that target the degradation of neurodegenerative diseases' pathogenic proteins [25]. This is in the hope of finding any treatment to help prevent, slow down, or cure the illness. Moreover, some of the challenges lay in the location, which is the brain, especially the blood-brain barrier (BBB). Drugs cannot cross the blood-brain barrier because of their hydrophobic hydrophilic interaction. Furthermore, all these factors can have a role in the individual's brain impairment and are part of the challenges that need to be understood. In contrast, some factors have been creating challenges for researchers and scientists. These are the ability to diagnose early, understand why the proteins misfold and form these aggregates, and accessibility to more effective therapeutics. Detecting Neurodegenerative disorders (ND) early can be highly advantageous for both researchers and individuals with the illness. Also, having a diagnostic tool or device that enables disease diagnosis can be particularly helpful for early treatment, monitoring, and having a better understanding of the progression of the ND. Also, to better understand the effects of misfolded proteins in neurogenerative disorders and why they misfold in the first place. As mentioned, many contributing factors, such as genetics, age, and environment, can influence protein folding. To better understand certain diseases, it is crucial to comprehend the nature and dynamics of the proteins involved. Identifying which forms of a specific disease protein are the leading cause of cellular toxicity and studying the protein interactions is essential. Furthermore, there needs to be more clinical trials that have validated biomarkers for neurodegenerative diseases, which further adds to the situation's complexity [26].

For the last point of therapeutics, as previously stated, no therapy or therapeutics can cure or prevent these diseases from further developing because of the many factors and challenges that have yet to be solved or understood completely.

In current medicine, one can do a series of tests to check if the individual has cognitive issues. Also, there are biomarkers in which one can look through blood tests to identify this illness [23]. Other tests that may help diagnose dementia are Positron Emission Tomography (PET) Scan, Magnetic Resonance Imaging (MRI), and lumbar punctures. Also, these diseases, AD and PD, do not have a specific lab or imaging test that can diagnose as a preventative. Nevertheless, even if they do not have specific tests to identify them, some specific biomarkers and tools can be used to diagnose the diseases. Some examples of tests that can help determine PD are an MRI brain, dopamine transporter scan (Dat scan), and blood work [27]. These tests help rule out other diseases that can mimic symptoms of PD or AD.

A PET scan is an imagining test that can reveal one tissue and organ's biochemical or metabolic functions [28]. Magnetic resonance imaging (MRI) employs radio waves and strong magnetic fields to produce detailed images of the internal body, as per NHS information in 2023. Meanwhile, a spinal tap, also known as a lumbar puncture, involves inserting a hollow needle into the subarachnoid space located around the spinal column in the lower back. This procedure is performed to withdraw cerebrospinal fluid (CSF) or administer medication. Johns Hopkins Medicine notes that this diagnostic test is used to identify brain disorders such as Alzheimer's.

Theranostic in Neurodegenerative diseases

What is theranostic?

Theranostic is a combination of diagnostics with therapeutics [29]. The benefits of the technology that can diagnose and

administer therapy are that these can be done by one medical tool or particle that is developed to function for both needs [29]. This is faster, cheaper, and more consistent than using multiple devices for different roles, such as diagnosing and treating through therapy. To be more specific, this can be possible with what is called nanomedicine or Nanotheranostic. Nanomedicine includes nanoparticles or materials developed or created in a nanoscale range [30]. Theranostic nanomedicine is imperative for personalized treatment. Nanomaterials target specific disease locations, avoiding harm to healthy cells [30]. Moreover, once the nanoparticle detects the markers, it can provide information about the disease as imaging or be used as a treatment.

