Journal of Medical Science, Biology, and Chemistry (JMSBC)

ISSN: 3079-2576 (Online)

Volume 2 Issue 2, (2025)

https://doi.org/10.69739/jmsbc.v2i2.716

https://journals.stecab.com/jmsbc

Published by
Stecab Publishing

Research Article

Artificial-Intelligence Applications in U.S. Parkinson's Disease Care: A Narrative Review of Diagnostic, Monitoring, and Treatment Tools

*[1]Gbenga Adeniyi Adediran, [2]Sylvester Tafirenyika, [3]Abena Serwaa Ampomaa Agyemang, [4]Ifedayo Akinfemisoye, [5]Maureen Amaka Mojekwu, [6]Musa Olayinka Hanafi, [7]Charity Uzezi Akpovino, [8]Udochukwu I. Okoronkwo, [9]Catherine Folake Fadamiro, [10]Ubalaeze Solomon Elechi

About Article

Article History

Submission: May 30, 2025
Acceptance : July 03, 2025
Publication : July 30, 2025

Keywords

Artificial-Intelligence, Diagnostic, Narrative Review, Parkinson's Disease, Treatment Tools

About Author

[1] Department of Computing and Engineering, Leeds Beckett University, Leeds, UK

[2] Department of Business Analytics, Hult International Business School, USA

[3] Department of Physical Therapy, Outreach Physical and Occupational Therapy and Speech Rehabilitation, New York City, New York, USA

[4] Department of Computer Engineering, Federal University of Technology, Akure, Nigeria

[5] Department of Cybersecurity, Yeshiva University, New York City, New York, USA

[6] Department of Computer Science and Engineering, University of Houston, Downtown, Houston, Texas, USA

[7] Department of Rehabilitation Counseling, University of Maryland, Eastern Shore, Maryland, USA

[8] College of Science and Technology, University of Houston, Downtown, Houston, Texas, USA

[9] Department of Computer Science, Federal University of Technology, Akure, Nigeria

[10] Department of Radiography, Faculty of Health Sciences and Technology, University of Nigeria, Nsukka, Enugu State, Nigeria

Contact @ Gbenga Adeniyi Adediran
gbengadediran@gmail.com

ABSTRACT

Parkinson's disease (PD), one of the most common neurodegenerative disorders in the United States, is rising in prevalence and exposing persistent gaps in access to specialist care. Advances in artificial intelligence (AI) now offer new ways to improve diagnosis, monitoring, and treatment. This narrative review synthesizes recent clinical studies, regulatory filings, reimbursement policies, and expert commentary to describe how machine-learning approaches applied to wearable sensors, speech and typing analysis, neuroimaging, and adaptive deep-brain stimulation are reshaping PD care. Several of these tools, such as Apple Watch-based StrivePD and NeuroRPM, KinesiaU™ sensor kits, and Medtronic's adaptive DBS platform, have received U.S. FDA clearance since 2020, and early trials suggest they can enrich clinical decision-making and support more continuous, personalized management. Because this is a narrative (rather than systematic) review, the literature search was not exhaustive, study quality was not graded with formal scoring instruments, and no meta-analysis was performed; consequently, selection bias and incomplete coverage are possible, and effect sizes across studies cannot be pooled or compared quantitatively. Real-world adoption also remains limited by workflow friction, regulatory and reimbursement uncertainty, data-privacy obligations, and algorithmic bias. Closing these gaps will require larger pragmatic trials, clinician training, and interoperable data infrastructure to ensure AI innovations are validated, equitable, and clinically useful for the growing U.S. PD population.

Citation Style:

Adediran, G. A., Tafirenyika, S., Agyemang, A. S. A., Akinfemisoye, I., Mojekwu, M. A., Hanafi, M. O., Akpovino, C. U., Okoronkwo, U. I., Fadamiro, C. F., & Elechi, U. S. (2025). Artificial-Intelligence Applications in U.S. Parkinson's Disease Care: A Narrative Review of Diagnostic, Monitoring, and Treatment Tools. *Journal of Medical Science, Biology, and Chemistry, 2*(2), 59-69. https://doi.org/10.69739/jmsbc.v2i2.716

1. INTRODUCTION

Parkinson's disease (PD) affects over one million people in the United States, with nearly 90,000 new diagnoses each year (Rebecca Gilbert, MD, 2024; Willis *et al.*, 2022). As the U.S. population ages, PD prevalence is expected to grow substantially, reaching about 1.2 million by 2030 (Mark Michaud, 2017). PD's motor and non-motor symptoms impose a high burden on patients, caregivers, and the healthcare system. The total economic cost of PD in the U.S. was estimated at $52 billion in 2020, rising to about $61.5 billion by 2025 (Carol Blymire, 2019; Michael J. Fox Foundation, 2019). Despite this burden, many Americans with PD face challenges accessing specialized care. Approximately 40% of U.S. PD patients do not see a neurologist, relying instead on primary care or no regular provider (Bajaj, 2023). This care gap, driven by specialist shortages and geographic disparities, is associated with worse outcomes. In our view, innovative solutions are needed to extend expert-level PD care to a broader patient population.

Artificial intelligence (AI) has emerged as a promising tool to enhance PD care delivery. "AI" in this context typically refers to machine learning (ML) algorithms capable of pattern recognition and predictive analytics using large datasets. In the past few years, researchers have leveraged AI to recognize subtle PD biomarkers from diverse sources, including wearable motion sensors, smartphone data, digitized voice recordings, medical imaging, and electronic health records. These AI-driven approaches can potentially detect PD earlier than clinical exams alone, continuously monitor symptom fluctuations in patients' home environments, and optimize treatment decisions based on individualized predictions. For example, advanced algorithms now achieve over 90% accuracy in distinguishing early PD from healthy controls using vocal features, and wearable sensors analyzed with ML can reliably capture tremor and bradykinesia outside the clinic (Atri *et al.*, 2022; Lonini *et al.*, 2018; Malekroodi *et al.*, 2024; Shen *et al.*, 2025; Sigcha *et al.*, 2023).

2. LITERATURE REVIEW

Such capabilities could augment clinicians' assessments, which are often limited by brief in-person exams and subjective patient reports. Equally important, AI may help personalize therapy for PD's highly heterogeneous course. Patients often face fluctuating medication responses, motor complications such as dyskinesias, and non-motor symptoms. AI algorithms can analyze continuous patient-generated data to identify patterns (Rebecca Gilbert, 2025) (for instance, linking certain motor fluctuations to medication timing or activity levels) and recommend tailored adjustments.

A notable example is the advent of adaptive deep brain stimulation devices that use embedded algorithms to modulate stimulation in real time according to the patient's neural signals (The BRAIN Blog, 2025). Early results suggest that such AI-enabled systems can improve symptom control with fewer side effects compared to traditional approaches (Guidetti *et al.*, 2025; Kim, 2025; Li *et al.*, 2025; The BRAIN Blog, 2025; Williams, 2025).

In summary, there is growing enthusiasm that AI technologies could transform PD care by easing diagnostic uncertainty, extending monitoring beyond clinic walls, and aiding treatment optimization. This narrative review examines the state of these AI applications in U.S. Parkinson's disease care. We focus on key domains, diagnostic tools, symptom monitoring modalities, and treatment optimization, and discuss the integration of AI into healthcare systems, including regulatory, reimbursement, and ethical challenges. We also appraise the current evidence for AI-driven interventions in PD and offer recommendations to ensure these innovations truly benefit patients and providers. Ultimately, leveraging AI in a thoughtful, patient-centered manner could help bridge existing gaps in PD care and improve outcomes for the growing number of Americans living with this disease.

