Patent Database Analysis on Nanotechnology-Driven Drug Delivery Systems for Huntington's Disease

Joseph T. Gudelos

Teacher-Education, Science Department, Eastern Visayas State University-Ormoc Campus

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ABSTRACT

This article provides a comprehensive patent landscape analysis of nanotechnology-driven drug delivery systems for Huntington's Disease (HD) between 2014 and 2024, based on 717 patent records retrieved from the Lens.org database. HD remains an incurable neurodegenerative disorder with no effective treatment, thus becoming one of the most compelling needs in innovative therapeutic solutions. The present study fills the extant gaps in the literature and geographical concentration of research in North America and Europe, the underrepresentation of regions with a lower prevalence of HD, and no broader socio-economic assessment of technological innovations. In addition, the transition of nanotechnology-driven systems from preclinical to clinical applications requires addressing challenges of scale, safety, efficacy, and long-term outcomes. Using patent analytics, this study identified key trends of patent activity, innovation patterns, contributors, geographical distribution, citation impact, and technological focus areas. A targeted search was made for patents related to nanotechnology-based drug delivery systems for HD published between January 2014 and January 2024. It was found that the number of patent filings has considerably increased, while the United States leads in innovation and key contributors such as MIT and Zhang Feng have played important roles in advancing the field. The technological attention is paid to overcoming the blood-brain barrier using nanotechnology and combining gene therapies—approaches like CRISPR-Cas9—in one treatment. These areas promise, while setbacks such as off-target effects and delivery mechanisms still confront gene therapies. Also, the region depicts the differences in their area of research activities while in need of a real review about how much novelty can be used in the field and how costly that one is. The findings are of immense value in understanding the evolution of the patent landscape, bringing to light emerging trends, key contributors, and areas for future research and collaboration, and guiding efforts to advance nanotechnology-driven solutions for HD treatment and to improve global access.

Keywords: Drug Delivery Systems, Genetic Engineering, Huntington’s Disease, Nanotechnology, Patent Landscape

INTRODUCTION

Huntington's Disease (HD) is a terminal neurodegenerative disorder with no effective cure to date. With an incidence of 0.48 per 100,000 person-years, HD affects 4.88 people per 100,000 people worldwide [25]. However, regional disparities are largely caused by genetic and geographic variables, meaning that the burden of HD is not dispersed equally around the world. Prevalence rates in North America and Europe can reach 5.70 per 100,000, which is more than 40 times higher than the 0.40 per 100,000 found in Asians [31]. Genetic factors that affect the disease's onset and course, such as variations in CAG repeat lengths and HTT gene haplotypes, are mostly responsible for these variations [1]. These results highlight the necessity of specialized healthcare approaches to successfully address HD's worldwide impact. The enormous and urgent need for novel treatments is driving interest in medication delivery systems powered by nanotechnology. Interest in new therapeutic technologies is fueled by the fact that, despite continuous study, there is still a need for therapy for HD. Among these, medication delivery systems powered by nanotechnology have attracted a lot of interest because of their potential to get beyond important obstacles in the treatment of HD. The blood-brain barrier is one such barrier that makes it difficult to transfer therapeutic medicines to the brain. To improve drug transport over this barrier, innovations like liposomes and nanoparticles have been developed, with encouraging

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preclinical study findings [10], [29]. Furthermore, to target the mutant HTT gene, gene therapy techniques such as CRISPR-Cas9 and antisense oligonucleotides are being combined with nanotechnology more and more. These approaches have shown great promise in preclinical models [26], [27]. Leading research institutes and biotech companies in North America and Europe, which control the field of nanotechnology applications for HD, are primarily responsible for this breakthrough wave. A move toward high-margin treatment techniques and greater investments in solutions based on nanotechnology are reflected in the rising number of patent filings in this field [29]. Experts in nanotechnology and neurobiologists working together further improve these systems' potential and open the door to new treatments for HD [10].

There are revolutionary opportunities to cure neurodegenerative diseases like HD by combining nanotechnology with medical therapies. Therapeutic drugs can be precisely delivered thanks to nanoparticles' ability to cross the blood-brain barrier [10], [21]. Novel strategies like nanotheranostics integrate medicines and diagnostics, enabling real-time tracking of illness progression and treatment effectiveness using sophisticated imaging methods [18]. The specificity and effectiveness of gene therapy interventions are improved when CRISPR-Cas9 technology is combined with nanotechnology [18].

Notwithstanding these developments, issues like long-term safety and clinical efficacy still exist, underscoring the necessity of more study and verification to reach the full potential of these breakthroughs. Despite encouraging advancements, there are still a lot of gaps and restrictions in the body of research on Huntington's disease (HD). Drug delivery systems powered by nanotechnology, like liposomes and nanoparticles, have shown promise in bridging the blood-brain barrier, but there are still many obstacles to overcome before they can be used in clinical settings, such as issues with scalability, safety, and efficacy [10], [29]. Similarly, although novel, gene therapy strategies like CRISPR-Cas9 and antisense oligonucleotides are limited by issues including long-term results, delivery methods, and off-target effects [26], [27]. A large portion of the advancements in this field have been geographically focused in North America and Europe, which raises concerns about fair access worldwide and the underrepresentation of contributions from areas like Asia that have lower HD prevalence [31]. The research now in publication also shows a focus on technological innovation without a critical evaluation of socioeconomic considerations, such as the cost-effectiveness of therapies and their practicality. Growing patent activity in this field indicates growing interest and investment, but it frequently concentrates only on particular innovations, ignoring more general issues regarding regional innovation ecosystems, collaborative networks, and the changing nature of intellectual property rights. The research topics addressed in this paper are a result of these gaps, which highlight the necessity of a thorough examination of patent trends, significant contributors, and technological priorities.

