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Huntington's disease: Advances in Genetics, Pathophysiology, Diagnosis, and Treatment

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ABSTRACT

Huntington's disease (HD) is an inherited genetic neurodegenerative disorder that affects a patient's motor and cognitive abilities. It results from an expanded CAG trinucleotide repeat in the Huntington's disease (HTT) gene. Due to the mutated HTT gene, which aggregates and causes neuronal dysfunction, finding a cure is highly challenging. Huntington's disease (HD) is a genetic disorder that affects the brain. In recent years, scientists have learned more about the genes and biological processes that cause the disease. This new knowledge has helped improve the way HD is diagnosed and understood. Researchers are also working on new treatments. Some of these include gene therapy and drugs that may protect brain cells. These advances give hope for better care and new ways to slow down the disease in the future. Additionally, we outline current methodologies for literature selection and discuss future research directions in HD management.

Keywords: Huntington's disease, HTT gene, Neurodegeneration, CAG repeat expansion

1. INTRODUCTION

Huntington's disease (HD) is a genetic neurodegenerative illness that follows an autosomal dominant inheritance pattern. It has an estimated prevalence of 5–10 cases per 100,000 individuals worldwide (Pringsheim et al., 2012). First described by George Huntington in 1872, the disease results from an expanded CAG trinucleotide repeat within the HTT gene, leading to the production of a mutant huntingtin protein that aggregates abnormally and causes progressive neuronal loss, especially in the striatum and cortex (MacDonald et al., 1993; Ross & Tabrizi, 2011). The disease typically manifests in midlife, although juvenile-onset cases have been reported and are generally more severe (Quarrell et al., 2013). Clinical symptoms encompass motor dysfunction, cognitive decline, and psychiatric disturbances, which collectively diminish the quality of life and usually result in death within 15–20 years of onset (Walker, 2007). Although significant progress has

been made in understanding the biological mechanisms of HD, there is currently no cure, and existing therapies primarily focus on symptomatic management (Wild & Tabrizi, 2017). This review summarizes recent developments in HD genetics, pathophysiology, diagnostic strategies, and treatment and discusses emerging therapeutic approaches.

2. METHODOLOGY

We conducted a systematic literature review using PubMed, Scopus, and Web of Science. The inclusion criteria encompassed peer-reviewed articles published within the last decade focusing on HD genetics, molecular mechanisms, clinical diagnosis, and treatment strategies. Exclusion criteria included non-English articles and studies lacking primary data. The search terms used included "Huntington's disease," "HTT gene," "pathophysiology of Huntington's disease," "clinical diagnosis of Huntington's disease," and "therapeutic approaches for Huntington's disease." We selected research papers based on relevance, quality, and contribution to the field. Literature review findings were categorized based on theme, and critical analysis was performed to evaluate strengths, limitations, and gaps in current knowledge.

3. RESULTS AND DISCUSSION

Genetic Basis of Huntington's Disease

The HTT gene, located on chromosome 4, typically contains 10 to 35 CAG repeats. In individuals with Huntington's disease (HD), this repeat expands to 36 or more, with expansions exceeding 40 repeats being fully penetrant (Andrew et al., 1993; Lee et al., 2012). Larger repeat expansions are associated with earlier disease onset and more severe progression (Langbehn et al., 1997; Squitieri et al., 2020). Recent studies have shown that uninterrupted CAG repeat length, rather than polyglutamine length, determines the timing of HD onset (Wright et al., 2019). The mutant huntingtin protein resulting from these expansions disrupts various cellular functions, contributing to neuronal degeneration (Langbehn et al., 2011). Specifically, mutant huntingtin has been found to stall ribosomes and repress protein synthesis, leading to neurodegeneration (Zhao et al., 2021).