3. METHODOLOGY

We performed a comprehensive narrative literature review to identify publications and information on AI applications in Parkinson's disease care. Using PubMed and Google Scholar, we searched for English-language articles published from January 2018 through May 2025 that evaluated or discussed AI techniques (including machine learning, deep learning, and related data-driven approaches) in the context of PD diagnosis, monitoring, or treatment. Key search terms combined "Parkinson's" with words such as "artificial intelligence," "machine learning," "deep learning," "diagnosis," "wearable," "sensor," "remote monitoring," "digital biomarker," "treatment," "management," and "outcomes." We prioritized studies with clinical data, especially those relevant to U.S. healthcare. Given the narrative (non-systematic) scope, we also included seminal earlier studies to provide background and select conference papers, regulatory documents, and industry releases for the current context.

4. RESULTS AND DISCUSSION

4.1. AI Technologies & modalities in PD care

A diverse range of AI technologies and data modalities are being explored to address different aspects of Parkinson's disease. Machine learning algorithms form the backbone of these innovations. In PD applications, supervised learning models are trained on labeled datasets (e.g., patients vs. controls or symptom severity ratings) to detect patterns that human observers might miss. Traditional classifiers (support vector machines, random forests) have been used alongside more complex deep learning architectures (convolutional and recurrent neural networks) for feature extraction from raw data. Unsupervised learning has also been applied to cluster PD subtypes or discover novel digital biomarkers (Dadu *et al.*, 2022). Importantly, recent efforts prioritize explainable AI techniques like SHAP (SHapley Additive exPlanations) to interpret what features drive an AI model's output, given the need for clinician trust in AI decision support (Shen *et al.*, 2025).

Wearable and mobile sensors provide one key modality fueling AI development in PD (Benyoucef *et al.*, 2025; Bougea, 2025; di Biase *et al.*, 2024; Smits Serena *et al.*, 2025). Body-worn sensors (accelerometers, gyroscopes, etc.) can continuously capture movement data related to tremor, bradykinesia, dyskinesia, gait, and balance. An accelerometry-based wearable on the wrist or belt can capture tremor episodes and motor fluctuations throughout the day. AI algorithms process these high-frequency time-series signals to quantify symptom

severity and patterns. The Personal KinetiGraph (PKG) watch uses a wrist accelerometer and special algorithms to create scores for bradykinesia, dyskinesia, and fluctuations, which closely match the results from UPDRS and AIMS scales in both lab and home environments (Moreau *et al.*, 2023a; Santiago *et al.*, n.d.). Systems like Kinesia and STAT-ON similarly couple inertial sensors with ML models to detect motor states, validated in multiple studies (Cox *et al.*, 2024a; Moreau *et al.*, 2023b; Rodríguez-Martín & Pérez-López, 2024; Santos García *et al.*, 2023). These platforms exemplify how sensors plus AI can create a "digital phenotype" of PD motor features in real-world settings. Smartphone sensors likewise support gait or tremor measurement through accelerometers and gyroscopes, and touchscreen tapping tasks. Typing-pattern analysis, as in the "neuroQWERTY" concept, shows promise for early motor impairment detection.

Voice and speech analysis is another active AI modality in PD. Dysarthria, characterized by voice changes, can be detected via acoustic markers. In a 2025 study by Shen *et al.* 2025, a hybrid CNN-RNN model analyzing mel-frequency cepstral coefficients and jitter achieved 91.11% accuracy with an AUC of 0.9125, using SHAP for interpretability (Shen *et al.*, 2025). Such voice-based models are being explored for monitoring progression or medication effects. Voice AI offers a noninvasive, cost-effective biomarker suitable for integration into telehealth or automated screening hotlines.

Neuroimaging AI has been investigated for PD, with mixed results (Valerio *et al.*, 2025). Studies apply ML to MRI and dopamine transporter (DaTscan) imaging to diagnose or predict disease (Klyuzhin *et al.*, 2018; Majhi *et al.*, 2024; Zhang, 2022). Radiomics and deep learning show potential in distinguishing PD and atypical Parkinsonism (Bian *et al.*, 2023; Feng *et al.*, 2024; Ling *et al.*, 2024). However, a recent review found only ~20% of neuroimaging AI studies met minimal methodology quality, and just 8% employed external test sets, indicating concerns about overfitting and inflated accuracy (Dzialas *et al.*, 2024; Shen *et al.*, 2025). Nonetheless, semi-automated tools like GE's DaTQUANT already aid dopamine-deficit quantification, and more sophisticated AI could further improve diagnostic specificity.

Emerging modalities include sensor-equipped pens or tablets to analyze handwriting and micrographia, camera-based computer vision systems to assess facial masking or bradykinesia in patient videos, and physiological sensors tracking autonomic markers like heart-rate variability linked to medication states. AI also facilitates multimodal data fusion, integrating wearables, voice, imaging, and clinical information into a comprehensive patient model (Information Fusion and Artificial Intelligence for Smart Healthcare, 2023; Shaik *et al.*, 2024). Such approaches can cross-verify signals, e.g., a tremor occurring with voice changes, thus enhancing robustness. To illustrate the breadth of artificial-intelligence applications across the Parkinson's disease (PD) care journey, Figure 1 maps key digital modalities onto the sequential phases of diagnosis, monitoring, and treatment.

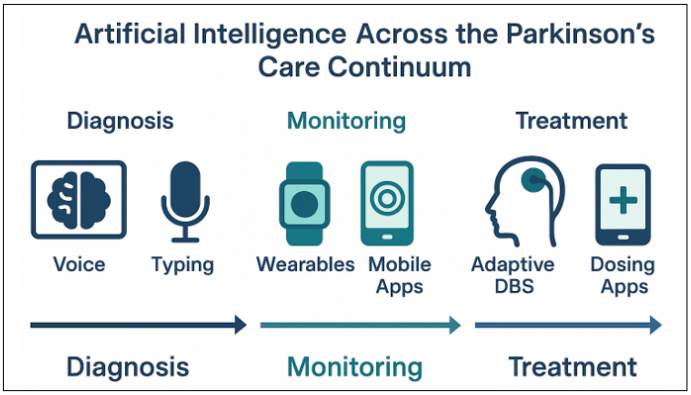

Figure 1. Artificial intelligence across the parkinson's care continuum.

4.2. Clinical applications

AI applications in Parkinson's disease care can be grouped into three broad clinical domains: diagnosis, symptom monitoring, and treatment optimization. Within each domain, we highlight how AI is being used in real or near-real clinical practice and the outcomes achieved to date. While many projects are still in pilot or research stages, a few have already leaped from routine care or commercial availability in the U.S.

4.3. Diagnosis & early detection

Diagnosing PD early remains a challenge; accuracy can be poor, and up to 30% of cases may be misdiagnosed at onset (Coarelli *et al.*, 2019; Parkinson's Resource Organization, 2020). AI tools aim to detect subtle signals before clinicians might. Voice-based ML models, for instance, detect mild dysarthria in prodromal cases and can flag risk for further evaluation (Dudek *et al.*, 2025; Rusz *et al.*, 2024). Typing-pattern analysis from smartphones has shown promise in distinguishing PD patients with excellent accuracy in early studies. While these tools aren't yet used widely in U.S. clinics, they demonstrate moderate evidence (proof-of-concept accuracy >90%) and, if validated in broader cohorts, could be integrated into primary-care decision support to prompt neurology referrals.

Imaging-based AI, such as ML classifiers for DaTscan interpretation, may assist radiologists in ambiguous cases. Though tools that aid diagnosis in other conditions (e.g., Alzheimer's PET interpretation) have already been FDA-cleared, no PD diagnostic AI holds standalone U.S. approval yet; current systems are positioned as adjunctive decision support, not replacements. As AI performance improves and clinicians become more comfortable, these tools are likely to gain traction.