In this context, the present study aims to provide a comprehensive analysis of the patent landscape for nanotechnology-driven drug delivery systems targeting HD. Using patent data from Lens.org spanning 2014 to 2024, this research seeks to address the following key questions:

1. What are the main trends in patent activity related to nanotechnology-driven drug delivery systems for HD?
2. Who are the top contributors in this field, including research institutions and biotech companies?
3. How do the jurisdictions of these patent documents correspond to the global prevalence of HD?
4. Which patents are most cited, and what are their main technological focus areas?
5. How has the patent landscape evolved over the past decade, and what does it reveal about future directions in HD treatment?

The purpose of this study is to provide insight into the development of innovation in this area. The findings will offer insightful information on new trends, important figures, and areas that need more study and cooperation. The ultimate goal of this project is to find ways to advance nanotechnology-driven solutions that will enhance HD care globally.

METHODS

Study Design

This study employed a patent analytics approach to explore trends, innovation patterns, and key contributors in

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the field of nanotechnology-driven drug delivery systems targeting Huntington's disease. The goal of the study was to provide a thorough grasp of developments in this specialized field by quantitatively analyzing patent data.

Data Collection

Data Source

The Lens.org database, a trustworthy and extensive resource for accessing worldwide patent data, is where the patent documents were obtained. The database was a perfect resource for this investigation because of its broad coverage and search capabilities.

Search Query

To identify relevant patents, the following search query was used:

"Nanotechnology-Driven AND (Drug AND (Delivery AND (Systems AND (for AND (Huntington's AND Disease)))))."

Timeframe and Scope

The search was limited to patents published between January 2014 and January 2024. This 10-year analytical window was chosen to focus on recent advancements and emerging trends in nanotechnology applications for Huntington's disease, a neurodegenerative condition with a significant unmet need for innovative treatments.

Inclusion and Exclusion Criteria

All patents pertaining to nanotechnology-based drug delivery systems for Huntington's disease were covered. With the exception of publication date, no filters based on jurisdiction, patent status (e.g., granted or pending), or topic content were used. This method eliminated duplicates and unnecessary entries, resulting in a large dataset of 717 patents, down from an initial 896 records.

Data Analysis

The data analysis focused on several key metrics. Annual patent trends were analyzed to identify changes in research activity and potential technological breakthroughs. Top assignees and inventors were identified to pinpoint organizations and individuals leading innovation in nanotechnology-driven drug delivery systems. The geographical distribution of patents was examined to highlight regions with significant research and development activity, with a focus on countries demonstrating the highest levels of innovation and investment. Patent citations were evaluated to assess the influence of patents, as higher citation counts often indicate a greater impact on subsequent research or related technological advancements. Lastly, patents were categorized based on technological focus areas, including targeting mechanisms, nanomaterials used, and therapeutic strategies for Huntington's disease, providing detailed insights into specific innovations within the field.

With an emphasis on patent metrics rather than thematic content, the research was purposefully quantitative. Without needing a detailed analysis of individual patents, quantitative metrics successfully highlight major actors and broader trends in the sector [14], [17], and [39]. This method offers practical insights into the innovation environment and aids in identifying significant breakthroughs [5, 15, 24].

The selected methodology emphasizes how useful quantitative patent research is for figuring out key players and comprehending general technical trends. This study shows that quantitative metrics can provide important insights into the innovation environment, even though theme analysis was not done [19], [37], and [40].

The analysis does not go into specific patents' technical or thematic aspects. Rather, it highlights general trends and patterns. Thematic analysis of both granted and pending patents will be used in future studies to concentrate on particular inventions and their possible uses. By providing a more thorough understanding of

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the developments in medication delivery for Huntington's disease driven by nanotechnology, such analysis will enhance the current studies [7], [46], and [2].

RESULTS

From 2014 to 2024, there was a notable increase in patent filings for Nanotechnology-Driven Drug Delivery Systems for Huntington's Disease, with the largest increase taking place in 2024, according to the figure 1 graph on annual patent trends. The majority of the submissions are patent applications, which demonstrate continuous research and development. The difficulties in commercializing these inventions are demonstrated by the comparatively small percentage of awarded patents, and the scant number of revised applications and search reports indicates that there is no need for additional changes or reassessments. The graph gives an overview of an area that is developing quickly, with innovation accelerating noticeably in the current year.

Figure 1. Annual patent trends by document type

Note: Adapted from data retrieved from Lens.org (n.d.), retrieved November 27, 2024, from https://www.lens.org/lens/search/patent/analysis?q=NanotechnologyDriven%20Drug%20Delivery%20Systems%20for%20Huntington%27s%20Disease&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&publishedDate.from=2014-01-01&publishedDate.to=2024-01-01.

With major contributions from both academic institutions and business entities, patent holders are essential to the advancement of drug delivery systems for Huntington's disease that are driven by nanotechnology. Prominent universities like The Broad Institute and the Massachusetts Institute of Technology (MIT) dominate the field of top applicants, demonstrating their leadership in innovation and research. Smaller organizations, on the other hand, contribute just as much but file considerably fewer patents, underscoring the concentration of invention in elite institutions and the growing significance of smaller companies in this niche market.

