Evaluating Arrhythmia Alerts from Smartwatches in Asymptomatic Emergency Patients

Acil Servise Başvuran Asemptomatik Hastalarda Akıllı Saat Aritmi Uyarılarının Değerlendirilmesi

Ömerul Faruk AYDIN[1], Gülbin AYDOĞDU UMAÇ[2]

ABSTRACT

Smartwatches equipped with photoplethysmography (PPG) sensors are increasingly used for arrhythmia detection, yet their diagnostic accuracy in asymptomatic patients presenting to the emergency department (ED) remains underexplored. This study aimed to evaluate the performance of PPG-equipped smartwatches in detecting arrhythmias among asymptomatic patients and compare smartwatch-generated alerts with standard 12-lead electrocardiograms (ECG). This retrospective observational study included 523 asymptomatic patients who presented to a tertiary care ED over a one-year period with smartwatch-generated arrhythmia alerts. All patients underwent a standard 12-lead ECG upon arrival. Arrhythmias were categorized as atrial fibrillation (AF), sinus bradycardia, bundle branch block (BBB), or ischemic changes. Diagnostic metrics including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were calculated for each condition. Misclassification rates were analyzed to assess smartwatch limitations. Of the patients, 35.27% had abnormalities detected by ECG, including AF (18.2%), sinus bradycardia (10.9%), BBB (17.5%), and ischemic changes (25.5%). For AF, smartwatches demonstrated a sensitivity of 53.85%, specificity of 69.06%, PPV of 28.87%, and NPV of 86.52%, with an overall accuracy of 66.18%. Detection rates were lower for sinus bradycardia (sensitivity 30.36%) and ischemic changes (sensitivity 4.88%). Misclassification rates were particularly high for ischemic changes (95.7%), sinus bradycardia (70%), and BBB (75%). While smartwatches exhibit moderate utility for AF detection, their limited accuracy for other arrhythmias underscores the need for algorithmic improvements. Despite these limitations, smartwatches may serve as supplementary tools to encourage early medical attention in asymptomatic patients.

Keywords: Smartwatches, Photoplethysmography, Arrhythmias, Emergency Department, Diagnostic Accuracy

ÖZ

Fotopletismografi (FPG) sensörleriyle donatılmış akıllı saatler, aritmi tespiti için yaygınlaşmakta, ancak asemptomatik hastaların acil servise (AS) başvurusunda tanısal doğrulukları hakkında sınırlı bilgi bulunmaktadır. Bu çalışmada, asemptomatik hastalarda FPG sensörlü akıllı saatlerin aritmi tespit performansı değerlendirilmiş ve cihazlardan gelen uyarılar standart 12 derivasyonlu elektrokardiyografi (EKG) sonuçlarıyla karşılaştırılmıştır. Bu retrospektif gözlemsel çalışma, bir yıl boyunca üçüncü basamak bir sağlık merkezinde yürütülmüştür. Çalışmaya, AS'ye akıllı saatlerinden gelen aritmi uyarılarıyla başvuran 523 asemptomatik hasta dahil edilmiştir. Tüm hastalara başvurduklarında standart 12 derivasyonlu EKG uygulanmıştır. Aritmiler; atriyal fibrilasyon (AF), sinüs bradikardisi (SB), dal bloğu (DB) ve iskemik değişiklikler olarak sınıflandırılmıştır. Tanısal metrikler duyarlılık, özgüllük, pozitif öngörü değeri (POÖ), negatif öngörü değeri (NOÖ) ve genel doğruluk olarak hesaplanmış, cihazların sınırlamalarını belirlemek için yanlış sınıflandırma oranları analiz edilmiştir. Hastaların %35,27'sinde EKG ile aritmi tespit edilmiştir. En sık görülen bulgular AF (%18,2), SB (%10,9), DB (%17,5) ve iskemik değişikliklerdir (%25,5). AF için cihazların duyarlılığı %53,85, özgüllüğü %69,06, genel doğruluğu ise %66,18 bulunmuştur. İskemik değişikliklerin duyarlılığı %4,88 gibi düşük bir düzeyde olup yanlış sınıflandırma oranı %95,7 olarak oldukça yüksektir. Sonuç olarak, akıllı saatler AF tespiti için sınırlı doğruluk sunarken, diğer aritmilerdeki performansları algoritmaların iyileştirilmesi gerektiğini göstermektedir. Buna rağmen, asemptomatik hastalarda erken tıbbi başvuruya teşvik açısından faydalı bir araç olabilirler.