4.4. Symptom monitoring & disease progression

Continuous symptom tracking has emerged as the most impactful AI application in PD. Unlike static clinic exams, these systems allow clinicians to follow patients over days.

The Personal KinetiGraph (PKG), FDA-cleared and widely used, captures movement data over 6–10 days and generates

objective bradykinesia and dyskinesia scores. A blinded randomized study showed that integrating PKG into care resulted in significantly greater symptom improvements, and clinicians changed management in ~30–40% of visits based on PKG insights (Nahab *et al.*, 2019). Additional studies document improved UPDRS scores and enhanced patient compliance in PKG-guided care (Nahab *et al.*, 2019). We judge such findings as moderate-to-high evidence of clinical benefit (Virbel-Fleischman *et al.*, 2023).

Other wearable systems, Kinesia 360 and STAT-ON, capture tremor, gait, freezing of gait, and dyskinesia (Santos García *et al.*, 2023). Although primarily validated in European cohorts, they are being introduced to U.S. practices; expert consensus now conditionally recommends these systems for remote symptom monitoring (Krause *et al.*, 2021). Mobile apps such as StrivePD, paired with Apple Watch, passively track tremor and motor fluctuations. FDA-cleared in 2022 via Apple's Movement Disorder API, this system allows clinicians to view symptom trends between visits and make medication adjustments based on those patterns. (Lindsey Mulrooney, 2022) This technology represents a new frontier of accessible, continuous monitoring. Beyond motor symptoms, AI tools assess adherence, sleep, and non-motor features (Babel *et al.*, 2021). Some smart pill dispensers detect medication intake using sensor fusion. Apps track sleep disruptions, which are common and burdensome in PD. These emerging tools represent a more comprehensive care model that extends beyond just movement to include other aspects of patient functioning (Chaudhuri *et al.*, 2022).

4.5. Treatment optimization & personalization

AI is now helping tailor PD therapies, especially in two areas: medication management and neuromodulation. Automated dosing tools, though still experimental, analyze symptom diaries and wearable data to suggest optimized levodopa timing and dosing intervals. Early pilot trials have shown that AI-recommended adjustments can improve motor control (Iii *et al.*, 2025; Lam *et al.*, 2022; Rasa, 2024). While low-level evidence (small sample sizes) currently limits adoption, these systems function as clinician aids rather than replacements.

Deep brain stimulation (DBS) is seeing transformative gains with AI. Automated programming algorithms analyze electrode location, patient signals, and symptom-response curves to infer optimal settings; Early feasibility studies show these match clinician-selected settings more quickly and reliably (Roediger *et al.*, 2023).

Adaptive DBS (aDBS) takes customization further. These systems sense brain activity (beta oscillations) and adjust stimulation in real time (Li *et al.*, 2025; The BRAIN Blog, 2025). Medtronic's Percept PC with BrainSense, FDA-approved in February 2025, allows this closed-loop therapy on U.S. patients (Franchina, 2025). North America's first clinical implantations took place shortly after approval. Early clinical trial data, such as the ADAPT-PD study, show sensory-derived stimulation significantly reduced motor symptoms compared to conventional DBS and was well tolerated (Stanslaski *et al.*, 2024). Financial accessibility remains limited to specialized centers, but this technology marks moderate evidence for personalization and efficacy due to its FDA clearance and trial results.

AI is also making inroads into rehabilitation (Rasa, 2024). Vision-based coaching apps offer exercise guidance for gait and voice therapy; gait-assist devices now recognize freezing episodes and provide cues. Although the data is still preliminary, these tools demonstrate an increasing role for AI in enhancing and expanding therapy beyond clinical settings. Table 1 provides a concise inventory of AI-enabled devices and software that have already secured FDA or CE approval, detailing their regulatory pathways, clinical functions, and current deployment status to ground the subsequent discussion on adoption gaps and unmet needs.

Table 1. Regulatory-cleared or CE-marked AI technologies for parkinson's disease care

Platform (Modality)	Regulatory Pathway & Year	Core Clinical Function	Deployment Status
StrivePD (Rune Labs, Apple Watch)	FDA 510(k) K213519, 2022 (Aguilar, 2024; Practical Neurology, 2022).	Passive detection of tremor & dyskinesia; medication, sleep, activity logs	Free U.S. App Store download; deployed in health-system pilots(Rune Labs Secures FDA Clearance for Parkinson's Disease Monitoring through StrivePD Ecosystem on Apple Watch, n.d.)
NeuroRPM (NeuroRPM Inc., Apple Watch)	FDA 510(k), 2023 (Business Wire, 2023).	Continuous AI quantification of bradykinesia, tremor & dyskinesia	Prescription-only rollout through academic movement-disorder centres (Business Wire, 2023).
Parky (H2O Therapeutics, Apple Watch)	FDA 510(k), 2022 + EU MDR cert., 2025 (Business Wire, 2023).	Real-time monitoring of tremor/dyskinesia with clinician dashboard	U.S. launch 2024; reimbursable via RPM codes; expanding in EU.
KinesiaU™ (Great Lakes NeuroTechnologies)	FDA-cleared Kinesia sensors (2014; portal 2021) (NeuroTechnologies, 2021).	Objective scoring of tremor, slowness & dyskinesia for therapy titration	Prescription system in U.S.; NICE conditional recommendation in UK (Moreau *et al.*, 2023a).

PDMonitor® (PD Neurotechnology)	CE Mark (Class IIa), 2023 (Moreau *et al.*, 2023a).	Whole-body motor-symptom profiling (tremor, bradykinesia, gait)	Deployed in 12 EU countries; U.S. 510(k) submission in preparation
BrainSense™ Adaptive DBS (Medtronic Percept PC)	FDA approval, Feb 2025	Closed-loop DBS auto-adjusts stimulation using beta LFPs beta Power	Commercial launch anticipated H2 2025 (U.S.); available in EU since 2024

4.6. Healthcare-system integration & implementation challenges

Efforts to pull AI for Parkinson's disease out of pilot studies and into everyday U.S. practice collide with five knotty obstacles: workflow fit, regulation, payment, privacy/security, and equity. Together, they explain why only a handful of AI tools have left the lab despite impressive technical accuracy. As a roadmap for overcoming translational hurdles, Figure 2 pairs the five most cited implementation barriers with pragmatic, system-level solutions.

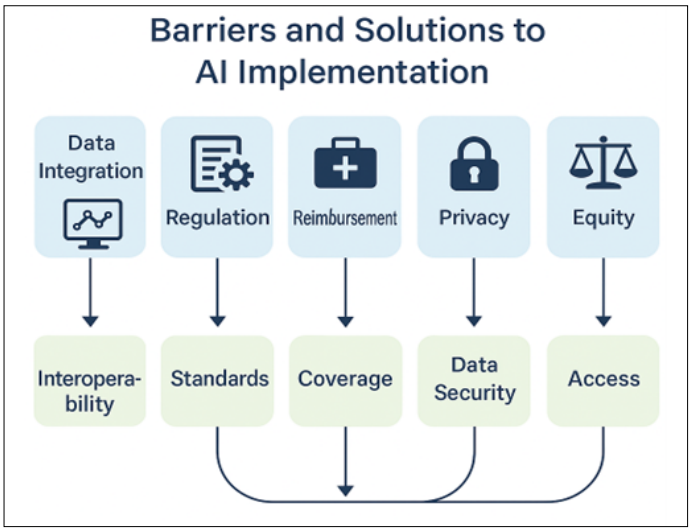

Figure 2. Barriers and solutions to AI implementation in parkinson's disease care.

The flowchart illustrates five implementation barriers: Data Integration, Regulation, Reimbursement, Privacy, and Equity, and their corresponding solutions: Interoperability, Standards, Coverage, Data Security, and Access. Each barrier is represented by a light-blue icon box; solutions appear in light-green boxes below, connected by arrows that indicate the remedial pathway. Curved connectors at the bottom highlight interdependencies among solutions, emphasizing that reimbursement coverage, for example, depends on regulatory standards and data security assurances.

