Research & Reviews: Journal of Medical and Health Sciences

Neurodegenerative Diseases: Mechanisms, Clinical Spectrum, and Emerging Therapeutic Strategies

Elena Petrova*

Department of Geriatrics, Moscow State Medical University, Moscow, Russia

Mini Review

Received: 01-Sep-2025, Manuscript No. JMAHS-25-187537; **Editor assigned:** 3-Sep-2025, Pre-QC No. JMAHS-25-187537 (PQ); **Reviewed:** 17-Sep-2025, QC No JMAHS-25-187537; **Revised:** 22-Sep-2025, Manuscript No. JMAHS-25-187537 (R); **Published:** 29-Sep-2025, DOI: 10.4172/jmahs.14.013

***For Correspondence**

Elena Petrova, Department of Geriatrics, Moscow State Medical University, Moscow, Russia

E-mail: elena.petrova@gmail.com

Citation: Elena Petrova, Neurodegenerative Diseases: Mechanisms, Clinical Spectrum, and Emerging Therapeutic Strategies. Rep Cancer Treat. 2025.14.013.

ABSTRACT

Neurodegenerative diseases represent a group of progressive disorders characterized by the gradual loss of structure and function of neurons. These conditions, including Alzheimer's disease, Parkinson's disease, Huntington's disease, and amyotrophic lateral sclerosis (ALS), pose significant challenges to global health due to their increasing prevalence and lack of curative therapies. This mini review provides a comprehensive overview of the pathophysiology, risk factors, clinical manifestations, and current therapeutic approaches for major neurodegenerative diseases. It also explores recent advances in molecular biology, biomarkers, and emerging treatments such as gene therapy, stem cell therapy, and disease-modifying drugs. Understanding the complex mechanisms underlying neurodegeneration is essential for developing effective strategies to prevent and manage these debilitating conditions.

KEYWORDS

Neurodegenerative diseases, Alzheimer's disease, Parkinson's disease, Huntington's disease, Amyotrophic lateral sclerosis (ALS), Neurodegeneration

INTRODUCTION

Neurodegenerative diseases are a heterogeneous group of disorders characterized by progressive neuronal loss, leading to cognitive decline, motor dysfunction, and behavioral changes. These diseases primarily affect the central nervous system and are often associated with aging, making them a growing public health concern worldwide.

The burden of neurodegenerative diseases is increasing due to rising life expectancy and demographic transitions. Despite extensive research, most of these disorders remain incurable, with current treatments primarily focused on symptom management rather than disease modification.

This mini review aims to provide a detailed overview of neurodegenerative diseases, including their underlying mechanisms, major types, clinical features, and recent advancements in therapeutic strategies.

Pathophysiology of Neurodegeneration

The pathogenesis of neurodegenerative diseases is complex and multifactorial, involving a combination of genetic, environmental, and cellular processes.

1. Protein Misfolding and Aggregation

One of the hallmark features of neurodegenerative diseases is the accumulation of misfolded proteins. For example:

- Amyloid-beta and tau proteins in Alzheimer's disease
- Alpha-synuclein in Parkinson's disease
- Huntingtin protein in Huntington's disease

These abnormal proteins aggregate to form toxic structures that disrupt cellular function and lead to neuronal death.

2. Oxidative Stress

Oxidative stress results from an imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defenses. Excess ROS can damage cellular components such as DNA, proteins, and lipids, contributing to neuronal degeneration.

3. Mitochondrial Dysfunction

Mitochondria play a critical role in energy production and cellular metabolism. Dysfunction of mitochondria leads to reduced energy supply and increased oxidative stress, both of which contribute to neuronal damage.

4. Neuroinflammation

Chronic activation of the immune system in the brain, particularly microglia and astrocytes, leads to inflammation. While initially protective, prolonged inflammation can exacerbate neuronal injury.

5. Impaired Protein Clearance

Defects in cellular mechanisms responsible for clearing misfolded proteins, such as the ubiquitin-proteasome system and autophagy, contribute to protein accumulation and toxicity.

Major Neurodegenerative Diseases

1. Alzheimer's Disease

Alzheimer's disease is the most common cause of dementia, characterized by progressive memory loss, cognitive decline, and behavioral changes. Pathologically, it is associated with amyloid plaques and neurofibrillary tangles.

Risk factors include aging, genetic predisposition, and lifestyle factors. Current treatments include cholinesterase inhibitors and NMDA receptor antagonists, which provide symptomatic relief but do not halt disease progression.

2. Parkinson's Disease

Parkinson's disease is a movement disorder characterized by tremors, rigidity, bradykinesia, and postural instability. It results from the loss of dopaminergic neurons in the substantia nigra.

The accumulation of alpha-synuclein in Lewy bodies is a key pathological feature. Treatment primarily involves dopamine replacement therapy, such as levodopa.

3. Huntington's Disease

Huntington's disease is a genetic disorder caused by a mutation in the HTT gene, leading to abnormal huntingtin protein. It is characterized by movement abnormalities, cognitive decline, and psychiatric symptoms.