Molecular Mechanisms Contributing to Pathogenesis

RNA Toxicity and Processing Defects

Expanded CAG repeats in the HTT gene not only produce aberrant proteins but also lead to the formation of toxic RNA species. These mutant RNA molecules can sequester essential RNA-binding proteins, thereby disrupting normal RNA processing and splicing (Galka-Marciniak et al., 2012; Fiszer & Krzyzosiak, 2013; Martí, 2016). Recent studies have highlighted the role of RNA-mediated toxicity in HD pathogenesis (Fiszer & Krzyzosiak, 2013).

Protein Misfolding and Aggregation

The mutant huntingtin protein tends to misfold and aggregate within neurons, which causes neuronal dysfunction and death. The result is so severe because mutant huntingtin forms intracellular inclusions, which aggregates interfere with various cellular processes in neurons, including proteasomal degradation and autophagy (Hipp et al., 2014; Rubinsztein, 2006). Research has highlighted the role of compromised protein clearance mechanisms in the pathogenesis of HD (Hipp et al., 2014).

DNA Repair Deficiencies and Somatic Expansion

Recent findings have revealed that the expanded CAG repeats in the HTT gene can further expand within somatic cells over time, particularly in neurons. This somatic expansion is associated with deficiencies in DNA repair pathways (Swami et al., 2009). A study published in Cell demonstrated that once the CAG repeat length reaches a critical threshold, it triggers neuronal death, providing insight into the delayed onset of HD symptoms despite the presence of the mutation from birth (McCarroll et al., 2025).

Mitochondrial Dysfunction

Mutant huntingtin has been shown to cause mitochondrial dysfunction, which leads to impaired energy production and increased oxidative stress. A recent study utilizing advanced 3D electron microscopy techniques revealed significant disruptions in the mitochondrial network within neurons of HD mouse models, characterized by fragmented and swollen mitochondria with disorganized internal structures (Martin-Solana et al., 2024).

Autophagy Impairment

Autophagy, the cellular process responsible for degrading and recycling damaged proteins and organelles, is impaired in Huntington's disease (HD). Mutant huntingtin interferes with autophagosome formation and function, which is responsible for the accumulation of toxic protein aggregates (Menzies et al., 2015). Research focusing on the link between autophagy and gene regulation has given us new insights into the disease process, potentially enabling the development of novel therapies (Oh et al., 2022).

Pathophysiology

In Huntington's disease, nerve cells in a brain area called the striatum are especially damaged. Recent studies have helped us better understand the main processes that cause this damage:

Somatic Expansion of CAG Repeats

A pivotal study revealed that the CAG trinucleotide repeats in the HTT gene can further expand within neurons over time. Once these repeats surpass a critical threshold of approximately 150, they produce toxic proteins that lead to neuronal death (Swami et al., 2024). This expansion process explains why individuals with the HD mutation can be asymptomatic for decades before the clinical onset.

Astrocytic Dysfunction

Astrocytes are essential for maintaining the health of neurons. In HD, astrocytes exhibit morphological and functional abnormalities, including impaired potassium and glutamate buffering, which contribute to neuronal excitotoxicity (Khakh et al., 2017). These dysfunctions underscore the importance of glial cells in HD pathology and present potential therapeutic targets.

Neuroinflammation

There is evidence that chronic activation of microglia and astrocytes leads to sustained neuroinflammation in HD. This inflammatory response exacerbates neuronal damage through the release of cytokines and reactive oxygen (Crotti & Glass, 2015). Targeting neuroinflammatory pathways is being explored as a therapeutic strategy to mitigate disease progression.

Dopamine Dysregulation

New research suggests that disrupted dopamine regulation, linked to impaired TrkB neurotrophin receptor signaling in specific neurons, may trigger HD onset. In mouse models, targeting the enzyme GSTO2, which influences dopamine metabolism, prevented motor symptoms, suggesting a potential pathway for early intervention (Lee et al., 2023).