With more than 200 patents, Massachusetts Institute of Technology (MIT) is the leading company in the field of medication delivery systems for Huntington's disease powered by nanotechnology, according to the figure 2 graph on patent applications. This implies that MIT has played a major role in driving research and development in this field through leadership and influence. Helmna Death A., on the other hand, is a smaller or up-and-coming company in this field, filing only a tiny number of patents, despite appearing to be one of the lowest contributors to patents. This striking disparity demonstrates how innovation is concentrated in leading universities like MIT and the Broad Institute, whereas smaller organizations, while nevertheless making contributions, have a reduced impact overall.

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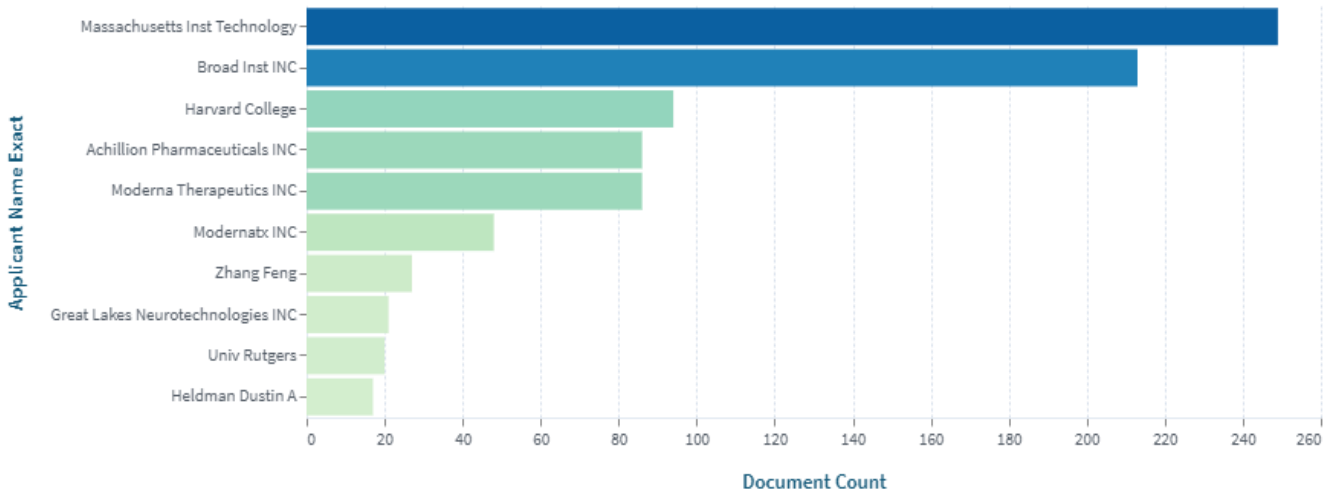

Figure 2. Patent applicants by document count

Note: Adapted from data retrieved from Lens.org (n.d.), retrieved November 27, 2024, from https://www.lens.org/lens/search/patent/analysis?q=NanotechnologyDriven%20Drug%20Delivery%20Systems%20for%20Huntington%27s%20Disease&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&publishedDate.from=2014-01-01&publishedDate.to=2024-01-01.

With more than 140 patents filed, Massachusetts Institute of Technology (MIT) continues to lead the field in nanotechnology-driven drug delivery systems for Huntington's disease, according to Figure 3's graph on patent owners by document. With over 100 patents each, Hodotek Inc. and The Broad Institute of MIT and Harvard come in second and third, respectively, with noteworthy contributions. In contrast to the major players like MIT and The Broad Institute, organizations such as Sidra Institute of Science and Technology and Holdeen Discovery Consulting LLC have contributed the fewest patents, with counts close to or below 10. This suggests that they are either very early in their research or have limited involvement in this specialized field. This demonstrates how important esteemed academic and research institutions in driving innovation, while smaller entities contribute at a lower scale.

