Smartwatch and arrhythmia : An Overview

Montres connectées et troubles du rythme cardiaque : Une mise au point

Mariem Jabeur, Selma Charfeddine, Rania Gargouri, Amine Bahloul, Leila Abid

University of Sfax, Medecine University of Sfax, Hedi Chaker University Hospital of SFAX, Department of Cardiology, 3000 Sfax, Tunisia

Summary

Smartwatches, initially designed for simple timekeeping and notifications, have evolved into sophisticated health monitoring devices, particularly in the detection and management of cardiac arrhythmias.

These wearable gadgets, equipped with an array of sensors, continuously record heart rate and other vital signs, facilitating real-time detection of cardiac irregularities.

The increasing popularity of smartwatches is driven by their convenience, accessibility, and ability to provide continuous physiological data, making them valuable tools for both individuals and healthcare providers. The integration of smartwatches into clinical practice, however, requires healthcare providers to be familiar with the technology to make well-informed decisions regarding diagnosis and treatment. This overview explores the capabilities of smartwatches in detecting and managing arrhythmias, focusing on their accuracy, clinical utility, and potential challenges in data interpretation and integration into clinical workflows.

Keywords

Smartwatch, Arrhythmia, Electrocardiography, PPG, Mobile Health, Atrial Fibrillation.

Résumé

L Initialement conçues pour indiquer l'heure et envoyer des notifications, les montres connectées ont évolué pour devenir des dispositifs sophistiqués de surveillance de l'état la santé, notamment dans la détection et la prise en charge des arythmies cardiaques.

Équipés de divers capteurs, ces appareils portables enregistrent en continu la fréquence cardiaque ainsi que d'autres paramètres vitaux, permettant ainsi une détection en temps réel des irrégularités du rythme cardiaque.

La popularité croissante des montres connectées s'explique par leur commodité, leur accessibilité et leur capacité à fournir des données physiologiques continues, ce qui en fait des outils précieux tant pour les individus que pour les professionnels de santé.

Cependant, l'intégration des montres connectées dans la pratique clinique nécessite que les professionnels de santé soient familiers avec cette technologie afin de prendre des décisions éclairées en matière de diagnostic et de traitement.

Cette revue explore les capacités des montres connectées dans la détection et la gestion des arythmies, en mettant l'accent sur leur précision, leur utilité clinique, ainsi que les défis potentiels liés à l'interprétation des données et à leur intégration dans les flux du travail clinique.

Mots-clés

Montre connectée, Arythmie, Électrocardiographie, PPG, Santé mobile, Fibrillation auriculaire

Correspondance

Mariem Jabeur, MD
Department of Cardiology. Hedi Chaker University Hospital, Sfax
Mariemjabeur2@gmail.com

INTRODUCTION

The proliferation of wearable technology, particularly smartwatches, has ushered in a new era of personal health monitoring, offering unprecedented opportunities for early detection and management of various health conditions. Smartwatches, equipped with an array of sensors, can continuously monitor vital signs such as heart rate, physical activity, and sleep patterns, providing a wealth of data that can be leveraged for proactive healthcare management (1,2). Among the most promising applications of smartwatches is the detection and monitoring of cardiac arrhythmias, irregularities in the heart's electrical system that can lead to serious complications such as stroke, heart failure, and sudden death (3). The integration of electrocardiogram technology into smartwatches, coupled with sophisticated algorithms, has enabled users to acquire on-demand ECG recordings and receive real-time arrhythmia interpretations (4). However, the widespread adoption of smartwatches in clinical practice necessitates a thorough understanding of their capabilities, limitations, and the challenges associated with data interpretation and clinical validation (5). This paper aims to provide a comprehensive overview of the use of smartwatches in arrhythmia detection, discussing the underlying technology, clinical evidence, challenges, and future directions in this rapidly evolving field.