New Therapeutic Approaches

Thanks to a better understanding of how Huntington's disease (HD) works, new treatment options are being developed: The company UniQure has created a gene therapy that targets the root cause of HD (UniQure, 2024). Novartis is working with PTC Therapeutics on a new drug that could lower the amount of harmful huntingtin protein in the body (Novartis, 2024). This shows that small-molecule drugs may play an important role in treating HD. These insights into the pathophysiology of Huntington's disease are guiding the creation of targeted therapies designed to delay or halt the development of the disease.

Clinical Symptoms

Huntington's disease causes movement problems, thinking difficulties, and mental health issues. These symptoms often start between ages 30 and 50 and get worse over 15 to 20 years (Ross & Tabrizi, 2011).

Motor Symptoms

The hallmark motor feature of HD is chorea—involuntary, sudden, quick movements that happen in different parts of the body. As the disease advances, patients may experience:

- Dystonia: Muscles remain tight for an extended period, causing the body to hold unusual or uncomfortable positions.
- Bradykinesia: Slowness of movement.
- Dysarthria: Speech difficulties.
- Dysphagia: Difficulty swallowing (Walker, 2007).

In juvenile-onset HD, rigidity and seizures are more prevalent, with chorea being less common (Quarrell et al., 2013).

Cognitive Symptoms

Cognitive decline in Huntington's disease (HD) primarily affects executive functions, including:

- Impaired planning and organization.
- Reduced cognitive flexibility.
- Difficulty with abstract thinking.
- Memory disturbances

These deficits contribute to challenges in daily activities and occupational performance.

Psychiatric Symptoms

Psychiatric manifestations often precede motor symptoms and may include:

- Depression and mood swings.
- Irritability and aggression.
- Obsessive-compulsive behaviors.
- Anxiety and apathy.

Sleep disturbances and, in rare cases, psychosis can also occur (van Duijn et al., 2014).

Systemic Symptoms

New research shows that Huntington's disease affects more than just the brain. It can also cause problems like weight loss, heart issues, and metabolism changes (Underwood et al., 2006).

Disease Progression

The disease usually develops in stages. In the early stage, people may notice small changes in thinking and mood, along with slight involuntary movements. During the middle stage stage, movement difficulties increase. The sudden, jerky movements called chorea become more noticeable. People often start having problems with speaking clearly and swallowing food or liquids. In the late stage, movement problems become very severe, making it hard or impossible to move without help. Thinking and memory skills also worsen a lot. At this stage, individuals typically require full-time care from others to manage their daily activities (Tabrizi et al., 2012). Understanding these symptoms helps doctors diagnose and manage HD earlier and better.

Biomarkers for Early Diagnosis

Detecting Huntington's disease early is important so treatment can start sooner and patients can take part in clinical trials, which is important for the eventual delay of disease onset. Biomarkers play a pivotal role in detecting presymptomatic changes and tracking disease progression.

Neuroimaging Markers

Imaging techniques such as MRI, PET, and functional MRI (fMRI) have been instrumental in identifying structural and functional brain alterations before symptom onset. Volumetric MRI studies have shown early atrophy in the brain caudate nucleus and putamen, correlating with disease severity. PET imaging helps visualize metabolic changes, particularly reduced glucose metabolism in affected brain regions (Tabrizi et al., 2009; Poudel et al., 2014).

Cerebrospinal Fluid (CSF) Markers

Emerging CSF biomarkers include neurofilament light chain (NfL), a marker of neuroaxonal damage. Elevated NfL levels in presymptomatic HD carriers suggest its potential as a prognostic biomarker (Byrne et al., 2017). Other potential CSF markers under investigation include mutant huntingtin protein fragments and inflammatory cytokines.

Genetic Testing Advancements

Genetic testing is still the most reliable way to diagnose Huntington's disease. Newer methods like whole-genome sequencing and CRISPR-based tests are being studied to measure CAG repeats more accurately and explore changes in gene activity. These tools may help doctors better predict when symptoms will start and how severe the disease might be (Moss et al., 2022).