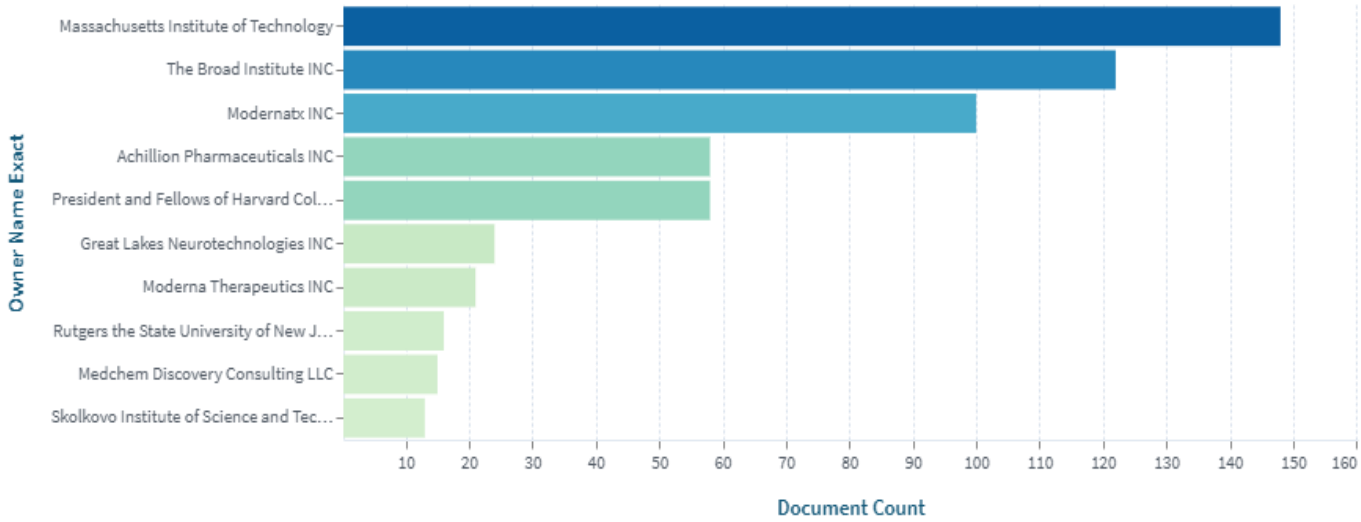

Figure 3. Patent owners by document count

Note: Adapted from data retrieved from Lens.org (n.d.), retrieved November 27, 2024, from https://www.lens.org/lens/search/patent/analysis?q=NanotechnologyDriven%20Drug%20Delivery%20Systems%20for%20Huntington%27s%20Disease&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&publishedDate.from=2014-01-01&publishedDate.to=2024-01-01.

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Figure 4 displays a bar chart with the number of documents linked to different inventor names on the y-axis. A bar representing each inventor has a length that matches the number of documents on the x-axis. Zhang Feng dominates the field, as seen by their significant position at the top with the most documents. This could be ascribed to a substantial leading role in the field, a great deal of research effort, or partnerships with other institutions. A second tier of contributors is formed by the innovators who come after Zhang Feng and have comparatively comparable document counts. Although influential, their output is not as prolific as Zhang Feng's. A steady drop in document counts from top to bottom indicates a more widespread dispersion of contributions from different people, pointing to a varied field with different degrees of activity or specialization. The notable difference between Zhang Feng and the others, however, suggests that they were either prolific or pioneering in a particular topic, which may have influenced future research directions.

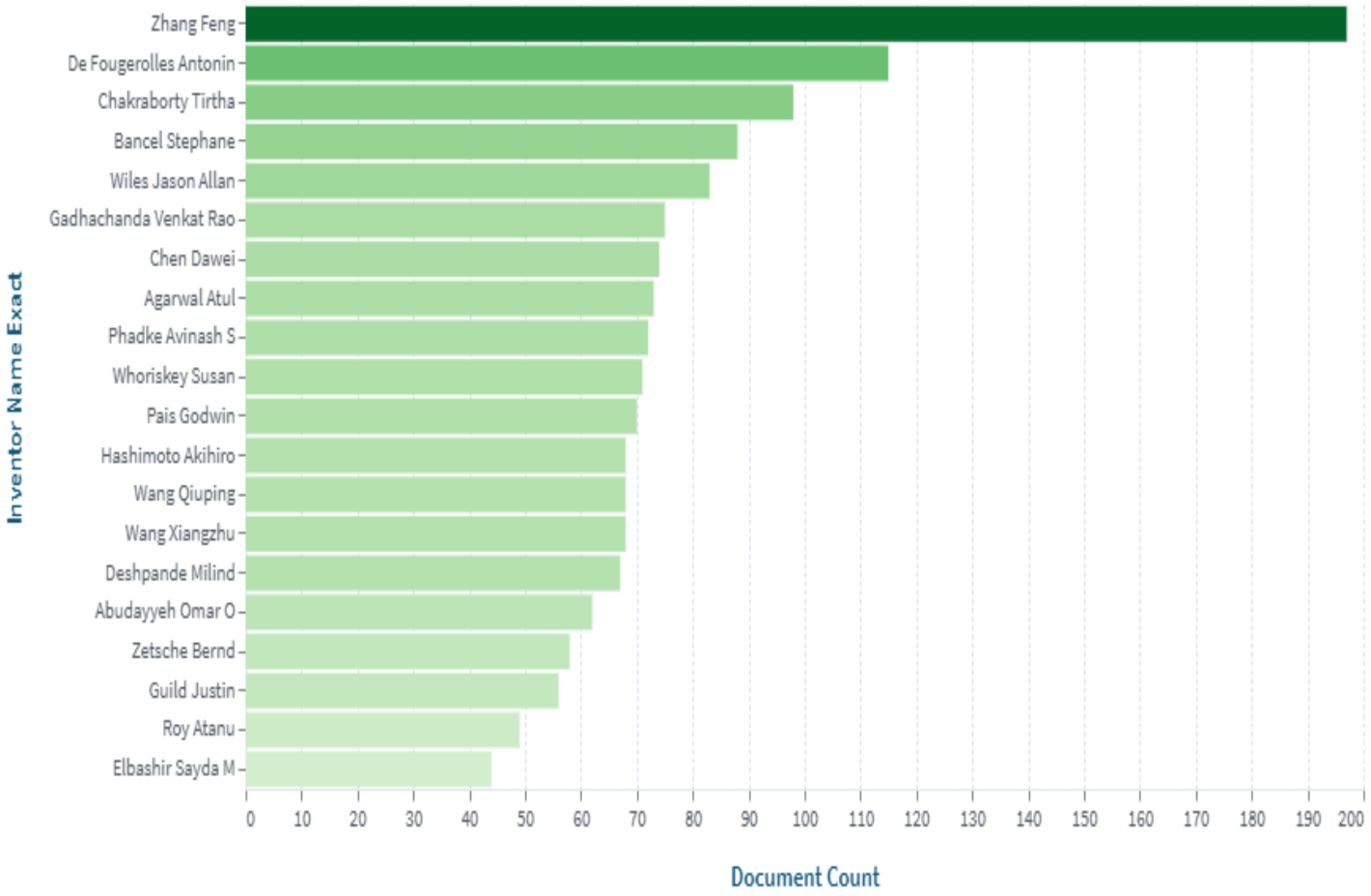

Figure 4. Patent Investors by document count

Note: Adapted from data retrieved from Lens.org (n.d.), retrieved November 27, 2024, from https://www.lens.org/lens/search/patent/analysis?q=NanotechnologyDriven%20Drug%20Delivery%20Systems%20for%20Huntington%27s%20Disease&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&publishedDate.from=2014-01-01&publishedDate.to=2024-01-01