SMARTWATCH TECHNOLOGY FOR ARRHYTHMIA DETECTION

Smartwatches employ a combination of photoplethysmography and electrocardiography to detect and monitor arrhythmias (6). Photoplethysmography utilizes light sensors to measure changes in blood volume in the peripheral circulation, providing an estimate of heart rate and rhythm (7). Electrocardiography, on the other hand, records the electrical activity of the heart through electrodes placed on the skin, offering a more detailed assessment of cardiac rhythm and morphology (8). The accuracy and reliability of smartwatch-based arrhythmia detection depend on several factors, including the quality of the sensors, the sophistication of the algorithms used for data processing, and the user's adherence to proper device usage (9). Despite their potential, concerns exist regarding the accuracy of these devices in active patients, particularly among the elderly who may find the small screen sizes and user interfaces challenging (6).

The development of wearable devices with embedded sensors has enabled the collection of data for analysis, catering to user needs and facilitating personalized services (10). The integration of advanced sensors, processors, and communication technologies in wearable devices presents a promising avenue for remote health monitoring, particularly for individuals diagnosed with cardiac arrhythmias, where sensor measurements can be used to predict the likelihood of cardiac failure (11). Modern smartwatches incorporate actigraphy to monitor rest and activity patterns, along with body position, offering comprehensive situational data that can be integrated with other physiological measurements. This holistic approach, shifting from reliance on patient ratings to automated assessment, could facilitate interventions targeting the phase preceding attacks and empower patients to use device feedback for self-directed behavioral changes (12).

CLINICAL EVIDENCE AND APPLICATIONS

The clinical utility of smartwatches in arrhythmia detection has been investigated in numerous studies, demonstrating their potential for identifying atrial fibrillation, the most common type of arrhythmia. Studies have shown that smartwatches can accurately detect atrial fibrillation with high sensitivity and specificity, comparable to traditional ECG monitoring devices (7). These devices, however, are likely to be superseded by handheld electrocardiographic devices, although similar predictive values have been calculated for handheld electrocardiographic devices using the investigator's data (13). The early detection of atrial fibrillation is crucial, as it can increase the risk of stroke and vascular dementia, especially in the elderly (14). Smartwatch-based arrhythmia detection can facilitate timely medical intervention, reducing the risk of adverse cardiovascular outcomes.

Smartwatches can also be used for continuous monitoring of patients with known arrhythmias, providing valuable insights into the frequency and duration of arrhythmia episodes. This information can aid in the management of arrhythmia, allowing for the optimization of medication dosages and the evaluation of treatment efficacy. Furthermore, the incorporation of smartwatches in clinical trials has been demonstrated to enhance patient participation, increase data precision, and provide robust, high-frequency data, improving the rigor and reliability of clinical research. Smartwatches provide the necessary resources and tools for patients to track their

health, adhere to treatment plans, and make informed decisions about their well-being, fostering a proactive approach to healthcare, and empowering patients to become partners in their health management (15). The detailed hemodynamic information gathered, facilitated by impedance cardiography, offers opportunities for personalized treatment strategies in managing hypertension, demonstrating the potential of wearable technology to refine treatment approaches based on individual patient profiles (16).

Continuous ECG monitoring using devices like Holter monitors has been employed to detect atrial fibrillation in high-risk patients experiencing palpitations, revealing the prevalence and management of AF (17). The diagnostic effectiveness of smartwatches for arrhythmia detection has been well-documented, particularly in identifying AF, with studies demonstrating comparable accuracy to traditional ECG monitoring devices (18). This capability is significant, especially considering that arrhythmias, including AF, can be asymptomatic and transient, making them challenging to diagnose through conventional methods (19).

CHALLENGES AND LIMITATIONS

Despite the promising potential of smartwatches in arrhythmia detection, several challenges and limitations need to be addressed. One major concern is the accuracy of these devices, which can be affected by factors such as motion artifacts, skin contact, and underlying medical conditions. Ensuring data security and privacy is also critical, as smartwatches collect sensitive health information that needs to be protected from unauthorized access. While mobile health technologies have the potential to lower costs and enhance outcomes in healthcare, their effectiveness hinges on the readiness of healthcare organizations to implement them, necessitating the standardization of processes and integration of mobile technology into established clinical pathways.

It's important to acknowledge that the data collected by wearable sensors may have limitations in accuracy, which can impact precise disease diagnosis and early treatment (20). Given that wearable devices will create more opportunities to monitor a person's health and capture more data to predict health risks, often more efficiently and in a more timely manner, it raises concerns as it allows for near-constant surveillance and the collection of excessive data that would otherwise have to remain unknown or uncollected (21).