4.7. Data integration & workflow

Raw sensor streams or model scores must land in front of a busy clinician at the right moment and in the right format. Prototype dashboards built at movement-disorder centers now ingest wearables through FHIR pipes and visualize trends such as "late-afternoon tremor spikes," yet building those interfaces required custom integrations and dedicated analysts (Center for Biologics Evaluation and Research, 2025). Commercial EHR vendors have begun offering SMART-on-FHIR launch points for digital Parkinson logs, but each new device still needs mapping and security vetting. Clinicians also demand explainability; if an algorithm warns that a patient's freezing risk doubled last week, the graph of stride-length variability must be one click away, or the alert will be ignored.

4.8. Regulatory landscape

The FDA treats most diagnostic or therapeutic AI as Software as a Medical Device (SaMD). Three draft guidance documents since 2023 sketch the road map: (1) Predetermined Change Control Plans allow manufacturers to pre-specify algorithm updates (Center for Devices and Radiological Health, 2024). (2) Guiding Principles on Transparency urge clear user-facing explanations of ML logic (Center for Devices and Radiological Health, 2024a); and (3) a 2024 AI lifecycle draft (now open for comment) details real-world performance monitoring and post-mark*et al*gorithm tweaks (Center for Devices and Radiological Health, 2025). For clinics, the takeaway is simple: choose vendors with an FDA-cleared model and a documented change-control plan or be ready to shoulder the regulatory burden yourself.

4.9. Reimbursement & financial incentives

Without payment, even FDA-cleared tools remain unutilized. The 2022–24 Physician Fee Schedule rules established Remote Therapeutic Monitoring CPT codes 98975–98981, which are intended to reimburse for device set-up and monthly data review related to non-physiologic metrics such as symptoms and adherence (Centers for Medicare & Medicaid Services, 2023). Neurologists can bill for services if the documentation connects the wearable data to active management; however, early adoption of this practice is inconsistent, as many clinicians are unaware of the billing codes, and some Medicare Administrative Contractors (MACs) have provided conflicting guidance. Private payers say they will cover AI wearables when solid evidence shows fewer ER visits or admissions—a hurdle the field has not yet cleared.

4.10. Privacy & security

Continuous motion, voice, and location signals are rich clinical fodder—and attractive personal fingerprints. HIPAA protects data once it enters a covered entity's system, but many Parkinson's apps collect information before any clinical hand-off, leaving them outside HIPAA's safe harbor (Office for Civil Rights (OCR), 2008). De-identification is not a panacea: researchers have re-identified >80% of supposedly anonymous sensor traces with pattern-matching algorithms (Malekzadeh *et al.*, 2019). Federal guidance, therefore, steers implementers toward privacy-by-design techniques: on-device preprocessing,

federated learning, and differential privacy, all featured in NIST's AI Risk Management Framework released in 2023 (Tabassi, 2023). Health systems deploying AI wearables must add robust consent flows, encryption, and breach-response plans—costs that can dwarf device price tags.

4.11. Bias & equity

AI models inherit the skew of their training data. Paik *et al.* coined the term "health-data poverty" to describe how under-representation of racial minorities and rural populations in training sets can amplify disparities when AI tools hit the wild (Paik *et al.*, 2023). For Parkinson's, wearables calibrated mainly on older white men may mis-score tremor amplitude in women or Black patients, leading to undertreatment. FDA's good-machine-learning-practice principles explicitly call for pre-market bias testing and post-market drift monitoring (Health, 2025), and NIST's framework adds practical checklists. Clinics piloting AI monitors now run subgroup accuracy audits and retrain models with more diverse datasets, but their use remains ad hoc. We need subsidy programs, such as loaner smartwatches and phone-free sensors, to prevent the digital divide from widening.

4.12. Organisational & human factors

Successful rollouts pair technology with change management. Early adopter centers designate an "AI nurse navigator" who filters sensor alerts, sparing neurologists from inbox overload. Liability questions persist: Who is responsible if an algorithm misses a fall risk flag? Current malpractice norms still place ultimate accountability on the physician, though legal scholars predict case law will evolve as AI autonomy rises. Interoperability headaches loom as clinics stack multiple AI tools: a gait-analysis app, an adaptive DBS programmer, and a speech monitor, all demanding their data channels. National efforts to standardize data models (FHIR "digital biomarker" profiles) are underway but incomplete.

Bottom line: AI promises more timely, personalized Parkinson's care, yet adoption hinges on solving workflow integration, aligning FDA and payer pathways, hard-wiring privacy, and ensuring fairness. Multi-stakeholder coordination, including clinicians, technologists, payers, regulators, and patients, is essential if AI is to move from pilot projects to an equitable national standard of care.

4.13. Current outcomes & evidence base

4.13.1. Diagnostic accuracy

Voice, gait, and typing classifiers routinely post 85–95% sensitivity/specificity in controlled datasets (Adams, 2017). Tabashum *et al.* found that only 35% tested models on an external cohort and barely 60% reported any hyperparameter tuning, leading the authors to grade evidence as "low–moderate" overall (Tabashum *et al.*, 2024). External-validation gaps are slowly closing: the Parkinson Voice Initiative and mPower are now enrolling thousands to prospectively verify voice and smartphone biomarkers, but results are pending. No stand-alone diagnostic AI is FDA-cleared; current tools act as screening adjuncts, not replacements for neurological examination.

4.13.2. Monitoring & management

Randomized and controlled studies give the strongest support to date. In a blinded trial, adding the Personal KinetiGraph (PKG) to usual care cut bradykinesia scores and drove more therapy adjustments than control visits (Cox *et al.*, 2024b). A multi-center "PKG Impact" study reported treatment changes in 74% of encounters when clinicians reviewed the device's objective motor graphs and fluctuation scores (Dominey *et al.*, 2020). Kinesia 360, another inertial-sensor suite, correlates closely with in-clinic UPDRS ratings and is being evaluated for remote titration workflows (Moreau *et al.*, 2023b). The Apple Watch/StrivePD pair, listed by the FDA in 2022, passively streams tremor and dyskinesia metrics to dashboards that early adopters say guide dose timing tweaks between visits (Larkin, 2022; Trevor Dermody, 2024). These data justify a moderate evidence grade for wearables: objective measurement changes practice, but most trials remain <200 patients and lack long-term health-economic endpoints.

4.13.3. Treatment optimisation

Medication-dosing decision support remains exploratory. Small N-of-1 app studies show improved diary scores when ML suggests schedule tweaks, yet cohorts are too small to draw firm conclusions (evidence is low).

Neuromodulation evidence is firmer. Automated programming algorithms (e.g., StimFit) matched expert-selected DBS settings and cut programming time in a crossover feasibility trial (Nahab *et al.*, 2019). aDBS, which senses beta oscillations and adjusts stimulation on-the-fly, reduced motor-symptom time by roughly 50% versus conventional continuous DBS in the ADAPT-PD pilot (Bott & Cookson, 2024) and gained FDA clearance for Medtronic's BrainSense platform in early 2025 (Park, 2025). A 2025 Nature Parkinson's Delphi study of 21 experts concluded that aDBS would benefit patients with fluctuating motor states and dyskinesia within five years (Guidetti *et al.*, 2025). Given regulatory approval plus converging trial data, we assign moderate evidence to AI-enhanced DBS, with the caveat that long-term QoL and battery-sparing advantages remain under study.