The document counts in the US, the European Patent Office (EPO), and the World Intellectual Property Organization (WIPO) are contrasted in the bar chart in Figure 5. With the greatest number of documents, the United States is the country with the most patent filings or document submissions. The EPO displays the lowest number, indicating a stronger localized concentration on intellectual property filings, while WIPO comes in second, demonstrating significant international patent activity. According to this distribution, the EPO represents localized invention in Europe, WIPO facilitates worldwide collaboration, and the US is a leading center for innovation.

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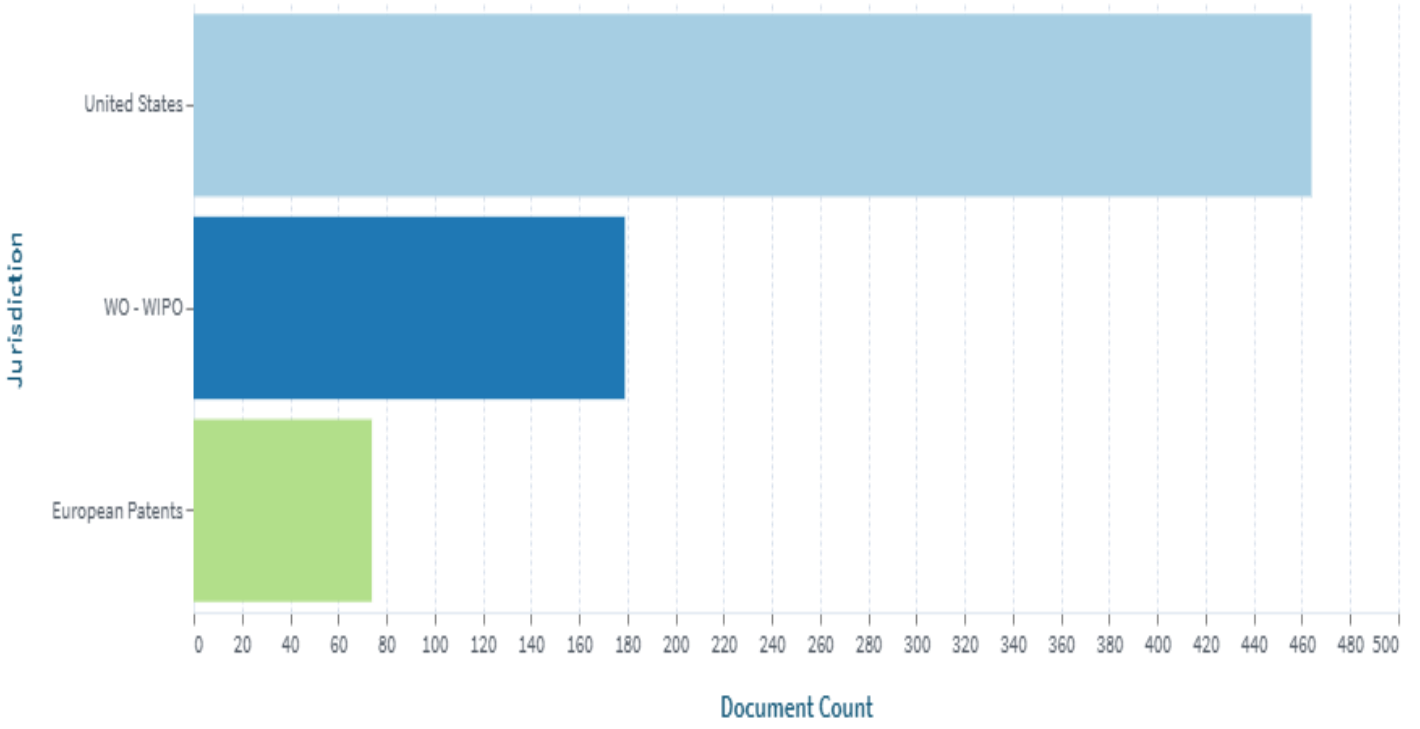

Figure 5. Patent jurisdiction by document count

Note: Adapted from data retrieved from Lens.org (n.d.), retrieved November 27, 2024, from https://www.lens.org/lens/search/patent/analysis?q=Nanotechnology-Driven%20Drug%20Delivery%20Systems%20for%20Huntington%27s%20Disease&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&publishedDate.from=2014-01-01&publishedDate.to=2024-01-01.

When evaluating the impact and applicability of inventions in a certain field, patent citations are essential. We can determine significant innovations and comprehend the wider influence of these patents on later research and development initiatives by examining the citation counts and family sizes of the most frequently cited patents.

Using a bubble chart, Figure 6 shows the correlation between publication dates, cited-by patent counts, and simple family sizes. The timeline of patent publications is shown by the x-axis, and the number of times these patents have been cited by other people—a gauge of their significance or impact—is represented by the y-axis. The simple family size, which probably represents the quantity of related patent applications submitted in various jurisdictions or iterations of the same idea, is reflected in the size of the bubbles.