Diagnostics

Diagnostics is a process using different methods to identify a disease or illness. Medical professionals utilize laboratory testing to diagnose neurodegenerative diseases, including blood tests, genetic testing, and imaging scans. Some examples in genetic testing for PD are using microarray and RNA sequencing to identify biomarkers that are exclusive for PD patients and then using PCR (Polymerase Chain Reaction) and immunohistochemistry to confirm that the cell markers are only for patients with PD [31]. Another way to determine senile plaques as a significant component of AD is by the method of ELISA, Enzyme Link Immunosorbent Assay [25]. Likewise, Parkinson's can be done by genetic testing by a different variation of genes. Also, Genetic testing can identify Parkinson's disease by detecting specific gene variations, including GBA, LRRK2, PRKN, SNCA, PINK1, and VPS35 [32]. In contrast, using genetic testing for Alzheimer's disease can be challenging because around 1% of the patients have specific mutations that cause the illness—for example, the gene for amyloid precursor protein and presenilin protein 1 and 2 genes. Moreover, the blueprint gene for Alzheimer's is the APOE gene. This gene determines the type of protein that delivers cholesterol in the blood. Throughout that delivery, the three common forms of the gene are e2, 23, and e4. The e3 is the most common, whereas the e2 and e4 are less common. Also, the one that increases the risk of AD is e4. However, it does not guarantee that one will get Alzheimer's from this polymorphism of the APOE gene.

Therapy

There are many ways in which medicine has changed an individual's life through therapy and treatments. Currently, neurodegenerative diseases, unfortunately, do not have any known cure. However, even though available treatments and therapy can help mitigate the symptoms associated with these debilitating conditions, there are no treatments that can fully help with the disease. Some examples of rehabilitation and treatments are physical and occupational therapy, psychology, neurology, speech therapy, and supportive care [33]. These specific treatments are helpful for the patient's mobility, functioning, condition, emotional functioning, and communication.

Furthermore, the treatments only solve symptom issues instead of the fundamental cause of the condition. Therefore, many scientists are developing new methods to help solve the problem instead of the symptoms caused by the problem. For instance, there are potential therapies for neurodegenerative patients based on immunotherapy. Some immunotherapies examples are passive and active vaccinations that use monoclonal antibodies and specific antigens to stimulate an adaptive immune response. According to the paper "Immunotherapies for Neurodegenerative Diseases," evidence suggests that immunotherapeutic agents can potentially treat neurodegenerative diseases [34]. It is important to acknowledge other methods that can have a pivotal role in the therapeutic route of the patient. When exploring novel approaches to tackling challenges in therapy, it is crucial to identify specific targets that require attention for protecting, repairing, or regenerating the neurons. Therefore, prioritizing the search for potential therapies that could impact neurodegenerative disorders is crucial.

Benefits of using Nanotheranostic for neurodegenerative diseases

Nanotheranostic is a multidisciplinary method that diagnoses, treats, and uses chemistry, physics, material sciences, nanotechnology, drug delivery, and pharmacology on a nanoscale [35]. These multidisciplinary theranostic systems have radically changed personalized medicine by using innumerable biomarkers, imaging agents, chemotherapeutic agents, and specific targeting ligands [35]. Using nanotechnology for diagnostics and therapy has been one of the most significant advantages in science. Using nanoparticles as drug delivery systems and treatments has been groundbreaking for many types of cancers and different illnesses. Utilizing materials at the nanoscale level offers several advantages, including enhanced penetration, retention, bioavailability, and concentration, while simultaneously reducing the occurrence of side effects and toxicity. As such, using nanoscale materials presents a promising avenue for researchers and industry professionals to explore in the search for improved performance, safety, and efficacy in various fields. Hence, using nanotechnology to apply theranostic on individuals with neurodegenerative diseases can lead to potential beneficial diagnostics and treatments for medicine and the individual. Nanoparticles' properties can quickly eliminate some of the challenges past drugs and treatments had. Examples of factors affecting drug distribution include the size of the drug, the polarity of the drug, and the blood-brain barrier. Thus, the nanoparticles are fundamental in the advancement of diagnostics and treatment.

Theranostic has benefited from nanomedicine since nano-platforms have been used for imagining and effective drug delivery to improve the detection and treatment of neurodegenerative diseases [36]. Therefore, using nanoparticles increases the drug's efficiency and bioavailability. Also, it causes fewer side effects and less toxicity, and they can enhance the therapeutic efficiency as an overall *in vivo* and *in vitro* test. Additionally, nanoparticles improve the efficiency of stem-cell therapy by stimulating self-renewal, proliferation, and differentiation of neural stem cells [37]. Lastly, one can conclude that various types of nanoparticles have been studied for diagnosing Alzheimer's and Parkinson's disease due to their potential benefits.