4.13.4. Patient-centred outcomes & safety

Wearable-guided care yields small yet statistically significant UPDRS improvements, but quality-of-life (PDQ-39) changes are inconsistent (Cox *et al.*, 2024b). Surveys indicate many patients feel "seen" between visits, though some report data fatigue when feedback lacks context (Dominey *et al.*, 2020). No major safety events attributable to AI software have surfaced; sensors are low-risk, and aDBS devices include hard-wired limits to prevent overstimulation (Rachel Dolhun, MD, DipABLM, 2025). False-positive alerts and anxiety remain theoretical concerns requiring post-market surveillance, now mandated in FDA lifecycle guidance.

4.13.5. Evidence gaps

- *External validity:* Most diagnostic AIs still lack U.S. community-cohort testing.
- *Health economics:* No study has yet shown reduced hospitalizations or net savings from AI monitoring.

• *Equity:* Few trials report subgroup accuracy; wearable datasets are skewed toward tech-savvy, higher-income users.

• *Long-term outcomes:* aDBS and dosing-advisor apps need multi-year follow-up to confirm durability and battery or medication-sparing claims.

4.13.6. Verdict

The evidence base is emerging but incomplete. Wearables already influence clinical decisions; adaptive neuromodulation has cleared the regulatory bar; diagnostic AIs are promising but unproven in the wild. Over the next five years, large pragmatic trials and payer-linked utilization studies will determine whether AI truly delivers safer, cheaper, and more equitable Parkinson's care or remains a high-tech side project awaiting its breakthrough moment.

5. CONCLUSION

Artificial intelligence has edged from novelty to necessity in Parkinson's practice, yet the journey is only half-run. Wearable dashboards already nudge levodopa schedules, adaptive stimulators quiet beta bursts in real time, and voice apps flag subtle dysarthria long before a clinic visit. Still, the evidence that these gains translate into longer walks, fewer falls, or a lighter caregiver load remains patchy. Regulatory sign-off means the tools are safe; it doesn't promise they change lives. The next five years must therefore pivot from accuracy papers to pragmatic trials embedded in day-to-day care, with costs, equity, and clinician workload tracked as tightly as UPDRS scores. Success will also turn on design: interfaces that fold quietly into the electronic chart, billing pathways clinicians actually understand, and privacy locks strong enough for skeptical patients. Done well, AI offers more than convenience; it can close the geographic and economic gaps that leave many Americans without specialist input. Done poorly, it risks amplifying them. Our review charts both the promise and the pitfalls; it hands stakeholders a practical agenda rather than a prediction. Whether we meet that agenda will determine whether AI becomes a silent partner for Parkinson's disease or just another gadget. The responsibility and opportunity belong equally to every sector today.

RECOMMENDATIONS

A decade from now, artificial intelligence could shift Parkinson's care from episodic check-ups to a learning system that fine-tunes therapy every day, yet only if three conditions are met: we prove benefit in diverse patients, build tools clinicians and payers can live with, and explore new science without repeating today's blind spots.

i. Prove real-world benefit: FDA clearance confirms that an algorithm works in a test lab; payers and guidelines demand evidence that it changes outcomes. Most diagnostic ML papers still skip external validation; only 35% in a 2024 systematic review used an independent cohort, and fewer than two-thirds tuned hyperparameters correctly (Tabashum *et al.*, 2024). Future trials should randomize usual care against the "usual + wearable dashboard," track UPDRS scores, falls, and utilization for 12–24 months, and publish neutral results as well as wins. The agency's Predetermined Change Control Plan draft tells developers they must collect post-market performance data as software evolves (Center for Devices and Radiological Health, 2024b; Health, 2024), giving a regulatory nudge toward larger, longer studies.

ii. Make AI workable, payable, and fair: Human-factors guidance already details usability testing for medical devices (Health, 2019), yet many Parkinson's apps still swamp clinicians with raw graphs. Co-design sessions with people who have tremor or impaired dexterity should shape every interface. On payment, neurologists can bill Medicare's Remote Therapeutic Monitoring codes 98975-98981 if wearable data informs active care—an option too few practices use because billing rules are unfamiliar (Department of Health & Human Services & Centers for Medicare & Services, 2021). National societies should add RTM billing to CME and certify "AI nurse navigators" who triage sensor alerts. Privacy and bias must stay front-of-mind: the NIST AI Risk-Management Framework urges federated learning and differential privacy to curb re-identification (Fried, 2022; Tabassi, 2023), while the White House AI Bill of Rights sets fairness and opt-out as baseline expectations for automated systems in health care (The White House, n.d.). Health systems deploying PD algorithms should publish annual accuracy audits by sex, race, and rurality; if error rates diverge, retraining or workflow tweaks are mandatory.

iii. Strive for responsible advancement in this field: Medtronic's 2025 FDA-approved BrainSense device shows adaptive DBS can exit the lab when safety controls are embedded from day one (Medtronic, 2025). Next up are multimodal models that fuse wearables, genomics, and imaging to forecast disease trajectories. Consortia are already piloting federated pipelines so centers can train shared models without shipping raw data (Health, 2024). Richer sensors are coming, too: sweat-chemistry patches for levodopa levels, mini-EMG chips for rigidity, and even cobot walkers that detect freezing and cue movement. Each leap will rekindle old challenges, workflow fit, reimbursement, and privacy, so every project should bake in usability testing, payer dialogue, and bias scans alongside classic algorithm metrics.

AUTHOR CONTRIBUTIONS

GAA and ST performed the literature search and synthesized clinical application data; ASA, IA, and MAM drafted the clinical sections; MOH, CUA, and UIO developed the leadership framework and implementation strategies; CFF and USE designed all figures and tables; all authors reviewed successive drafts, provided critical intellectual input, and approved the final manuscript.

REFERENCES

Adams, W. R. (2017). High-accuracy detection of early Parkinson's Disease using multiple characteristics of finger movement while typing. *PLoS ONE, 12*(11), e0188226. https://doi.org/10.1371/journal.pone.0188226

Aguilar, M. (2024, January 11). *Rune Labs, which makes an app to track Parkinson's symptoms, raises $12 million.* STAT. https://www.statnews.com/2024/01/11/parkinsons-symptoms-app-strive-pd-rune-labs

Atri, R., Urban, K., Marebwa, B., Simuni, T., Tanner, C., Siderowf, A., Frasier, M., Haas, M., & Lancashire, L. (2022). Deep Learning for Daily Monitoring of Parkinson's Disease Outside the Clinic Using Wearable Sensors. *Sensors, 22*(18), Article 18. https://doi.org/10.3390/s22186831

Babel, A., Taneja, R., Mondello Malvestiti, F., Monaco, A., & Donde, S. (2021). Artificial Intelligence Solutions to Increase Medication Adherence in Patients With Non-communicable Diseases. *Frontiers in Digital Health, 3*, 669869. https://doi.org/10.3389/fdgth.2021.669869

Bajaj, S. (2023, July 10). *Why nearly half of Americans with Parkinson's don't see a neurologist.* STAT. https://www.statnews.com/2023/07/10/parkinsons-diagnosis-neurologist-referral-medicare-patients/

Benyoucef, Y., Melliti, I., Harmouch, J., Asadi, B., Del Mastro, A., Lapuente-Hernández, D., & Herrero, P. (2025). Wearable Sensors and Artificial Intelligence for the Diagnosis of Parkinson's Disease. *Journal of Clinical Medicine, 14*(12), Article 12. https://doi.org/10.3390/jcm14124207

Bian, J., Wang, X., Hao, W., Zhang, G., & Wang, Y. (2023). The differential diagnosis value of radiomics-based machine learning in Parkinson's disease: A systematic review and meta-analysis. *Frontiers in Aging Neuroscience, 15*. https://doi.org/10.3389/fnagi.2023.1199826

Bott, I., & Cookson, C. (2024, August 19). Implants reduce Parkinson's symptoms by reading brain activity. *Financial Times.*