Anahtar Kelimeler: Akıllı Saatler, Fotopletismografi, Aritmiler, Acil Servis, Tanısal Performans

Ethical approval was obtained from the Memorial Şişli Hospital Institutional Ethics Committee (Approval Number: 004, Approval Date: 26.12.2024).

[1] Asst. Prof., MD, Ömerul Faruk AYDIN, Emergency Medicine, İstanbul Yeni Yüzyıl University, Department of Emergency Medicine, omerulfaruk.aydin@yeniyuzyil.edu.tr, ORCID: 0000-0002-4279-297X
[2] MD., Gülbin AYDOĞDU UMAÇ, Emergency Medicine, İzmir City Hospital, Department of Emergency Medicine, dr.gulbinaydogdu@gmail.com, ORCID: 0000-0002-9874-0343

İletişim / Corresponding Author: Ömerul Faruk AYDIN
e-posta/e-mail: omerulfaruk.aydin@yeniyuzyil.edu.tr

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INTRODUCTION

According to the World Health Organization, cardiovascular diseases, including myocardial infarction, stroke, heart failure, cardiac arrhythmias, and valvular heart disorders, account for approximately 45% of all deaths, causing an estimated 17.9 million deaths annually, making them a leading cause of mortality worldwide.[1] Among these conditions, arrhythmias account for 15-20% of all deaths and are a significant cause of concern due to their association with sudden cardiac death.[2,3] Their impact on mortality and morbidity is particularly pronounced in both the general population and in emergency departments (EDs), which serve as the initial point of care and advanced medical intervention.

In recent years, the widespread use of smartphones worldwide has also led to an increased adoption of wearable smart devices.[4] Among these wearable devices, smartwatches equipped with technologies such as electronics, software, sensors, actuators, and network connectivity offer a critical opportunity in the mobile technology market to monitor personal health in real-time, including cardiovascular health measures.[5] The frequent occurrence of arrhythmias and their impact on mortality epidemiology have led these sensors to focus increasingly on arrhythmia detection.

Smartwatches today are capable of monitoring biometric data, including oxygen saturation, sleep patterns, blood pressure, and heart rate, through various sensors. One of the most used sensors in smartwatches is photoplethysmography (PPG), which enables these devices to record single-lead electrocardiograms (ECG), measure pulse rates, and generate arrhythmia alerts. PPG is an optical measurement technique that noninvasively detects changes in blood volume within the microvascular system.[6] Smartwatch technology utilizes this method by detecting and measuring the user's peripheral pulse when the device is worn on the wrist. Advances in technology have enabled PPG-equipped devices to diagnose patients' heart rhythms within 30 seconds.[7]

When examining the symptoms of patients presenting to the ED, numerous life-threatening symptoms are reported, while asymptomatic presentations are relatively rare.[8] However, a disease can lead to severe outcomes even without symptoms, making research on asymptomatic emergency presentations limited.[9] Today, the advancement of wearable devices has introduced a new reason for emergency admissions: alerts generated by the device indicating a "pathological condition." If such an alert occurs without accompanying symptoms, it necessitates both the confirmation of its accuracy and the early detection and management of the pathological condition. In these scenarios, emergency departments serve as the first point of contact due to the acute nature of the situation.

The perception of heart rhythm abnormalities varies significantly among individuals. Palpitations are the most reported symptom in patients with various types and durations of cardiac rhythm disturbances. However, while some patients are acutely aware of minor irregularities in their heartbeat, others may remain completely unaware of rapid tachyarrhythmia episodes. Arrhythmias such as atrial fibrillation (AF), persistent supraventricular tachycardia (SVT), and non-sustained ventricular tachycardia (NSVT), even when asymptomatic, can have significant implications for patient outcomes.[10,11] At this point, the potential of technologically advanced smartwatches capable of dynamic monitoring for early diagnosis and treatment remains underexplored, placing these devices in a strategically important position.