Emerging Therapeutic Strategies

A better understanding of how Huntington's disease affects cells has made it possible to develop treatments that directly target its cause. One of the most promising strategies is gene silencing, which tries to reduce the amount of harmful huntingtin protein. A key tool in this approach is antisense oligonucleotides (ASOs) — short strands of genetic material that block the gene's message before it makes the protein. By targeting specific gene transcripts, ASOs can lower huntingtin levels and may be especially useful for treating brain diseases like HD (Kordasiewicz et al., 2022).

Additionally, efforts to enhance DNA repair mechanisms to prevent the somatic expansion of CAG repeats are underway. Targeting mismatch repair proteins like MSH3 has been proposed as a potential therapeutic strategy. Ablation of Msh3 prevented somatic expansion throughout the brain and periphery, and the reduction of Msh3 by 50% decreased the rate of expansion (Bunting et al., 2025).

Pharmaceutical companies are also investing in the development of disease-modifying treatments. Novartis has entered into a licensing agreement for PTC Therapeutics' experimental drug PTC518, which targets the underlying causes of HD and has shown promise in reducing levels of the mutant huntingtin protein (Novartis, 2024).

Treatment Strategies

No cure for HD exists. Current treatment methods primarily focus on managing symptoms and improving quality of life. Recent research has explored both symptomatic treatments and potential disease-modifying therapies (Frank, 2014; Ross et al., 2011).

Symptomatic Treatments

Motor Symptoms

- *Chorea Management*: Tetrabenazine and deutetrabenazine are approved for reducing chorea associated with HD. These medications work by depleting dopamine, thereby mitigating involuntary movements (Frank, 2010).
- *Alternative Medications*: Antipsychotics like olanzapine and benzodiazepines may also be used to manage chorea, especially when accompanied by psychiatric symptoms (Bonelli & Hofmann, 2007).

Psychiatric Symptoms

- *Depression, Anxiety*: Selective Serotonin Reuptake Inhibitors (SSRIs) and mirtazapine are commonly prescribed to address mood disturbances in HD patients (Kassubek et al., 2014).
- *Irritability, Psychosis*: Atypical antipsychotics can be effective in managing irritability, aggression, and psychotic features (Groves et al., 2011).

Cognitive Symptoms

At the moment, there are no drugs that can stop or reverse memory and thinking problems in Huntington's disease. However, non-drug methods like cognitive exercises and keeping a regular daily routine may help to some extent (Stout et al., 2012).

Non-Pharmacological Interventions

- *Physical Therapy*: Regular exercise can help maintain mobility balance and reduce fall risk (Bilney et al., 2003).
- *Occupational Therapy*: Assists patients in adapting to daily living activities, promoting independence for as long as possible (Goh & Chiu, 2019).
- *Speech and Language Therapy*: Addresses difficulties with speech and swallowing, common in later stages of HD (Heemskerk & Roos, 2011).

Disease-Modifying Therapies

Recent research has focused on therapies aimed at altering the disease course by targeting its underlying genetic and molecular mechanisms.

- *Gene Silencing Approaches*: Antisense oligonucleotides (ASOs) are designed to minimalize the production of mutant huntingtin protein. Tominersen, an ASO developed by Roche and Ionis Pharmaceuticals, showed promise in early trials but faced setbacks in later stages (Tabrizi et al., 2022). Research continues to optimize delivery and dosage.
- *Small Molecule Therapies*: PTC518, developed by PTC Therapeutics, is an oral therapy that modulates RNA splicing to lower mutant huntingtin levels. Novartis has entered a licensing agreement to further develop and commercialize this compound (PTC Therapeutics, 2022).
- *Gene Therapy*: UniQure's AMT-130 is an experimental gene therapy aiming to deliver microRNAs that silence the HTT gene. Early-phase clinical trials are underway to assess its safety and efficacy (Evers et al., 2023).