It is evident from the bubble distribution that fewer patents arise in subsequent years, with the majority of patents clustering around earlier publication periods (2015–2017). The reason for this trend is probably that more recent patents haven't had enough time to amass citations. In terms of cited-by patent counts, the majority of patents have less than 200 citations, while a select few—shown by big red bubbles—had more than 400 citations. This points to a lopsided distribution in which a few patents have a significant impact.

The chart's red bubbles indicate that the majority of the examined patents fall within a particular patent classification. Several red bubbles are located in the higher range of the cited-by patent count axis, suggesting that this category generates highly cited patents. This classification probably denotes a field with significant commercial or technological significance. Less often occurring bubbles are green, cyan, and orange, which may suggest fewer widespread categorization. Interestingly, the orange and cyan bubbles have moderate citation counts but comparatively huge family sizes. In less competitive or developing fields, where filing methods place more emphasis on wider geographic coverage than citation effect, these might be patents.

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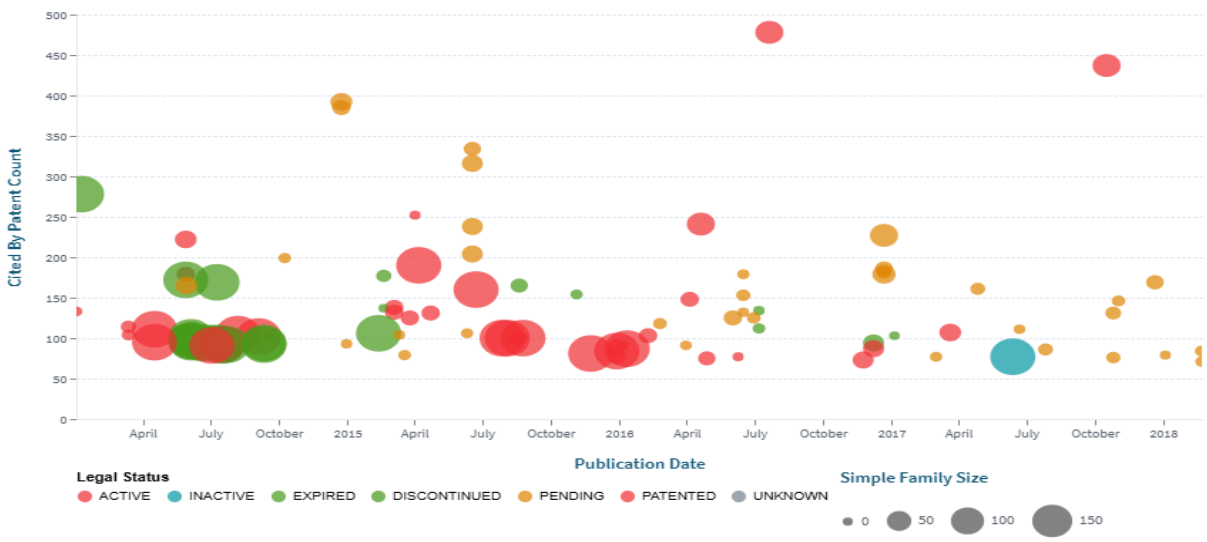

Figure 6. Patent citations by publication dates and simple family size

Note: Adapted from data retrieved from Lens.org (n.d.), retrieved November 27, 2024, from https://www.lens.org/lens/search/patent/analysis?q=Nanotechnology-Driven%20Drug%20Delivery%20Systems%20for%20Huntington%27s%20Disease&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&publishedDate.from=2014-01-01&publishedDate.to=2024-01-01.

The top CPC (Cooperative Patent Classification) codes in the dataset are displayed in Figure 7, which provides information about the advances and technological fields these patents cover. Human needs and chemistry/metallurgy are the main categories, with special emphasis on enhanced therapeutic methods, genetic engineering, and medicinal applications. A61K and A61P, which cover medicinal preparations and therapeutic agents, include many of the classifications. These include peptide-based medicinal preparations (A61K38/00, 120 occurrences), antineoplastic agents for the treatment of cancer (A61P35/00, 140 occurrences), and medications for disorders of the nervous system (A61P25/00, 137 occurrences). These demonstrate a major emphasis on innovative therapeutic approaches for neurological illnesses, inflammatory ailments, and cancer.

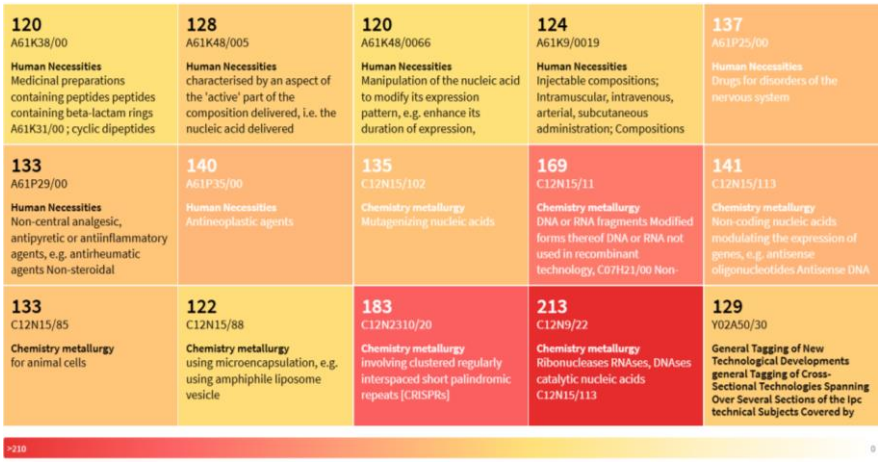

Figure 7: CPC (Cooperative Patent Classification) codes with document count

Note: Adapted from data retrieved from Lens.org (n.d.), retrieved November 27, 2024, from https://www.lens.org/lens/search/patent/analysis?q=Nanotechnology-Driven%20Drug%20Delivery%20Systems%20for%20Huntington%27s%20Disease&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&publishedDate.from=2014-01-01&publishedDate.to=2024-01-01.