This study aims to evaluate the characteristics of patients presenting to the ED with arrhythmia alerts generated by Photoplethysmography (PPG)-Equipped Smartwatches despite being asymptomatic, as well as to assess the sensitivity and specificity of arrhythmia detection in asymptomatic patients.

METHODS

Study Design and Setting

This retrospective, observational study was conducted at Memorial Şişli Hospital, a tertiary care center, over a one-year period. The study focused on assessing the diagnostic accuracy of photoplethysmography-equipped smartwatches in detecting arrhythmias among asymptomatic patients presenting to the ED. Ethical approval was obtained from the Memorial Şişli Hospital Institutional Ethics Committee (Approval Number: 004, Approval Date: 26.12.2024).

Study Population

Patients included in the study were those presenting with arrhythmia alerts generated by smartwatches equipped with PPG sensors. Eligible patients were asymptomatic at the time of presentation and underwent a standard 12-lead electrocardiogram upon arrival. Patients with incomplete data or missing smartwatch arrhythmia alerts were excluded. Additionally, cases involving pre-existing arrhythmia diagnoses under alternative monitoring methods were not included.

Arrhythmia Classification

Arrhythmias were categorized based on standard definitions.[12] Bradyarrhythmias included findings such as sinus bradycardia and atrioventricular block, defined as heart rates below 55 bpm. Tachyarrhythmias encompassed conditions such as AF, atrial flutter, and ventricular tachycardia, defined as heart rates at or exceeding 100 bpm. Ischemic abnormalities were characterized by the presence of pathologic Q waves, abnormal ST segments, or T waves. Cases without any arrhythmias were classified as normal sinus rhythm.

Data Collection

Demographic information, such as age and gender, along with smartwatch models and clinical findings, were retrieved from patient records. Smartwatch models included various brands capable of generating arrhythmia alerts. Each alert was compared with the corresponding findings from the standard 12-lead electrocardiogram performed at the ED. Diagnostic agreement between smartwatch-detected arrhythmias and electrocardiographic findings was analyzed.

Diagnostic Performance Metrics

The diagnostic performance of the smartwatches was evaluated in terms of sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy. These metrics were calculated using confusion matrices, and confidence intervals at 95% were estimated using the Wilson score method. Misclassification trends were identified for each arrhythmia type to assess the limitations of smartwatch-based detection.

Analysis

The data were analyzed using SPSS (version 30.0, IBM Corp, Armonk, NY). Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated using confusion matrices to evaluate the diagnostic performance of the smartwatch compared to standard 12-lead ECG. Confidence intervals (95%) for these metrics were calculated using the Wilson score method. Descriptive statistics, including mean ± standard deviation for age and proportions for categorical variables (e.g., gender and diagnoses), were used to summarize the study population.

RESULTS AND DISCUSSION

During the one-year study period, 523 asymptomatic patients presented to the emergency department due to arrhythmia alerts generated by smartwatches with photoplethysmography sensors, among whom 275 were found to have acute cardiac changes on bedside electrocardiograms at presentation and were included in the analysis; of these patients, approximately 47% (n = 129) used an Apple Watch, 23% (n = 63) a Samsung Galaxy Watch, 12% (n = 33) a Fitbit Sense,

9% (n = 25) a Withings ScanWatch, and 9% (n = 25) an AliveCor KardiaMobile.

The mean age of the cohort was 45 ± 11.4 years, and 60% were male. Despite being asymptomatic, only 35.27% of patients were found to have at least one abnormality correctly detected by their smartwatch when compared to standard 12-lead electrocardiograms. The most frequently observed abnormalities on standard ECG included atrial fibrillation in 18.2% of cases, sinus bradycardia in 10.9%, bundle branch block in 17.5%, and ischemic changes in 25.5% (Table 1).