Clinical Trials and Future Directions

Participation in clinical trials is very important for advancing HD research. Patients and families are encouraged to explore ongoing studies evaluating novel therapeutic approaches. Resources like ClinicalTrials.gov provide updated information on active trials (Mestre et al., 2023). While current treatments focus on symptom management, ongoing research offers hope for disease-modifying therapies that may alter the progression of Huntington's disease in the future.

Precision Medicine in Huntington's Disease

As mentioned before, Huntington's disease is a neurodegenerative disorder caused by the mutated HTT gene that currently has no cure. This leads to the accumulation of a mutated form of the huntingtin protein, resulting in neuronal dysfunction. Personalized medicine approaches aim to customize treatments based on individual genetic and molecular profiles, potentially leading to more effective interventions (Tabrizi et al., 2022; Leavitt et al., 2023).

Allele-Specific Gene Silencing

A personalized approach to treating Huntington’s disease focuses on silencing only the mutant HTT gene while keeping the normal gene active. This is done using antisense oligonucleotides (ASOs), which are specially designed to recognize and target unique genetic markers called single nucleotide polymorphisms (SNPs) found only on the mutant gene (Skotte et al., 2014). By focusing on these SNPs, ASOs can selectively reduce the number of the toxic huntingtin proteins. Clinical implementation of this method faces challenges common to personalized genetic medicine, requiring novel solutions from clinical scientists and regulatory authorities (van Roon-Mom et al., 2018).

Pharmacogenetic Considerations

Pharmacogenetics examines how genetic variations influence individual responses to medications. In HD, understanding these variations can guide the selection and dosing of treatments to maximize efficacy and minimize adverse effects. For instance, the drug deutetrabenazine is indicated for the treatment of chorea associated with HD. The recommended smallest dose is 6 mg once daily, with gradual titration up to 48 mg daily (FDA, 2017).

Personalized Treatment Approaches

Because Huntington’s disease (HD) affects each person differently, researchers are working on treatments that can be tailored to individual needs. The HD-MED study is one example. It is a long-term project that looks at how well-personalized drug treatments work based on a patient’s genes and symptoms (Schobel et al., 2023). This kind of research helps develop treatments that better fit how the disease affects each person.

New Therapies with Personalized Potential

Recent research has led to new treatment options that could fit well into personalized care:

Gene Therapy: UniQure’s AMT-130 is an experimental therapy that uses microRNAs to silence the HTT gene, which causes HD. Early clinical trials are testing its safety and how well it works (Evers et al., 2023).

Small-Molecule Drugs: PTC Therapeutics created a pill called PTC518 that lowers the harmful huntingtin protein by changing how RNA works. Because of its promise, Novartis joined to help develop it. This shows growing interest in using small drugs for personalized HD treatment (PTC Therapeutics, 2022).

These new treatments don't just relieve symptoms—they target the disease's root causes, giving hope for better and more personalized care in the future.

Ethical and Social Considerations

Huntington's disease (HD) raises important ethical issues because it is a predictable genetic disorder with a serious and progressive impact on the brain (Bombard et al., 2013).

Genetic Counseling

Predictive genetic testing can be stressful and may create challenges, such as discrimination at work or tough decisions about having children. Because of these risks, genetic counselors play a vital role in supporting individuals by explaining the testing process and possible outcomes, helping them make well-informed decisions (Nance & Paulsen, 2013).

Patient's Quality of Life

As HD worsens, it becomes harder to maintain a good quality of life. To support patients, a team approach is needed, including physical therapy to keep moving, speech therapy to help communication, and mental health care for emotional support. New technologies like brain-computer interfaces (BCIs) are also being tested to help patients communicate better in the later stages of the disease (Dégeilh et al., 2021).

Ethical Dilemmas in Predictive Testing

Because genetic testing can tell if someone will develop Huntington's disease before symptoms appear, it raises ethical questions. For example, should people without symptoms get tested when there is no cure? Testing may affect their insurance, job opportunities, and decisions about having children (Erwin et al., 2010).