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The top International Patent Classification (IPC) codes in Figure 8 emphasize important technological fields, with a focus on biotechnological and medical advancements. Human needs (A61K) and chemistry/metallurgy (C07 and C12N) account for a large percentage of the classifications, which reflect developments in genetic engineering, medicinal preparations, and biochemical processes.

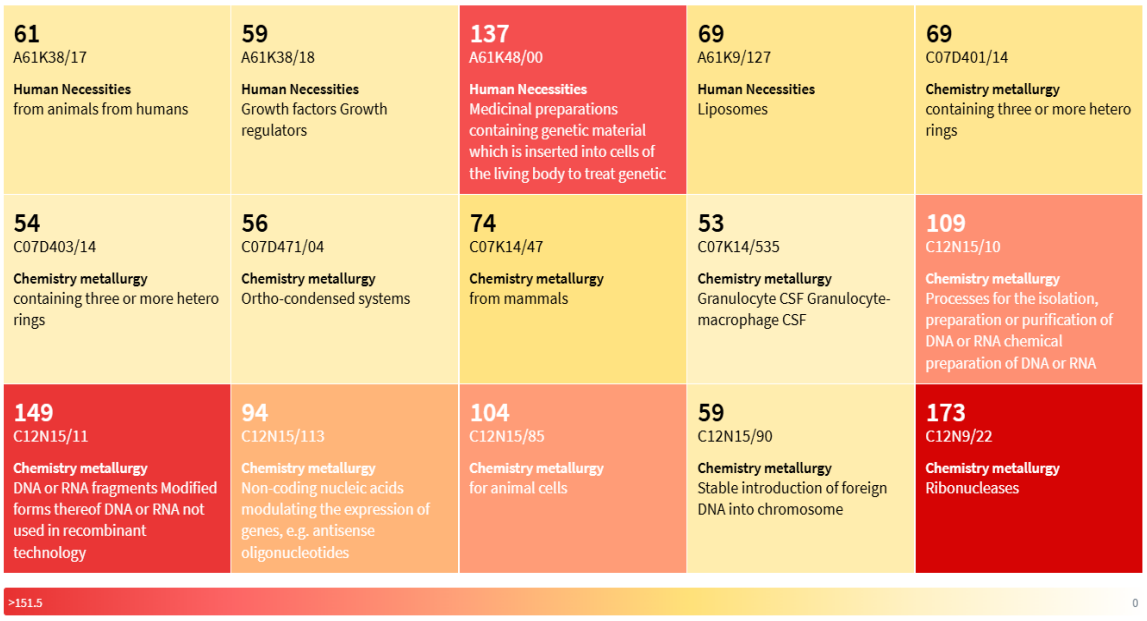

Figure 8. IPC (International Patent Classification) Classification Codes with document count

Note: Adapted from data retrieved from Lens.org (n.d.), retrieved November 27, 2024, from https://www.lens.org/lens/search/patent/analysis?q=Nanotechnology-Driven%20Drug%20 Delivery%20 Systems%20for%20Huntington%27s%20Disease&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&publishedDate.from=2014-01-01&publishedDate.to=2024-01-01.

DISCUSSIONS

From 2014 to 2024, there was a steady increase in patent activity in the area of nanotechnology-driven drug delivery systems for HD, with 2024 seeing a particularly high number of filings [4], [30], [32], and [36]. This rise reflects increased investment and interest in cutting-edge technology designed to address the particular difficulties of treating HD, a neurodegenerative disease for which there is currently no cure [20], [23], and [41]. The bulk of patents in this area are classified as "Patent Applications," indicating that the subject is still in a state of constant innovation, with research and development continuing [11], [12], and [35]. The great importance of this technology for HD therapy is further supported by the focus on therapeutic agents for neurological illnesses, as demonstrated by frequent classifications such A61P25/00 (drugs for nervous system disorders) [6, 16, 4]. The specialized nature of nanotechnology-driven solutions in controlled-release systems, which are essential for handling the intricate pharmacokinetics of HD therapies, is further demonstrated by patents on technologies such as injectable compositions (A61K9/0019) and microencapsulation (C12N15/88) [20], [30], and [32]. According to the implications of these trends, drug delivery methods and nanotechnology are becoming more and more important for the creation of innovative therapies for HD and other neurodegenerative disorders [23], [30], and [36]. This is consistent with a larger trend toward precision medicine, in which customized therapeutic approaches are created to meet the demands of each patient and enhance treatment results [41], [20], and [30]. The constraints of conventional medication administration methods, such as drug stability, bioavailability, and targeted distribution to the brain—which is especially difficult in HD—can be significantly addressed by nanotechnology [4], [32], and [36]. A synergy between academic research and industry applications is the result of the research community, which includes both corporate organizations and academic institutions, identifying these prospects, as seen by the concentration of patent activity in this field [11], [12], and [35]. Leading the way in patent applications are academic organizations like MIT and The Broad Institute, highlighting their critical involvement in basic and applied