The smartwatch demonstrated variable diagnostic performance across conditions. For AF, sensitivity was 53.85%, and specificity was 69.06%, with a positive predictive value (PPV) of 28.87% and a negative predictive value (NPV) of 86.52% (Table 2). The overall accuracy for detecting AF was 66.18%. Sinus bradycardia detection was less effective, with a sensitivity of 30.36% and specificity of 63.47%, yielding an accuracy of 56.73%. Similarly, for bundle branch block (BBB), sensitivity was 25.93%, specificity was 62.44%, and overall accuracy was 55.27%. For ischemic changes, sensitivity dropped to 4.88%, while specificity was moderately high at 59.40%. The smartwatch struggled particularly with ischemic findings, as only 4.3% of ischemic changes detected by standard ECG were identified.

Table 1. Prevalence of Abnormalities Detected by Smartwatches Compared to 12-Lead Electrocardiograms

Diagnosis	Prevalence (%)
Any abnormality	35.27
Atrial fibrillation (AF)	18.2
Sinus bradycardia	10.9
Bundle branch block (BBB)	17.5
Ischemic changes (ST/T-wave)	25.5

Table 2. Diagnostic Performance of Smartwatches in Detecting Arrhythmias

Rhythm/Condition	Sensitivity (%) [95% CI]	Specificity (%) [95% CI]	PPV (%) [95% CI]	NPV (%) [95% CI]	Accuracy(%) [95% CI]
AF	53.85 [43–64]	69.06 [60–77]	28.87 [20–39]	86.52 [79–92]	66.18 [59–73]
Sinus bradycardia	30.36 [20–43]	63.47 [54–72]	17.53 [10–27]	78.09 [69–85]	56.73 [50–64]
BBB	25.93 [16–38]	62.44 [53–71]	14.43 [8–24]	77.53 [68–84]	55.27 [48–62]
Ischemic changes (ST/T-wave)	4.88[1–13]	59.40 [50–68]	2.06 [0.5–7]	78.09 [69–85]	51.27 [45–59]

AF: Atrial fibrillation; BBB: Bundle branch block; PPV: Positive Predictive Value; NPV: Negative Predictive Value

Misclassifications were common across all conditions. Among 50 patients with confirmed atrial fibrillation, 46% were misclassified as “normal” by the smartwatch (Table 3 and 4). For sinus bradycardia and bundle branch block, misclassification rates were 70% and 75%, respectively. The majority of ischemic changes (95.7%) were also misclassified as normal rhythms, reflecting the device’s limited ability to detect abnormalities outside Lead I.

In terms of clinical relevance, smartwatch alerts provided minimal additional value in identifying ischemic heart disease, as only 3 cases of ischemic changes were detected compared to 70 on standard ECG.

Table 3. Analysis of Misclassifications

Condition	Total Cases	Misclassified Cases (n)	Type of Misclassification	Frequency (%)
AF	50	23	Classified as "Normal"	46.0
Sinus bradycardia	30	21	Classified as "Normal"	70.0
BBB	48	36	Classified as "Normal"	75.0
Ischemic changes (ST/T-wave)	70	67	Classified as "Normal"	95.7

AF: Atrial fibrillation; **BBB:** Bundle branch block

Table 4. Distribution of Abnormalities Detected by Smartwatch vs. 12-lead ECG

Condition	Detected by Smartwatch (n)	Detected by 12-lead ECG (n)	Proportion Correctly Identified (%)
AF	27	50	54.0
Sinus bradycardia	9	30	30.0
BBB	12	48	25.0
Ischemic changes (ST/T-wave)	3	70	4.3

AF: Atrial fibrillation; **BBB:** Bundle branch block; **ECG:** Electrocardiogram

Today, smartwatches equipped with PPG sensors offer promising non-invasive technology for detecting arrhythmia. However, the diagnostic limitations of these devices remain a frequently debated topic. Considering that asymptomatic arrhythmia is thought to contribute more to mortality and morbidity than symptomatic ones, this study's finding that 35.27% of asymptomatic patients presenting to the emergency department had abnormalities detected on ECG highlights the technology's diagnostic potential. Although it remains below the gold standard of dynamic rhythm monitoring, the ability of these devices to encourage patients to seek emergency care positions them as a valuable tool in clinical practice. From this perspective, our study suggests that smartwatches function as a passive monitoring system for asymptomatic cardiac arrhythmia. Although their detection capabilities show limited concordance with ECG results, they offer a promising opportunity for identifying arrhythmias that patients might otherwise remain unaware of due to their asymptomatic nature.