Confidentiality and Disclosure

Protecting genetic information is essential because if it is shared without permission, it could lead to unfair treatment—such as problems getting a job or health insurance. At the same time, sharing a person's genetic status can affect their family members, who might also be at risk. So, ethical guidelines need to find a careful balance between respecting an individual's privacy and considering the responsibilities toward their relatives (Andorno, 2004).

Reproductive Choices

Reproductive technologies, including preimplantation genetic diagnosis, are tools used to analyze embryos before implantation (PGD) allow at-risk individuals to avoid passing on the HD mutation. While effective, PGD raises ethical questions regarding embryo selection and the risk of promoting eugenic attitudes (Knoppers & Isasi, 2004).

Social Implications

People with Huntington's disease (HD) and their families often experience stigma and discrimination, especially when applying for jobs or insurance. Because genetic information can be misused—for example, causing discrimination in jobs or insurance—it is crucial to have strong laws that protect people with Huntington's disease. At the same time, educating the public about HD can help reduce fear and misunderstandings, which lowers stigma and promotes fair treatment and inclusion for affected individuals.

Ethical Considerations in Research

Running clinical trials for Huntington's disease involves important ethical questions, especially when working with vulnerable people. Participants need clear and honest information to understand the risks and benefits. To deal with these challenges, it's important that doctors, ethics experts, and lawmakers work as a team. Strong support networks and clear laws can help defend the rights of people with Huntington's disease and make sure that new genetic tools are used in a careful and fair manner.

Huntington's disease (HD) is a brain disorder caused by a specific genetic mutation, but so far, there is no cure. Researchers have learned a lot about the genes and molecules involved in HD, which helps them find new treatment targets. They discovered that issues such as harmful RNA, proteins that fold incorrectly, and errors in DNA repair are key factors in the development of the disease.

This has led to new treatment ideas, such as gene therapy and drugs that target these issues. However, turning these ideas into actual treatments remains challenging. For example, promising methods like allele-specific gene silencing and CRISPR gene editing need to overcome challenges such as unwanted effects on other genes, safe and effective ways to deliver the treatment into the body, and ensuring they are safe for long-term use before they can be widely adopted.

The way Huntington's disease affects the body is very complex. It involves problems with how brain cells communicate, damage to the cell's energy centers (mitochondria), including neurons, brain inflammation, and issues with the cell's ability to clean itself. Understanding these mechanisms has led to the development of neuroprotective strategies aimed at mitigating cellular damage. Clinical trials investigating mitochondrial enhancers, anti-inflammatory agents, and autophagy modulators are ongoing, but efficacy remains variable. Huntington's disease (HD) progresses differently in each individual, which means that treatments should ideally combine various approaches targeting different aspects of the disease to achieve meaningful benefits.

From a clinical standpoint, the symptoms of HD go beyond the traditional triad of motor, cognitive, and psychiatric disturbances. Early psychiatric symptoms of Huntington's disease are often mistaken for other problems, which can be very hard for patients and their families. It is important to correctly tell Huntington's disease apart from other brain disorders like Parkinson's and Alzheimer's to provide the right treatment. New tools, such as brain scans and tests of spinal fluid, may help diagnose HD earlier. However, these methods still need to be tested in larger studies to confirm how well they work.

Treatment options for Huntington's disease have improved over time. New approaches like gene therapy, stem cell transplants, and drugs that protect brain cells show promise. However, many clinical trials have faced problems because these treatments were not always effective or had safety issues. At the same time, personalized medicine — which tailors treatments based on a person's genes and individual characteristics - is becoming more important. This includes using genetic information to choose the best drugs and predict disease risk. But personalized medicine for HD is still new and needs more research to identify which patients will benefit most and how to improve treatments.