While the use of smartwatches is growing in popularity for monitoring heart rate and rhythm in patients with cardiovascular disease (22), it is crucial to acknowledge the challenges related to data accuracy, security, and patient compliance. Although wearable devices can improve chronic disease monitoring and provide personalized interventions, it's important to tackle problems with data correctness, user participation, cost, and privacy (23). The integration of artificial intelligence with wearable technology holds significant potential for chronic disease management, but there is an urgent need to address the organization, analysis, and privacy protection of patient data (24,25).

The future of smartwatches in arrhythmia detection appears promising, with ongoing technological advancements and increasing clinical evidence supporting their use. Ongoing research is focused on improving the accuracy and reliability of these devices, as well as developing new algorithms for detecting a wider range of arrhythmias. With the rise of the Internet of Things, wearable devices have emerged as key contributors to the development of e-health, facilitating remote patient monitoring and disease management by automatically collecting and transmitting patient health data for analysis (26). In order to fully realize the potential of wearables in cardiovascular medicine, it is crucial to foster collaboration among healthcare providers, researchers, policymakers, and industry stakeholders (27).

The widespread adoption of wearable technologies holds great promise for shifting healthcare toward a proactive and personalized approach, ultimately leading to improved patient outcomes and reduced healthcare costs (27). Consumer health wearables are being increasingly utilized by patients and practitioners to identify and discuss symptoms, with some patients even suggesting treatments based on online search results (28). The integration of wearable technology and artificial intelligence in healthcare is expected to transform medical treatment models, enhance patient outcomes, reduce physician workload, and lower medical costs, representing a significant advancement in personalized medical treatment (29). Wearable computing is enabling more personalized healthcare by integrating vital-sign data, health-related behavioral data, environmental-exposure data with clinical and genetic data (30). Personalized health monitoring systems leverage wearable technology and artificial intelligence to provide real-time alerts, personalized insights, and comprehensive

CONCLUSION

In summary, smartwatches have emerged as a valuable tool for arrhythmia detection, offering continuous monitoring and early detection capabilities.

By providing continuous data streams and actionable insights, wearables empower individuals to take proactive measures to improve their cardiovascular health and facilitate early intervention when necessary