Smartwatches are not designed to diagnose, treat, cure, mitigate, or prevent any disease or medical condition, and they are not recommended as a replacement for traditional ECG or medical advice.[13] This is because they have several limitations, such as reliance on a single sensor and susceptibility to errors from usage or calibration, which can sometimes result in either a lack of alerts or false alerts. In our study, smartwatches were observed to detect abnormalities concordant with standard 12-lead ECG in only 35.27% of asymptomatic patients presenting to the ED.

While studies in literature frequently focus on the accuracy of smartwatch alerts in symptomatic patients, research on asymptomatic individuals remains limited. Apple, in an internal study, claims that its algorithm demonstrates 98% sensitivity and 99% specificity in classifying AF and normal sinus rhythm.[14] In other studies, among patients who received an AF notification from their smartwatch, ECG results confirmed atrial fibrillation in 153 patients (34%).[15] This percentage is similar to the findings of our study; however, our research extends its focus to all arrhythmia and ECG abnormalities. In this regard, the judicious use of smartwatches can be life-saving, particularly in detecting asymptomatic arrhythmias, which might otherwise go unnoticed.

Studies have shown that smartphones achieve high specificity (94%) and sensitivity (96%) in detecting AF, while smartwatches exhibit lower sensitivity when compared to medical-grade devices.[16] In our study, we observed a sensitivity of 53.85% and a specificity of 69.06% for smartwatches in detecting AF. While these devices demonstrate limited yet partially effective capability in identifying this common arrhythmia, the overall accuracy rate of 66.18% suggests that they could serve as a supportive tool for AF diagnosis. However, the potential impact of false-negative and false-positive results on clinical decisions should not be overlooked. High sensitivity and specificity for AF detection are frequently highlighted as advantages in studies, particularly for early identification in asymptomatic patients. Our findings support these assertions and align with existing literature, emphasizing the value of smartwatches in this context.[17] However, as observed in our study, monitoring patients with a low likelihood of arrhythmia can increase the rate of false positives, underscoring the need for cautious interpretation of smartwatch-generated alerts.

Cardiac arrhythmias are associated with significant mortality, morbidity, and financial burden and, one of the primary limitations of conventional screening tools in detecting arrhythmias is the transient nature of arrhythmia episodes.[18] Wearable devices, therefore, offer opportunities for dynamic and long-term monitoring of arrhythmia. In our study, diagnostic performance was observed to be even lower for sinus bradycardia (sensitivity 30.36%, specificity 63.47%) and bundle branch block (sensitivity 25.93%, specificity 62.44%). In recent years, research has increasingly focused on wearable devices for screening and early detection of undiagnosed atrial fibrillation (AF), with notable improvements in success rates over time.[19] Consequently, the specificity of smartwatches and wearable devices in detecting AF is steadily improving.[20] The U.S. Food and Drug Administration (FDA) has even granted approval for certain smartwatches to detect atrial fibrillation. However, significant limitations persist in detecting ischemic changes, often leading to misinterpretations.[21] Accurate detection of bundle branch blocks and bradycardia highlights the importance of smartwatch placement, with the wrist being the most reliable site for measurement. Despite being worn on the wrist, our study did not achieve the success rates reported in current literature for detecting all arrhythmias.[22] We attribute this primarily to the asymptomatic nature of our study group. We believe that the use of smartwatches in screening may yield different success rates compared to symptomatic presentations in healthcare settings. This highlights the need for studies involving larger and more diverse research groups to better understand the diagnostic potential of wearable devices.