Bougea, A. (2025). Application of Wearable Sensors in Parkinson's Disease: State of the Art. *Journal of Sensor and Actuator Networks, 14*(2), Article 2. https://doi.org/10.3390/jsan14020023

Business Wire. (2023, March 23). NeuroRPM Inc. Announces FDA Clearance for NeuroRPM, the AI-Powered Remote Monitoring App for Parkinson's Disease on Apple Watch. *Business Wire.* https://www.businesswire.com/news/home/20230323005557/en/NeuroRPM-Inc.-Announces-FDA-Clearance-for-NeuroRPM-the-AI-Powered-Remote-Monitoring-App-for-Parkinsons-Disease-on-Apple-Watch

Carol Blymire. (2019, June 13). *Study Finds Parkinson's $52 Billion Economic Burden Double Previous Estimates.* Parkinson's Disease. https://www.michaeljfox.org/news/study-finds-parkinsons-52-billion-economic-burden-double-previous-estimates

Center for Biologics Evaluation and Research. (2025). *Devices Guidances.* FDA. https://www.fda.gov/vaccines-blood-biologics/general-biologics-guidances/devices-guidances

Center for Devices and Radiological Health. (2024a). *Transparency for Machine Learning-Enabled Medical Devices: Guiding Principles.* FDA. https://www.fda.gov/medical-devices/software-medical-device-samd/transparency-machine-learning-enabled-medical-devices-guiding-principles

Center for Devices and Radiological Health. (2024b, March 12). *Marketing Submission Recommendations for a Predetermined Change Control Plan for Artificial Intelligence-Enabled Device Software Functions.* FDA. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/marketing-submission-recommendations-predetermined-change-control-plan-artificial-intelligence

Center for Devices and Radiological Health. (2025). *Artificial Intelligence and Machine Learning in Software as a Medical Device.* FDA. https://www.fda.gov/medical-devices/software-medical-device-samd/artificial-intelligence-and-machine-learning-software-medical-device

Centers for Medicare & Medicaid Services. (2023, November 16). *Medicare and Medicaid Programs; CY 2024 Payment Policies Under the Physician Fee Schedule and Other Changes to Part B Payment and Coverage Policies; Medicare Shared Savings Program Requirements; Medicare Advantage; Medicare and Medicaid Provider and Supplier Enrollment Policies; and Basic Health Program.* Federal Register. https://www.federalregister.gov/documents/2023/11/16/2023-24184/medicare-and-medicaid-programs-cy-2024-payment-policies-under-the-physician-fee-schedule-and-other

Chaudhuri, K. R., Hand, A., Obam, F., & Belsey, J. (2022). Cost-effectiveness analysis of the Parkinson's KinetiGraph and clinical assessment in the management of Parkinson's disease. *Journal of Medical Economics, 25*(1), 774-782. https://www.tandfonline.com/doi/abs/10.1080/13696998.2022.2080437

Coarelli, G., Garcin, B., Roze, E., Vidailhet, M., & Degos, B. (2019). Invalidation of Parkinson's disease diagnosis after years of follow-up based on clinical, radiological and neurophysiological examination. *Journal of the Neurological Sciences, 406*, 116454. https://doi.org/10.1016/j.jns.2019.116454

Cox, E., Wade, R., Hodgson, R., Fulbright, H., Phung, T. H., Meader, N., Walker, S., Rothery, C., & Simmonds, M. (2024a). Results of the review of clinical effectiveness. In Devices for remote continuous monitoring of people with Parkinson's disease: A systematic review and cost-effectiveness analysis. *National Institute for Health and Care Research.* https://www.ncbi.nlm.nih.gov/books/NBK605974/

Cox, E., Wade, R., Hodgson, R., Fulbright, H., Phung, T. H., Meader, N., Walker, S., Rothery, C., & Simmonds, M. (2024b). Results of the review of clinical effectiveness. In *Devices for remote continuous monitoring of people with Parkinson's disease: A systematic review and cost-effectiveness analysis.* National Institute for Health and Care Research. https://www.ncbi.nlm.nih.gov/books/NBK605974/

Dadu, A., Satone, V., Kaur, R., Hashemi, S. H., Leonard, H., Iwaki, H., ... & Faghri, F. (2022). Identification and prediction of Parkinson's disease subtypes and progression using

machine learning in two cohorts. *npj Parkinson's Disease, 8*(1), 172. https://doi.org/10.1038/s41531-022-00439-z

Department of Health & Human Services & Centers for Medicare & Services. (2021, November 10). *CMS Manual System*. https://www.cms.gov/files/document/r11118cp.pdf

di Biase, L., Pecoraro, P. M., Pecoraro, G., Shah, S. A., & Di Lazzaro, V. (2024). Machine learning and wearable sensors for automated Parkinson's disease diagnosis aid: A systematic review. *Journal of Neurology, 271*(10), 6452–6470. https://doi.org/10.1007/s00415-024-12611-x

Dominey, T., Kehagia, A. A., Gorst, T., Pearson, E., Murphy, F., King, E., & Carroll, C. (2020). Introducing the Parkinson's KinetiGraph into Routine Parkinson's Disease Care: A 3-Year Single Centre Experience. *Journal of Parkinson's Disease, 10*(4), 1827–1832. https://doi.org/10.3233/JPD-202101

Dudek, M., Hemmerling, D., Kaczmarska, M., Stepien, J., Daniol, M., Wodzinski, M., & Wojcik-Pedziwiatr, M. (2025). Analysis of Voice, Speech, and Language Biomarkers of Parkinson's Disease Collected in a Mixed Reality Setting. *Sensors, 25*(8), Article 8. https://doi.org/10.3390/s25082405

Dzialas, V., Doering, E., Eich, H., Strafella, A. P., Vaillancourt, D. E., Simonyan, K., & van Eimeren, T. (2024). Houston, We Have AI Problem! Quality Issues with Neuroimaging-Based Artificial Intelligence in Parkinson's Disease: A Systematic Review. *Movement Disorders, 39*(12), 2130–2143. https://doi.org/10.1002/mds.30002

Feng, J., Huang, Y., Zhang, X., Yang, Q., Guo, Y., Xia, Y., Peng, C., & Li, C. (2024). Research and application progress of radiomics in neurodegenerative diseases. *Meta-Radiology, 2*(1), 100068. https://doi.org/10.1016/j.metrad.2024.100068

Franchina, P. (2025, February 28). FDA Approves New Adaptive DBS System. American Parkinson Disease Association. https://www.apdaparkinson.org/article/fda-approves-new-adaptive-dbs-system/

Fried, M. H. M., Ina. (2022, October 4). *White House's AI "Bill of Rights" enters crowded field.* Axios. https://www.axios.com/2022/10/04/white-house-ai-protections-artificial-intelligence-bill-of-rights

Guidetti, M., Bocci, T., De Pedro Del Álamo, M., Deuschl, G., Fasano, A., Martinez-Fernandez, R., Gasca-Salas, C., … Priori, A. (2025). Will adaptive deep brain stimulation for Parkinson's disease become a real option soon? A Delphi consensus study. *Npj Parkinson's Disease, 11*(1), 110. https://doi.org/10.1038/s41531-025-00974-5

Health, C. for D. and R. (2019, September 2). *Applying Human Factors and Usability Engineering to Medical Devices*. FDA. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/applying-human-factors-and-usability-engineering-medical-devices

Health, C. for D. and R. (2024, August 22). *Predetermined Change Control Plans for Medical Devices*. FDA. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/predetermined-change-control-plans-medical-devices

Health, C. for D. and R. (2025). *Good Machine Learning Practice for Medical Device Development*: Guiding Principles. *FDA*. https://www.fda.gov/medical-devices/software-medical-device-samd/good-machine-learning-practice-medical-device-development-guiding-principles