REFERENCES

1. Hughes A, Shandhi MMH, Master H, Dunn J, Brittain EL. Wearable Devices in Cardiovascular Medicine. Circulation Research [Internet]. Lippincott Williams & Wilkins; 2023 Mar 2 [cited 2025 Apr];132(5):652. Available from: https://doi.org/10.1161/circresaha.122.322389
2. Odeh VA, Chen Y, Wang W, Ding X. Recent Advances in the Wearable Devices for Monitoring and Management of Heart Failure. Reviews in Cardiovascular Medicine [Internet]. IMR Press; 2024 Oct 28 [cited 2025 Feb];25(10). Available from: https://doi.org/10.31083/j.rcm2510386
3. Shanmuganathan PKP, Sivaratri V. Integrating Deep Learning for Arrhythmia Detection with Automated Drug Delivery: A Comprehensive Approach to Cardiac Health Monitoring and Treatment. arXiv (Cornell University) [Internet]. 2024 Oct 18 [cited 2025 Feb];Available from: http://arxiv.org/abs/2410.19827
4. Doshi A, Ebert R, Grinnell J, Saxon LA. Consumer-facing Diagnostic Sensors in a Patient with Implantable Cardioverter-Defibrillator. Journal of Innovations in Cardiac Rhythm Management [Internet]. 2019 Sep 1 [cited 2025 Feb];10(9):3822. Available from: https://doi.org/10.19102/icrm.2019.100907
5. Bayoumy K, Gaber M, Elshafeey A, Mhaimeed O, Dineen EH, Marvel FA, et al. Smart wearable devices in cardiovascular care: where we are and how to move forward. Nature Reviews Cardiology [Internet]. Nature Portfolio; 2021 Mar 4 [cited 2025 Apr];18(8):581. Available from: https://doi.org/10.1038/s41569-021-00522-7
6. Hudock NL, Hughes H, Shaheen N, Ramadan A, Parikh K, Anamika F, et al. Wearable health monitoring: wave of the future or waste of time? Global Cardiology Science and Practice [Internet]. 2024 Apr 24 [cited 2025 Feb];2024(3). Available from: https://doi.org/10.21542/gcsp.2024.21
7. Mizuno A, Changolkar S, Patel MS. Wearable Devices to Monitor and Reduce the Risk of Cardiovascular Disease: Evidence and Opportunities. Annual Review of Medicine [Internet]. Annual Reviews; 2020 Sep 4 [cited 2025 Apr];72(1):459. Available from: https://doi.org/10.1146/annurev-med-050919-031534
8. Khan AH, Hussain M, Malik MK. Arrhythmia Classification Techniques Using Deep Neural Network. Complexity [Internet]. 2021 Jan 1 [cited 2025 Apr];2021(1). Available from: https://doi.org/10.1155/2021/9919588
9. Hosseini MM, Hosseini STM, Qayumi K, Hosseinzadeh S, Tabar SSS. Smartwatches in healthcare medicine: assistance and monitoring; a scoping review. BMC Medical Informatics and Decision Making [Internet]. BioMed Central; 2023 Nov 3 [cited 2025 Apr];23(1). Available from: https://doi.org/10.1186/s12911-023-02350-w
10. Garcia-Ceja E, Brena R, Carrasco-Jiménez JC, Garrido L. Long-Term Activity Recognition from Wristwatch Accelerometer Data. Sensors [Internet]. 2014 Nov 27 [cited 2025 Feb];14(12):22500. Available from: https://doi.org/10.3390/s141222500
11. Hussein D, Bhat G, Doppa JR. Adaptive Energy Management for Self-Sustainable Wearables in Mobile Health. Proceedings of the AAAI Conference on Artificial Intelligence [Internet]. 2022 Jun 28 [cited 2025 Feb];36(11):11935. Available from: https://doi.org/10.1609/aaai.v36i11.21451
12. Leibold N, Schruers K. Assessing Panic: Bridging the Gap Between Fundamental Mechanisms and Daily Life Experience. Frontiers in Neuroscience [Internet]. Frontiers Media; 2018 Oct 24 [cited 2025 Mar];12. Available from: https://doi.org/10.3389/fnins.2018.00785
13. Cheung CC, Gin K, Andrade JG. Watch Out [Internet]. Vol. 5, JACC. Clinical electrophysiology. Elsevier BV; 2019 [cited 2025 Feb]. p. 525. Available from: https://doi.org/10.1016/j.jacep.2019.02.008
14. Gregorio C de, Franco AD, Panno AV, Franco MD, Scaccianoce G, Campanella F, et al. Subclinical Atrial Fibrillation on Prolonged ECG Holter Monitoring: Results from the Multicenter Real-World SAFARI (Silent Atrial Fibrillation ANCE-Sicily Research Initiative) Study. Journal of Cardiovascular Development and Disease [Internet]. 2023 Aug 4 [cited 2025 Apr];10(8):336. Available from: https://doi.org/10.3390/jcdd10080336
15. Jeddi Z, Bohr A. Remote patient monitoring using artificial intelligence. In: Elsevier eBooks [Internet]. Elsevier BV; 2020 [cited 2025 Apr]. p. 203. Available from: https://doi.org/10.1016/b978-0-12-818438-7.00009-5
16. Wang L, Lu Y, Wang H, Gu J, Ma ZJ, Lian Z, et al. Effectiveness of an impedance cardiography guided treatment strategy to improve blood pressure control in a real- world setting: results from a pragmatic clinical trial. 2021.
17. Halimi F, Sabouret P, Huberman JP, Ouazana L, Guedj D, Djouadi K, et al. Atrial fibrillation detection with long-term continuous Holter ECG recording in patients with high cardiovascular risk and

clinical palpitations: the prospective after study. Clinical Research in Cardiology [Internet]. 2022 Sep 28 [cited 2025 Mar];112(6):807. Available from: https://doi.org/10.1007/s00392-022-02109-9