CONCLUSION

This study evaluated the diagnostic performance of smartwatches equipped with photoplethysmography sensors in detecting arrhythmias in asymptomatic patients presenting to the ED, compared to standard ECG. The findings revealed that smartwatches could detect abnormalities in only 35.27% of cases. While the devices demonstrated moderate success in detecting AF, with a sensitivity of 53.85% and specificity of 69.06%, their performance was notably lower for bradycardia, bundle branch block, and ischemic changes. High rates of misclassification, particularly for ischemic changes and more complex arrhythmia, emphasize the need for cautious interpretation of smartwatch alerts and reinforce that these devices should not replace standard diagnostic methods. Despite these limitations, smartwatches provide valuable insights and play a significant role in encouraging health-seeking behavior. However, this study highlights the current limitations of smartwatches in detecting arrhythmias in asymptomatic patients presenting to EDs.

Limitations

This study is limited by its retrospective design and single-center setting, which may affect generalizability. The analysis focused solely on asymptomatic patients and relied on smartwatch alerts from various brands, potentially introducing variability in detection performance. User-related factors, such as incorrect device usage, were not assessed, and long-term clinical outcomes of undetected abnormalities were not explored. High misclassification rates, particularly for ischemic changes, underscore the need for improved algorithms.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Ö.F.A.: Conceptualization, data collection, formal analysis, writing – original draft, project administration. G.A.U.: Methodology, formal analysis, writing – review and editing, supervision. All authors have read and approved the published version of the manuscript.