Iii, R. D., Isaacson, S., Richard Dewey, J., Betté, S., Lyons, K. E., Yang, Z., Zhao, Q., Nguyen, A. T., Zhang, Z., & Pahwa, R. (2025). A Pilot Study of AI-Controlled Transcutaneous Peripheral Nerve Stimulation for Essential Tremor. *Tremor and Other Hyperkinetic Movements, 15*(1). https://doi.org/10.5334/tohm.991

Information fusion and artificial intelligence for smart healthcare: A bibliometric study. (2023). *Information Processing & Management, 60*(1), 103113. https://doi.org/10.1016/j.ipm.2022.103113

Kim, M. (2025, April 3). *An AI-enhanced treatment has reduced Parkinson's symptoms for some people.* The Washington Post. https://www.washingtonpost.com/wellness/2025/04/03/parkinsons-adaptive-dbs-deep-brain-stimulation/

Klyuzhin, I., Shenkov, N., Rahmim, A., & Sossi, V. (2018). Use of deep convolutional neural networks to predict Parkinson's disease progression from DaTscan SPECT images. *Journal of Nuclear Medicine, 59*(supplement 1), 29–29.

Krause, E., Randhawa, J., & Mehanna, R. (2021). Comparing subjective and objective response to medications in Parkinson's disease patients using the Personal KinetiGraphTM. *Parkinsonism & Related Disorders, 87*, 105–110. https://doi.org/10.1016/j.parkreldis.2021.05.008

Lam, T. Y. T., Cheung, M. F. K., Munro, Y. L., Lim, K. M., Shung, D., & Sung, J. J. Y. (2022). Randomized Controlled Trials of Artificial Intelligence in Clinical Practice: Systematic Review. *Journal of Medical Internet Research, 24*(8), e37188. https://doi.org/10.2196/37188

Larkin, H. D. (2022). Apple Watch Parkinson Disease Symptom Monitor Is Cleared. *JAMA, 328*(5), 416. https://doi.org/10.1001/jama.2022.12641

Li, Q., Wang, K., Li, J., Wei, P., Shan, Y., Li, J., Zhu, J., Zheng, Z., Niu, C., Xiong, C., Li, W., … Zhang, Y. (2025). Adaptive vs Conventional Deep Brain Stimulation of the Subthalamic Nucleus for Treatment of Parkinson's Disease: A Multicenter Retrospective Study. Neuromodulation: *Technology at the Neural Interface*. https://doi.org/10.1016/j.neurom.2025.04.011

Lindsey Mulrooney. (2022, June 27). *Parkinson Disease Monitoring App Available for Apple Watch.* AJMC. https://www.ajmc.com/view/parkinson-disease-monitoring-app-

available-for-apple-watch

Ling, R., Wang, M., Lu, J., Wu, S., Wu, P., Ge, J., ... & Jiang, J. (2024). Radiomics-guided deep learning networks classify differential diagnosis of parkinsonism. *Brain Sciences, 14*(7), 680. https://doi.org/10.3390/brainsci14070680

Lonini, L., Dai, A., Shawen, N., Simuni, T., Poon, C., Shimanovich, L., Daeschler, M., Ghaffari, R., Rogers, J. A., & Jayaraman, A. (2018). Wearable sensors for Parkinson's disease: Which data are worth collecting for training symptom detection models. *Npj Digital Medicine, 1*(1), 64. https://doi.org/10.1038/s41746-018-0071-z

Majhi, B., Kashyap, A., Mohanty, S. S., Dash, S., Mallik, S., Li, A., & Zhao, Z. (2024). An improved method for diagnosis of Parkinson's disease using deep learning models enhanced with metaheuristic algorithm. *BMC Medical Imaging, 24*(1), 156. https://doi.org/10.1186/s12880-024-01335-z

Malekroodi, H. S., Madusanka, N., Lee, B., & Yi, M. (2024). Leveraging Deep Learning for Fine-Grained Categorization of Parkinson's Disease Progression Levels through Analysis of Vocal Acoustic Patterns. *Bioengineering, 11*(3), 295. https://doi.org/10.3390/bioengineering11030295

Malekzadeh, M., Clegg, R. G., Cavallaro, A., & Haddadi, H. (2019). Mobile Sensor Data Anonymization. Proceedings of the International Conference on *Internet of Things Design and Implementation, 49–58.* https://doi.org/10.1145/3302505.3310068

Mark Michaud. (2017, August 16). Telemedicine as Effective as In-Person Care for Parkinson's Disease. *URMC Newsroom.* https://www.urmc.rochester.edu/news/story/telemedicine-as-effective-as-in-person-care-for-parkinsons-disease

Medtronic. (2025, February 24). Medtronic earns U.S. FDA approval for the world's first Adaptive deep brain stimulation system for people with Parkinson's. Medtronic News. https://news.medtronic.com/2025-02-24-Medtronic-earns-U-S-FDA-approval-for-the-worlds-first-Adaptive-deep-brain-stimulation-system-for-people-with-Parkinsons

Michael J. Fox Foundation. (2019, June 13). Parkinson's Disease Economic Burden on Patients, Families and the Federal Government Is $52 Billion, Doubling Previous Estimates | Parkinson's Disease. The Michael J. Fox Foundation for Parkinson's Research. https://www.michaeljfox.org/publication/parkinsons-disease-economic-burden-patients-families-and-federal-government-52-billion

Moreau, C., Rouaud, T., Grabli, D., Benatru, I., Remy, P., Marques, A. R., ... & Fabbri, M. (2023). Overview on wearable sensors for the management of Parkinson's disease. *npj Parkinson's Disease, 9*(1), 153. https://doi.org/10.1038/s41531-023-00585-y

Nahab, F. B., Abu-Hussain, H., & Moreno, L. (2019). Evaluation of clinical utility of the personal KinetiGraph® in the management of Parkinson disease. *Advances in Parkinson's Disease, 8*(3), 42-61. https://doi.org/10.4236/apd.2019.83005

NeuroTechnologies, G. L. (2021, January 8). *Great Lakes NeuroTechnologies Releases KinesiaU Provider Portal Enabling Real-Time Remote Monitoring of Patients With Parkinson's Disease.* Great Lakes NeuroTechnologies. https://www.glneurotech.com/blog/2021/01/08/great-lakes-neurotechnologies-releases-kinesiau-provider-portal-enabling-real-time-remote-monitoring-of-patients-with-parkinsons-disease/

Office for Civil Rights (OCR). (2008, May 7). Summary of the HIPAA Privacy Rule. https://www.hhs.gov/hipaa/for-professionals/privacy/laws-regulations/index.html

Paik, K. E., Hicklen, R., Kaggwa, F., Puyat, C. V., Nakayama, L. F., Ong, B. A., ... & Villanueva, C. (2023). Digital Determinants of Health: Health data poverty amplifies existing health disparities—A scoping review. *PLOS Digital Health, 2*(10), e0000313. https://doi.org/10.1371/journal.pdig.0000313

Park, A. (2025, February 24). Parkinson's Patients Now Have a New Way to Manage Symptoms. *TIME.* https://time.com/7260870/deep-brain-stimulation-parkinsons-disease/

Parkinson's Resource Organization. (2020, May 31). *How often is parkinson's misdiagnosed*? Parkinson's Resource Organization. https://www.parkinsonsresource.org/news/articles/how-often-is-parkinsons-misdiagnosed/

Practical Neurology. (2022, June 14). FDA Clears Parkinson Disease Monitoring Application—PracticalNeurology. *Practical Neurology; US HealthConnect.* https://practicalneurology.com/news/fda-clears-parkinson-disease-monitoring-application/2469942/