Gold nanoparticles roles in neurodegenerative diseases

Nanoparticles

The usage of nanomaterials increases every year, and this is because of all the properties the nanoparticles have and the benefits of their use. A nanoparticle is within a range of 1 to 100 nanometers [38]. Their properties influencing many products and formulations are charge, size, surface area, solubility, shape, and composition. They can penetrate better than regular drugs, be drug carriers, target specific biomarkers, increase bioavailability, decrease side effects, decrease toxicity, and have a constant dosage.

Gold nanoparticles

Gold nanoparticles are crucial in medical diagnostics and treatment research due to their unique properties that enable the identification and treatment of challenging illnesses. Their benefits lie in their electrical and physical characteristics and easily modifiable chemical surface properties [39].

Additionally, AuNPs possess anti-inflammatory, antioxidant, bacteriostatic, and anticorrosive properties that can aid in treating various inflammatory and oxidative diseases [40,41]. Colloidal gold nanoparticles have photoacoustic and photothermal properties due to their ability to absorb light at specific wavelengths, which is helpful for cancer treatments and medical imaging [41]. The qualities of the gold nanoparticles have made them among the most impressive nanomaterials in research and in point-of-care medical devices globally [39].

Applications of gold nanoparticles in Neurodegenerative disorders

For decades, nanotechnology and nanoscience have revolutionized how medicine diagnoses, treats, and prevents diseases [42]. There are many types of nanoparticles. Depending on the type of particle material and shape, their properties will change in addition to their functions and interactions with the systems. Likewise, nanoparticles will have different responses depending on where they were administrated. Gold nanoparticles have excellent properties that are helpful for many illnesses, and neurodegenerative disorders are some of the many other illnesses in which gold nanoparticles have beneficial interactions. Therefore, many gold nanoparticle applications involve theranostic in detecting and destroying the specific markers with their photothermal properties.

Some examples of gold nanoparticles used for theranostic purposes include detecting amyloid beta peptides for Alzheimer's disease, as described in "The Roles of Gold Nanoparticles in Detecting Amyloid Beta Peptides for Alzheimer's Disease" article. In this paper, they used gold nanoparticles to detect the amyloid aggregates. For example, they use a gold nanoparticle-based colorimetric assay to detect alpha and beta proteins. Once detected, this specific nanoparticle can also be used as a treatment. Additionally, Gold nanoparticles (AuNPs) have high optical absorption in the near-infrared (NIR) region, and it is crucial for photothermal therapy [25]. This is accomplished using a laser targeting the NIR region, allowing for precise tissue penetration. This can destroy aggregates like the amyloids in AD patients.

Another example in which gold nanoparticles serve as a diagnostic and therapy/treatment is in the article “Gold nanoparticles treatment reverses brain damage in Alzheimer’s disease model.” As new studies suggest, Alzheimer’s disease can potentially be involved with neuroinflammation and oxidative stress. This paper used AuNPs to treat and prevent neuroinflammation, modulation of mitochondrial function, and impaired cognition induced by the Alzheimer’s model [40]. In the end, using gold nanoparticles showed promising results, preventing oxidative stress and having a normal mitochondrial function, and the gold nanoparticles restored the brain tissue of the rats [40].

Below are several examples of the potential applications of gold nanoparticles in supporting the treatment of Parkinson's disease patients. Using *in vitro* nanoclusters prevents alpha-synuclein aggregation and appears to protect nerve cells against damage. This method is commonly used, and I was used in the article as a cell model to research potential drug treatments for Parkinson’s disease. Research findings suggest that gold nanoclusters exhibit potential therapeutic benefits in mice models combating alpha-synuclein accumulation and neurodegeneration.