References

1. World Health Organization (WHO). Cardiovascular diseases. [Internet]. 2025 [Accessed: March 18, 2025]. Available from: https://www.who.int/health-topics/cardiovascular-diseases
2. Srinivasan NT, Schilling RJ. Sudden Cardiac Death and Arrhythmias. Arrhythm Electrophysiol Rev. 2018;7(2):111-7. https://doi.org/10.15420/aer.2018:15:2.
3. Gaur U, Gadkari C, Pundkar A. Associated Factors and Mortality of Arrhythmia in Emergency Department: A Narrative Review. Cureus. 2024;16(9):e68645. https://doi.org/10.7759/cureus.68645
4. Case MA, Burwick HA, Volpp KG, Patel MS. Accuracy of Smartphone Applications and Wearable Devices for Tracking Physical Activity Data. JAMA. 2015;313(6):625-6. https://doi.org/10.1001/jama.2014.17841
5. Hickey AM, Freedson PS. Utility of Consumer Physical Activity Trackers as an Intervention Tool in Cardiovascular Disease Prevention and Treatment. Prog Cardiovasc Dis. 2016;58(6):613-9. https://doi.org/10.1016/j.pcad.2016.02.006
6. Allen J. Photoplethysmography and its application in clinical physiological measurement. Physiol Meas. 2007;28(3):R1-39. https://doi.org/10.1088/0967-3334/28/3/r01
7. Turakhia MP, Desai M, Hedlin H, Rajmane A, Talati N, Ferris T, et al. Rationale and design of a large-scale, app-based study to identify cardiac arrhythmias using a smartwatch: The Apple Heart Study. Am Heart J. 2019;207:66-75. https://doi.org/10.1016/j.ahj.2018.09.002
8. Weigel K, Nickel CH, Malinovska A, Bingisser R. Symptoms at presentation to the emergency department: Predicting outcomes and changing clinical practice? Int J Clin Pract. 2018;72(1). https://doi.org/10.1111/ijcp.13033
9. Wong CX, Brown A, Lau DH, Chugh SS, Albert CM, Kalman JM, et al. Epidemiology of Sudden Cardiac Death: Global and Regional Perspectives. Heart Lung Circ. 2019;28(1):6-14. https://doi.org/10.1016/j.hlc.2018.08.026
10. Boriani G, Valzania C, Biffi M, Diemberger I, Ziacchi M, Martignani C. Asymptomatic lone atrial fibrillation - how can we detect the arrhythmia? Curr Pharm Des. 2015;21(5):659-66. https://doi.org/10.2174/1381612820666140825142639
11. Mairesse GH, Moran P, Van Gelder IC, Elsner C, Rosenqvist M, Mant J, et al. Screening for atrial fibrillation: a European Heart Rhythm Association (EHRA) consensus document endorsed by the Heart Rhythm Society (HRS), Asia Pacific Heart Rhythm Society (APHRS), and Sociedad Latinoamericana de Estimulación Cardíaca y Electrofisiología (SOLAECE). Europace. 2017;19(10):1589-623. https://doi.org/10.1093/europace/eux177
12. Caillol T, Strik M, Ramirez FD, Abu-Alrub S, Marchand H, Buliard S, et al. Accuracy of a Smartwatch-Derived ECG for Diagnosing Bradyarrhythmias, Tachyarrhythmias, and Cardiac Ischemia. Circulation: Arrhythmia and Electrophysiology. 2021;14(1):e009260. https://doi.org/10.1161/CIRCEP.120.009260
13. AFib Institute. Atrial Fibrillation: A Guide to Wearable ECG Smart Watches. [Internet]. [Accessed: March 18, 2025]. Available from: https://afibinstitute.com.au/atrial-fibrillation-a-guide-to-wearable-ecg-smart-watches/
14. American College of Cardiology. Apple Heart Study Identifies AFib in Small Group of Apple Watch Wearers. [Internet]. 2019 [Accessed: March 18, 2025]. Available from: https://www.acc.org/Latest-in-Cardiology/Articles/2019/03/08/15/32/sat-9am-apple-heart-study-acc-2019
15. Perez MV, Mahaffey KW, Hedlin H, Rumsfeld JS, Garcia A, Ferris T, et al. Large-Scale Assessment of a Smartwatch to Identify Atrial Fibrillation. N Engl J Med. 2019;381(20):1909-17. https://doi.org/10.1056/nejmoa1901183
16. Prasitlumkum N, Cheungpasitporn W, Chokesuwattanaskul A, Thangjui S, Thongprayoon C, Bathini T, et al. Diagnostic accuracy of smart gadgets/wearable devices in detecting atrial fibrillation: A systematic review and meta-analysis. Arch Cardiovasc Dis. 2021;114(1):4-16. https://doi.org/10.1016/j.acvd.2020.05.015
17. American College of Cardiology [Internet]. Smartwatches and Atrial Fibrillation: What Works and What Needs Improvement? Available from: https://www.acc.org/Latest-in-Cardiology/Articles/2024/05/29/16/56/http%3a%2f%2fwww.acc.org%2fLatest-in-Cardiology%2fArticles%2f2024%2f05%2f29%2f16%2f56%2fSmartwatches-and-Atrial-Fibrillation
18. Pay L, Çağdaş Yumurtaş A, Iltaf Satti D, Man Ho Hui J, Shi Kai Chan J, Mahalwar G, et al. Arrhythmias Beyond Atrial Fibrillation Detection Using Smartwatches: A Systematic Review. Anatol J Cardiol. 2023;27(3):126-31. https://doi.org/10.14744/AnatolJCardiol.2023.2799
19. Lubitz SA, Faranesh AZ, Selvaggi C, Atlas SJ, McManus DD, Singer DE, et al. Detection of Atrial Fibrillation in a Large Population Using Wearable Devices: The Fitbit Heart Study. Circulation. 2022;146(19):1415-24. https://doi.org/10.1161/circulationaha.122.060291
20. Avram R, Ramsis M, Cristal AD, Nathan V, Zhu L, Kim J, et al. Validation of an algorithm for continuous monitoring of atrial fibrillation using a consumer smartwatch. Heart Rhythm. 2021;18(9):1482-90. https://doi.org/10.1016/j.hrthm.2021.03.044
21. Buelga Suárez M, Pascual Izco M, Pastor Pueyo P, Lozano Granero C, García Montalvo J, Alonso Salinas GL. Smartwatch ECG Tracing and Ischemic Heart Disease: ACS Watch Study. Cardiology. 2023;148(1):78-82. https://doi.org/10.1159/000528116
22. Ploux S, Strik M, Caillol T, Ramirez FD, Abu-Alrub S, Marchand H, et al. Beyond the wrist: Using a smartwatch electrocardiogram to detect electrocardiographic abnormalities. Arch Cardiovasc Dis. 2022;115(1):29-36. https://doi.org/10.1016/j.acvd.2021.11.003