Rachel Dolhun, MD, DipABLM. (2025, March 11). Ask the MD: The Next Generation of DBS Is Here. Parkinson's Disease. The Michael J. Fox Foundation. https://www.michaeljfox.org/news/ask-md-next-generation-dbs-here

Rasa, A. R. (2024). Artificial Intelligence and Its Revolutionary Role in Physical and Mental Rehabilitation: A Review of Recent Advancements. *BioMed Research International,* 2024, 9554590. https://doi.org/10.1155/bmri/9554590

Rebecca Gilbert, MD. (2024, September 24). *How many people have Parkinson's disease.* APDA. American Parkinson Disease Association. https://www.apdaparkinson.org/article/parkinsons-disease-registries/

Rebecca Gilbert, MD. (2025, May 29). *How AI is Revolutionizing Parkinson's Research & Care.* APDA. American Parkinson Disease Association. https://www.apdaparkinson.org/article/ai-and-parkinsons-disease-research-and-care/

Rodríguez-Martín, D., & Pérez-López, C. (2024). Commercial symptom monitoring devices in Parkinson's disease: Benefits, limitations, and trends. *Frontiers in Neurology*, 15. https://doi.org/10.3389/fneur.2024.1470928

Roediger, J., Dembek, T. A., Achtzehn, J., Busch, J. L., Krämer,

A.-P., Faust, K., Schneider, G.-H., Krause, P., Horn, A., & Kühn, A. A. (2023). Automated deep brain stimulation programming based on electrode location: A randomised, crossover trial using a data-driven algorithm. *The Lancet Digital Health, 5*(2), e59–e70. https://doi.org/10.1016/S2589-7500(22)00214-X

Rune Labs Secures FDA Clearance for Parkinson's Disease Monitoring through StrivePD Ecosystem on Apple Watch. (n.d.). Retrieved June 17, 2025, from https://www.prnewswire.com/news-releases/rune-labs-secures-fda-clearance-for-parkinsons-disease-monitoring-through-strivepd-ecosystem-on-apple-watch-301566472.html?utm_source=chatgpt.com

Rusz, J., Krack, P., & Tripoliti, E. (2024). From prodromal stages to clinical trials: The promise of digital speech biomarkers in Parkinson's disease. *Neuroscience & Biobehavioral Reviews, 167*, 105922. https://doi.org/10.1016/j.neubiorev.2024.105922

Santiago, A., Langston, J. W., Gandhy, R., Dhall, R., Brillman, S., Rees, L., & Barlow, C. (n.d.). Qualitative Evaluation of the Personal KinetiGraphTM Movement Recording System in a Parkinson's Clinic. *Journal of Parkinson's Disease, 9*(1), 207–219. https://doi.org/10.3233/JPD-181373

Santos García, D., López Ariztegui, N., Cubo, E., Vinagre Aragón, A., García-Ramos, R.,... García Ruíz, P. (2023). Clinical utility of a personalized and long-term monitoring device for Parkinson's disease in a real clinical practice setting: An expert opinion survey on STAT-ONTM. *Neurología, 38*(5), 326–333. https://doi.org/10.1016/j.nrl.2020.10.013

Shaik, T., Tao, X., Li, L., Xie, H., & Velásquez, J. D. (2024). A survey of multimodal information fusion for smart healthcare: Mapping the journey from data to wisdom. *Information Fusion, 102*, 102040. https://doi.org/10.1016/j.inffus.2023.102040

Shen, M., Mortezaagha, P., & Rahgozar, A. (2025). Explainable artificial intelligence to diagnose early Parkinson's disease via voice analysis. *Scientific Reports, 15*(1), 11687. https://doi.org/10.1038/s41598-025-96575-6

Sigcha, L., Borzì, L., Amato, F., Rechichi, I., Ramos-Romero, C., Cárdenas, A., Gascó, L., & Olmo, G. (2023). Deep learning and wearable sensors for the diagnosis and monitoring of Parkinson's disease: A systematic review. *Expert Systems with Applications, 229*, 120541. https://doi.org/10.1016/j.eswa.2023.120541

Smits Serena, R., Hinterwimmer, F., Burgkart, R., von Eisenhart-Rothe, R., & Rueckert, D. (2025). The Use of Artificial Intelligence and Wearable Inertial Measurement Units in Medicine: Systematic Review. *JMIR mHealth and uHealth, 13*, e60521. https://doi.org/10.2196/60521

Stanslaski, S., Summers, R. L. S., Tonder, L., Tan, Y., Case, M., Raike, R. S., Morelli, N.,... On behalf of the ADAPT-PD Investigators. (2024). Sensing data and methodology from the Adaptive DBS Algorithm for Personalized Therapy in Parkinson's Disease (ADAPT-PD) clinical trial. *Npj Parkinson's Disease, 10*(1), 174. https://doi.org/10.1038/s41531-024-00772-5

Tabashum, T., Snyder, R. C., O'Brien, M. K., & Albert, M. V. (2024). Machine Learning Models for Parkinson Disease: Systematic Review. *JMIR Medical Informatics, 12*(1), e50117. https://doi.org/10.2196/50117

Tabassi, E. (2023). Artificial Intelligence Risk Management Framework (AI RMF 1.0) (No. NIST AI 100-1; p. NIST AI 100-1). *National Institute of Standards and Technology (U.S.)*. https://doi.org/10.6028/NIST.AI.100-1

The BRAIN Blog. (2025, March 6). BRAIN Initiative Research Leads to FDA Approval of Adaptive Deep Brain Stimulation for Parkinson's Disease. *BRAIN Initiative*. https://braininitiative.nih.gov/news-events/blog/brain-initiative-research-leads-fda-approval-adaptive-deep-brain-stimulation

The White House. (n.d.). Blueprint for an AI Bill of Rights | OSTP. *The White House*. Retrieved June 17, 2025, from https://bidenwhitehouse.archives.gov/ostp/ai-bill-of-rights/

Trevor Dermody. (2024, April 12). H2o Therapeutics' Apple Watch feature for Parkinson's gets FDA medical device listing. *MobiHealthNews*. https://www.mobihealthnews.com/news/h2o-therapeutics-apple-watch-feature-parkinsons-gets-fda-medical-device-listing

Valerio, J. E., Aguirre Vera, G. de J., Fernandez Gomez, M. P., Zumaeta, J., & Alvarez-Pinzon, A. M. (2025). AI-Driven Advances in Parkinson's Disease Neurosurgery: Enhancing Patient Selection, Trial Efficiency, and Therapeutic Outcomes. *Brain Sciences, 15*(5), 494. https://doi.org/10.3390/brainsci15050494

Virbel-Fleischman, C., Mousin, F., Liu, S., Hardy, S., Corvol, J. C., Benatru, I., ... & Grabli, D. (2023). Symptoms assessment and decision to treat patients with advanced Parkinson's disease based on wearables data. *npj Parkinson's Disease, 9*(1), 45. https://doi.org/10.1038/s41531-023-00489-x

Williams, S. (2025, February 24). The research behind adaptive deep brain stimulation for Parkinson's disease. *News Center*. https://med.stanford.edu/news/all-news/2025/02/deep-adaptive-brain-stimulation-parkinsons.html?utm_source=chatgpt.com

Willis, A. W., Roberts, E., Beck, J. C., Fiske, B., Ross, W., Savica, R., Van Den Eeden, S. K., Tanner, C. M., & Marras, C. (2022). Incidence of Parkinson disease in North America. *Npj Parkinson's Disease, 8*(1), 170. https://doi.org/10.1038/s41531-022-00410-y

Zhang, J. (2022). Mining imaging and clinical data with machine learning approaches for the diagnosis and early detection of Parkinson's disease. *Npj Parkinson's Disease, 8*(1), 13. https://doi.org/10.1038/s41531-021-00266-8