18. Hatamian FN, Ravikumar N, Vesal S, Kemeth FP, Struck M, Maier A. The Effect of Data Augmentation on Classification of Atrial Fibrillation in Short Single-Lead ECG Signals Using Deep Neural Networks. ICASSP 2022 - 2022 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) [Internet]. 2020 Apr 9 [cited 2025 Feb];1264. Available from: https://doi.org/10.1109/icassp40776.2020.9053800
19. Boulif A, Ananou B, Ouladsine M, Delliaux S. A Literature Review: ECG-Based Models for Arrhythmia Diagnosis Using Artificial Intelligence Techniques. Bioinformatics and Biology Insights [Internet]. SAGE Publishing; 2023 Jan 1 [cited 2025 Mar];17. Available from: https://doi.org/10.1177/11779322221149600
20. Shajari S, Kuruvinashetti K, Komeili A, Sundararaj U. The Emergence of AI-Based Wearable Sensors for Digital Health Technology: A Review. Sensors [Internet]. Multidisciplinary Digital Publishing Institute; 2023 Nov 29 [cited 2025 Apr];23(23):9498. Available from: https://doi.org/10.3390/s23239498
21. Mennella C, Maniscalco U, Pietro GD, Esposito M. Ethical and regulatory challenges of AI technologies in healthcare: A narrative review. Heliyon [Internet]. Elsevier BV; 2024 Feb 1 [cited 2025 Feb];10(4). Available from: https://doi.org/10.1016/j.heliyon.2024.e26297
22. Tamura T. Current progress of photoplethysmography and SPO2 for health monitoring. Biomedical Engineering Letters [Internet]. Springer Science+Business Media; 2019 Feb 1 [cited 2025 Apr];9(1):21. Available from: https://doi.org/10.1007/s13534-019-00097-w
23. Jafleh EA, Alnaqbi FA, Almaeeni HA, Faqeeh S, Alzaabi MA, Zaman KA. The Role of Wearable Devices in Chronic Disease Monitoring and Patient Care: A Comprehensive Review. Cureus [Internet]. Cureus, Inc.; 2024 Sep 8 [cited 2025 Apr]; Available from: https://doi.org/10.7759/cureus.68921
24. Channa A, Popescu N, Skibińska J, Bürget R. The Rise of Wearable Devices during the COVID-19 Pandemic: A Systematic Review. Sensors [Internet]. Multidisciplinary Digital Publishing Institute; 2021 Aug 28 [cited 2025 Apr];21(17):5787. Available from: https://doi.org/10.3390/s21175787
25. Xie Y, Lu L, Gao F, He S, Zhao H, Fang Y, et al. Integration of Artificial Intelligence, Blockchain, and Wearable Technology for Chronic Disease Management: A New Paradigm in Smart Healthcare. Current Medical Science [Internet]. 2021 Dec 1 [cited 2025 Apr];41(6):1123. Available from: https://doi.org/10.1007/s11596-021-2485-0
26. Meisami S, Meisami S, Yousefi M, Aref MR. Combining Blockchain and IoT for Decentralized Healthcare Data Management. International Journal on Cryptography and Information Security [Internet]. 2023 Mar 30 [cited 2025 Feb];13(1):35. Available from: https://doi.org/10.5121/ijcis.2023.13102
27. Bhaltadak V, Ghewade B, Yelne S. A Comprehensive Review on Advancements in Wearable Technologies: Revolutionizing Cardiovascular Medicine. Cureus [Internet]. Cureus, Inc.; 2024 May 29 [cited 2025 Apr]; Available from: https://doi.org/10.7759/cureus.61312
28. Piwek L, Ellis DA, Andrews S, Joinson A. The Rise of Consumer Health Wearables: Promises and Barriers. PLoS Medicine [Internet]. Public Library of Science; 2016 Feb 2 [cited 2025 Feb];13(2). Available from: https://doi.org/10.1371/journal.pmed.1001953
29. Liang J, Xian D, Liu X, Fu J, Zhang X, Tang B, et al. Usability Study of Mainstream Wearable Fitness Devices: Feature Analysis and System Usability Scale Evaluation. JMIR mhealth and uhealth [Internet]. 2018 Nov 8 [cited 2025 Feb];6(11). Available from: https://doi.org/10.2196/11066
30. Amft O. How Wearable Computing Is Shaping Digital Health. IEEE Pervasive Computing [Internet]. 2018 Jan 1 [cited 2025 Feb];17(1):92. Available from: https://doi.org/10.1109/mprv.2018.011591067