Besides medical challenges, Huntington's disease also raises important ethical and social issues. Genetic testing can provide important information for people at risk, but it may also cause emotional stress and raise concerns about privacy and family planning. People with Huntington's disease (HD) and their families often face unfair treatment and judgment, especially when applying for jobs or insurance. Because of this, strong laws are needed to protect their rights. There are also ethical issues in clinical trials - it's very important to make sure participants understand the risks and that vulnerable people are properly protected.

In summary, we have learned a lot about Huntington's disease and how to treat it, but many questions still need answers. Future studies should work on improving gene-editing methods, finding the best combination of treatments, and making personalized therapies available to more patients. Additionally, it is crucial that researchers, doctors, ethicists, and patient groups collaborate to address the numerous challenges of HD and deliver improved care for those affected. The discussion of Huntington's disease reveals a complex interplay of genetic, clinical, therapeutic, and ethical dimensions, which are summarized in Table 1.

Table 1. Summary of Key Discussion Points on Huntington's Disease

Topic	Key Points
Genetic Cause	HD is caused by a CAG repeat expansion in the HTT gene.
Symptoms	Involves motor, cognitive, and psychiatric symptoms that worsen over time.
Diagnosis	Genetic testing confirms the diagnosis; early diagnosis is crucial for intervention.
Pathophysiology	Includes RNA toxicity, protein misfolding, and cellular dysfunction.
Treatment Strategies	Currently focused on symptom management and emerging gene therapies.
Ethical Considerations	Issues include genetic testing, consent in research, and discrimination risks.
Social Impact	Patients and families face stigma and need strong legal and social support.
Future Directions	Personalized medicine and combination therapies show promise but need more research.

4. CONCLUSIONS

Huntington's disease (HD) is a complex and devastating neurodegenerative disorder with profound genetic, molecular, clinical, and ethical implications. Advances in understanding the genetics and molecular causes of Huntington's disease—such as RNA toxicity, protein misfolding, and problems with DNA repair—have revealed the processes that drive nerve cell damage. This damage happens because of faulty communication between brain cells (synaptic dysfunction), damaged energy factories in cells (mitochondria), brain inflammation, and problems with the cell's cleaning process (autophagy). Understanding these processes highlights the need to develop treatments that specifically target these problems.

Clinically, HD manifests with a wide spectrum of motor, cognitive, and psychiatric symptoms, progressing from subtle early-stage changes to severe functional impairment in later stages. Expanding diagnostic capabilities through biomarkers, neuroimaging, and genetic screening enhances early detection, while precision medicine approaches offer individualized treatment strategies based on genetic and molecular profiling. Personalized medicine, including allele-specific gene silencing, pharmacogenetic therapies, and gene-editing techniques, represents a promising frontier for disease-modifying treatments.

Current treatments for Huntington's disease are moving beyond just managing symptoms. New approaches, such as gene therapy, stem cell treatments, and drugs that protect brain cells, are being tested in clinical trials. Comparing HD with other brain diseases helps us understand common problems and identify treatments that may work for multiple conditions.

Besides the science, ethical and social issues are very important. Genetic testing raises concerns about privacy, family decision-making, and potential discrimination. As a result, patients require robust legal protections and psychological support. It is also crucial to conduct research carefully and ethically, particularly when evaluating new treatments. To improve care and discover more effective treatments, it is essential to integrate new scientific methods, personalized medicine, and robust ethical principles. This teamwork will help patients with Huntington's disease in the future.

Author's Contributions

Karolina Jałocha - Conceptualization, review and editing, investigation, methodology, supervision
Marek Borecki - Methodology, investigation, resources
Patrycja Pysz - Visualization, data curation, investigation
Kinga Świtała - Review, resources, writing- rough preparation
Agnieszka Czernecka - Review, data curation, resources
Kinga Erazmus - Resources, writing- rough preparation, data curation
Maria Mroczka - Review, visualization, formal analis
Justyna Kuciel - Review, writing- rough preparation, data curation
Dominik Tomczak - Review and editing, formal analis, supervision

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Conflict of interest

The authors declare that there is no conflict of interest.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

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