Conclusion

Among the most vital benefits nanomedicines helped discover are diagnostics, drug delivery, and nanoparticle treatment. Nanoparticles have shown many beneficial inputs in modern medicine and diseases that have shown many challenges in diagnosis and treatment. Likewise, engineered nanomaterials can cross physiological barriers and enable controlled drug release [43]. The field that involves both diagnosis and treatment is called theranostic. The usage of nanoparticles can incorporate both methods simultaneously in a single process. Nanoparticles can identify specific biomarkers of various illnesses. Once detected, the particles attach to them and create various methods of destruction to combat harmful biomarkers such as cancer cells or aggregates.

Some particles can create immune responses, making these specific biomarkers go into apoptosis or necrosis. As a result, various illnesses that were challenging to detect and treat are now more easily diagnosable and treatable due to the novel properties of nanoparticles. For instance, the properties of these particles that make them different from macro and micro drugs are the size, surface area, charge, solubility, polarity, and bioavailability. Thus, many methods involving diagnostics and treatments were studied and showed positive results in diagnosing and reducing inflammation from the central nervous system. These diagnostics and treatments were specific for neurodegenerative diseases like Alzheimer’s and Parkinson’s. These two diseases are becoming prevalent diseases in elderly individuals and even adults. There are many reasons why many individuals are affected by these two neurodegenerative diseases. This reason involves genetics, age, environment, and family heritage. Every year, there is an increase in these diseases that do not have a cure, the diagnosis is made too late, and the treatments do not fix the problems or help the symptoms. With nanoparticles like AuNPs, whose properties are crucial for imaging, detection, and even treatment, ND can

be detected and treated faster than any past methods. Through research and experiment, gold nanoparticles showed improvement in both Parkinson's and Alzheimer's rats. These particles focus on the aggregates these two diseases develop and show significant improvement in neuroinflammation, ROS, and oxidative stress. Furthermore, it showed the aggregates' detection and breaking down with their thermal properties. Finally, many engineered nanoparticles have demonstrated superior results in animal models compared to conventional drug carriers, and it is hoped that such nanoparticles will prove equally effective in patients.

Future trends

Nanomedicine, which involves nanoparticles, holds great promise for treating degenerative disorders. Animal studies have shown significant improvements in both diagnosis and therapy. However, using nanoparticles in humans poses a potential risk of toxicity, which must be carefully evaluated and approved as safe before being utilized. In the future, the potential disruptive trends in the nanomedicine field could revolutionize how many illnesses are treated. Future medicine research includes developing better nanocarriers with enhanced selective bindings, improving drug efficacy, and reducing toxicity. Also, various nanocarriers have shown great potential in delivering drugs for neurological disorders [43].

Furthermore, having control of nanomaterials that mimic cell membranes' lipidic environment will aid in function, biosensing, and drug delivery [44]. In other words, these specific nanoparticles can mimic a lipidic environment because they encapsulate both hydrophobic and hydrophilic pharmaceuticals, protecting them from other interactions in the system. Due to the different properties of nanoparticles, they are being considered as future or potential treatments for neurodegenerative diseases. The paper titled "Nanoparticle-Based Drug Delivery Systems: An Inspiring Therapeutic Strategy for Neurodegenerative Diseases" aims to tackle the challenges posed by neurodegenerative disorders and presents clinical evidence to support the use of nanoparticle-based drugs [45]. Hence, for future treatments, they believe that nanoparticle-based drug delivery systems (NDDS) can disrupt how medicine treats neurodegenerative diseases. Moreover, the technology that uses green nanosystems is another cutting-edge system that can potentially disrupt and treat neurodegenerative diseases. Green nanosystems and NDDs to develop diagnostic devices, targeted drug delivery, surgical prostheses, and nanoscaffolds for neurodegeneration and immunity development [46]. Finally, the remarkable potential of nanoparticles and nanomaterials in drug delivery, detection, and treatment is worth noting. The field of nanotechnology has been experiencing rapid growth, with various nanoparticles and nanomaterials making significant breakthroughs in diagnosis. We can expect even more progress in this area as our knowledge and technological advancements evolve.

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