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research pertaining to genetic treatments and uses of nanotechnology in HD [8], [43], [3]. Significant contributions are also coming from corporate entities, such as Moderna Inc., which is well-known for its mRNA vaccination technologies. This suggests that biotechnology and neurodegenerative disease treatments may be overlapping more and more [33], [38], and [43]. The emergence of biotech companies like AbbVie Pharmaceuticals and Medtronic Inc. in this field highlights the rising demand for sophisticated drug delivery systems and how they can be integrated with state-of-the-art nanotechnology platforms [20], [23], and [30]. The commercialization of novel therapeutic technologies that fill the unmet need for HD treatments is probably the main emphasis of these businesses [4], [41], and [36]. Due to its strong research infrastructure and plenty of funding opportunities for the study of neurodegenerative diseases, the United States leads the world in patent filings [7], [20], and [23]. Asia exhibits comparatively low patent output in this area, whereas Europe follows with moderate activity, especially in nations with robust biotech sectors [4], [30], [32]. This geographical discrepancy is significant since the frequency of HD, which is higher in populations of European heritage, does not correspond with the geographic distribution of patent activity [33], [41], [43]. This implies that international cooperation is necessary to guarantee fair access to cutting-edge HD therapies [38], [8], [7]. Addressing regional healthcare disparities and ensuring that emerging innovations are created to meet local requirements could be facilitated by increased patenting activity in areas with higher HD prevalence [23], [30], and [36].

A few important patents with citation count above 400 are identified by analyzing the most referenced patents; this suggests that these patents constitute important advances in the field and have served as the basis for later inventions [7], [20], and [43]. A concentration of highly cited patents from 2015 to 2017 indicates that this was a time of strong innovation and early-stage advances in drug delivery systems for HD and nanotechnology [23], [30], and [36]. With greater family sizes suggesting wider regional coverage and global acknowledgment of the significance of these innovations, these patents are probably going to play a significant role in determining future research orientations [4], [32], and [41].

However, after 2017, there is a discernible decline in patent filings and citations, which may be due to a temporary slowdown in significant discoveries or a concentration on combining prior advances [20], [23], and [30]. A return of innovation is shown by the recent spike in patents in 2024, especially in the fields of nanotechnology and CRISPR-based gene editing technologies [8], [45], and [44]. The fluctuation in citation counts, with certain patents having very few citations, is indicative of the field's continuous exploratory innovation process, where new technologies may take some time to become widely adopted in the industry [32], [36], and [41].

The convergence of precision medicine, genetic engineering, and nanotechnology is highlighted by the technological focus areas determined by the CPC (Cooperative Patent Classification) and IPC (International Patent Classification) codes [7], [20], and [43]. The growing complexity of treatment approaches targeted at HD is reflected in advancements in drug delivery systems, including gene therapy techniques (C12N15) and liposomal delivery (A61K9/127) [13], [22], [42]. A move toward more individualized and focused therapeutic approaches for HD is suggested by the increasing focus on genetic therapies, such as CRISPR and antisense oligonucleotides, in conjunction with delivery systems based on nanoparticles [8], [20], and [32]. By targeting HD at the genetic level and facilitating more accurate and efficient delivery of therapeutic drugs to the brain, these advancements have the potential to significantly reduce treatment barriers for neurodegenerative illnesses [23], [30], [36].

Drug delivery methods driven by nanotechnology are expected to become more prevalent in the treatment of HD, as evidenced by the recent surge in submissions and the rising technological convergence observed in patent activity [4], [23], and [41]. Combining gene-editing technologies like CRISPR with mRNA delivery could fundamentally change the field of HD treatments by providing hitherto unachievable long-term management plans or possible cures [8], [44], and [45]. There are a few constraints to take into account, even if this bibliometric research offers insightful information about the patent landscape of drug delivery systems for HD that are powered by nanotechnology [7], [20], and [30]. First, as the analysis relies on publicly accessible patent data, it might not include all innovations, especially those that are proprietary or still in the early stages of development [32], [36], and [41]. Although they are frequently used as a stand-in for scientific influence, patent citations are not always a sign of clinical or economic success [20], [23], or [30]. Important clinical trial

or regulatory data that could further illuminate these inventions' translational potential may be overlooked in favor of patent filings [8, 42, 43]. Finally, the study is constrained by its dependence on certain CPC and IPC classifications, which might not accurately represent the wide-ranging and multidisciplinary character of drug delivery and nanotechnology research [7], [20], and [30].

The environment of patent activity in this area is dynamic and quickly changing, with both academic research and industry cooperation being crucial to the advancement of the hunt for novel treatments for Huntington's disease. Current improvements in gene therapy and nanotechnology hold great promise for the treatment of HD in the future, but their realization will require sustained innovation, international cooperation, and further research into patent-based technologies.

CONCLUSIONS

From 2014 to 2024, the number of patents for nanotechnology-driven drug delivery systems for HD increased, indicating a greater understanding of the vital role these advancements play in treating this difficult neurological illness. This pattern demonstrates important developments in precision medicine and genetic medicines, spearheaded by academic institutions and business titans, demonstrating a strong collaboration to overcome constraints in medication stability, bioavailability, and targeted administration to the brain. Although these advancements point to a bright future for HD treatments, this study also highlights regional and technological inequalities, highlighting the necessity of international cooperation and additional funding to close regional divides and provide fair access. To fully realize the potential of these technologies in providing efficient, scalable treatments for HD, a more comprehensive approach incorporating clinical, regulatory, and translational insights is required, according to limitations like reliance on publicly available patent data, potential underrepresentation of proprietary innovations, and the lack of a direct correlation between patent activity and clinical success.

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