As an autosomal dominant condition, it has a strong genetic basis. Currently, treatment is supportive and focuses on symptom management.

4. Amyotrophic Lateral Sclerosis (ALS)

ALS is a progressive neurodegenerative disease affecting motor neurons, leading to muscle weakness, paralysis, and eventual respiratory failure.

The exact cause is not fully understood, but genetic and environmental factors are implicated. Available treatments, such as riluzole, offer limited benefits in slowing disease progression.

Risk Factors

Neurodegenerative diseases are influenced by a variety of risk factors:

- **Age:** The most significant risk factor
- **Genetics:** Family history and genetic mutations
- **Environmental exposures:** Toxins, pollutants
- **Lifestyle factors:** Diet, physical activity, smoking
- **Comorbid conditions:** Cardiovascular diseases, diabetes

Understanding these risk factors is important for prevention and early intervention.

Clinical Manifestations

The clinical presentation of neurodegenerative diseases varies depending on the specific condition but generally includes:

- Cognitive impairment and memory loss
- Motor dysfunction such as tremors and weakness

- Behavioral and psychological changes
- Speech and swallowing difficulties

Early diagnosis can be challenging due to overlapping symptoms and gradual onset.

Diagnostic Approaches

Diagnosis of neurodegenerative diseases involves a combination of clinical evaluation and advanced diagnostic tools:

- **Neuroimaging:** MRI and CT scans
- **Biomarkers:** CSF analysis and blood tests
- **Genetic testing:** For hereditary conditions
- **Neuropsychological assessments:** To evaluate cognitive function

Advances in biomarker research are improving early detection and disease monitoring.

Current Therapeutic Strategies

1. Symptomatic Treatment

Most current therapies focus on alleviating symptoms rather than curing the disease.

2. Pharmacological Approaches

Medications are used to manage symptoms such as cognitive decline, motor dysfunction, and psychiatric disturbances.

3. Non-Pharmacological Interventions

- Physical therapy
- Cognitive rehabilitation
- Lifestyle modifications

These approaches help improve quality of life.

Emerging Therapies

1. Gene Therapy

Gene therapy aims to correct or modify genetic defects associated with neurodegenerative diseases.

2. Stem Cell Therapy

Stem cells have the potential to replace damaged neurons and restore function.

3. Disease-Modifying Drugs

Research is focused on developing drugs that target underlying disease mechanisms, such as protein aggregation and inflammation.

4. Immunotherapy

Immunotherapy approaches aim to clear toxic proteins and modulate immune responses.

Challenges in Neurodegenerative Research

- Lack of effective disease-modifying treatments
- Complexity of disease mechanisms
- Difficulty in early diagnosis
- High cost of research and treatment
- Ethical considerations in experimental therapies

Future Perspectives

The future of neurodegenerative disease research is promising, with several areas of focus:

- Development of early diagnostic tools
- Personalized medicine approaches
- Integration of artificial intelligence in research

- Improved understanding of disease mechanisms
- Collaborative global research efforts

These advancements are expected to lead to more effective prevention and treatment strategies.

CONCLUSION

Neurodegenerative diseases represent a significant and growing challenge in global healthcare. Despite advances in understanding their pathophysiology, effective treatments remain limited.

Ongoing research into molecular mechanisms, biomarkers, and innovative therapies offers hope for the development of disease-modifying treatments. A multidisciplinary approach involving clinicians, researchers, and policymakers is essential to address the complex challenges associated with these disorders.

Improving awareness, early diagnosis, and patient care will be crucial in reducing the burden of neurodegenerative diseases and enhancing the quality of life for affected individuals.

REFERENCES

1. Cesario A, Ferri L, Galetta D, Pasqua F, Bonassi S, et al. (2007) Post-operative respiratory rehabilitation after lung resection for non-small cell lung cancer. Lung Cancer 57: 175-180.
2. Bobbio A, Chetta A, Ampollini L, Primomo GL, Internullo E, et al. (2008) Preoperative pulmonary rehabilitation in patients undergoing lung resection for non-small cell lung cancer. Eur J Cardiothorac Surg 33: 95-98.
3. Spruit MA, Janssen PP, Willemsen SCP, Hochstenbag MMH, Wouters EFM (2006) Exercise capacity before and after an 8-week multidisciplinary inpatient rehabilitation program in lung cancer patients: a pilot study. Lung Cancer 52: 257-260.
4. Divisi D, Francesco CD, Leonardo GD, Crisci R (2013) Preoperative pulmonary rehabilitation in patients with lung cancer and chronic obstructive pulmonary disease. Eur J Cardiothorac Surg 43: 293-296.
5. Brunelli A, Pompili C, Salati M, Refai M, Berardi R, et al. (2014) Preoperative maximum oxygen consumption is associated with prognosis after pulmonary resection in stage I non-small cell lung cancer. Ann Thorac Surg 98: 238-242.