ATRIAL FIBRILLATION –
WHAT ARE THE BENEFITS OF M-HEALTH?

Migotanie przedsionków –
co daje nam m-health?

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Abstract

The development of mobile technologies has led to a growing popularity of health-related applications (m-health/mobile health). Some of these devices enable users to register single-lead electrocardiograms, which can facilitate diagnosis and help prevent complications associated with the most common arrhythmias, such as atrial fibrillation. This study reviews the performance of devices based on oscillometry and plethysmography, as well as those capable of generating ECG recordings that may serve as a basis for atrial fibrillation diagnosis. Given the increasing prevalence of modern technologies across diverse population groups (including healthy individuals, physically active people, and patients with diagnosed cardiovascular disease), it is essential to consider the limitations associated with their use.

Streszczenie

Rozwój technologii mobilnych spowodował wzrost popularności aplikacji związanych ze zdrowiem (m-health/mobile health). Część z tych urządzeń pozwala na rejestrację jednoodprowadzeniowego elektrokardiogramu, co może ułatwiać diagnostykę i zapobieganie powikłaniom najczęstszych arytmii, np. migotania przedsionków. W pracy omówiono działanie urządzeń opartych na oscylometrii i pletyzmografii oraz takich, które pozwalają na uzyskanie zapisu elektrokardiogramu i mogą stanowić podstawę rozpoznania migotania przedsionków. Ze względu na rosnącą powszechność wykorzystania nowoczesnych technologii w różnych grupach populacyjnych (w tym osób zdrowych, aktywnych fizycznie oraz pacjentów z rozpoznanymi schorzeniami układu krążenia), niezbędne jest uwzględnienie ograniczeń związanych z ich zastosowaniem.

Introduction

With the widespread adoption of smartphones and other mobile devices, the popularity of health-related applications (m-health/mobile health) has been steadily increasing. Some of these apps allow users to monitor parameters such as blood pressure or body weight, replacing traditional paper logs. Others enable the recording of heart rate or single-lead electrocardiograms (ECG), either as standalone tools or in combination with a dedicated device.

ECG monitoring via mobile devices can serve as a method for detecting asymptomatic arrhythmias – potential causes of severe yet preventable complications. A notable example is atrial fibrillation (AF), where complications can be prevented through anticoagulant therapy. Beyond clinical settings, these tools can also support individuals at increased risk of cardiac events due to lifestyle factors, pre-existing health conditions, or the type of sports they practise.

Aim of study

The aim of this study is to present the available methods of ECG monitoring using mobile devices and their efficacy in detecting the most common arrhythmia, which is AF.

Diagnosis of atrial fibrillation

AF has an estimated prevalence of 1–2% [1]. However, because many patients remain asymptomatic and therefore undiagnosed, the true prevalence of this condition is likely underestimated. According to the 2024 European Society of Cardiology (ESC) guidelines for the management of atrial fibrillation, the gold standard for diagnosing AF is an ECG recording, regardless of the number of leads [2]. This means that AF can also be diagnosed using single-lead recordings, such as those obtained from mobile devices. The guidelines additionally introduce the concept of device-detected subclinical AF, which – although insufficient for establishing a definitive diagnosis – serves as a prognostic marker for future AF [2].

Available technologies

The 2024 ESC guidelines divide the available rhythm-assessment tools into diagnostic and non-diagnostic categories [2]. The former include standard 12-lead ECG, Holter monitoring, telemetry, handheld devices, dedicated patches, biotextiles, and smart devices (watches and smartphones). These tools allow for the acquisition of single- or multi-lead ECG recordings. It is worth noting that the first three options are limited to outpatient or hospital settings. Tools classified as non-diagnostic are based solely on heart rhythm assessment using plethysmography, oscillometry, accelerometry, mechanocardiography, acoustic analysis, or pulse palpation. They do not allow for recording an ECG trace, and a diagnosis cannot be established on their basis. However, abnormalities detected by these devices may indicate an increased risk of arrhythmia and prompt further diagnostic evaluation.

Oscillometry

Oscillometric analysis is used in automatic blood pressure monitors. This method relies on detecting changes in the volume of the limb enclosed by the cuff, depending on the cuff-inflation pressure. In addition to determining systolic and diastolic blood pressure values, the measurement also provides the heart rate [3].

By measuring pulse intervals during gradual deflation of the cuff, the device can calculate both the mean value and the standard deviation of the intervals, which in turn allows the determination of an irregularity index. Based on this, the device can classify the rhythm as regular or irregular, resulting in a notification indicating a potential risk of arrhythmia [4].

Pucci et al. compared the effectiveness of AF screening using the Microlife WatchBP blood pressure monitor with standard 12-lead ECG [5]. The study population consisted of patients admitted to an internal medicine ward. The sensitivity of the blood pressure monitor for AF detection was 86%, while specificity reached 96%. The authors noted that false-negative results were associated with AF presenting with regular ventricular activity (QRS complexes). Among patients with newly diagnosed AF, the device demonstrated 100% effectiveness.

Photoplethysmography

Photoplethysmography (PPG) is a method based on assessing variations in blood volume within blood vessels by analysing changes in the parameters of a reflected light beam. This enables measurement of the periodic rise and fall in vascular filling, allowing determination of a time interval equivalent to the R-R interval on an ECG. A smartphone camera can be used to record the reflected light, with a fingertip placed over the lens. The application installed on the device then evaluates rhythm regularity and informs the user of potential abnormalities [6].

Chan et al. evaluated the effectiveness of AF detection using the Cardiio Rhythm app on an iPhone 4S [7]. Each of the three PPG recordings performed was classified as either regular or irregular; if at least two out of three were determined to be irregular, the application identified AF. The sensitivity of this method was approximately 93%, with a specificity of nearly 98%. The authors noted potential difficulties in obtaining a correct recording, such as motion artifacts from finger movement and inadequate finger placement on the camera. The study also compared the above method with the performance of the AliveCor Heart Monitor, which provides a single-lead ECG recording. The specificity of both methods was comparable; however, the sensitivity of the automatic AliveCor algorithm was 71.4%, a lower value than reported in the earlier study by Lau et al. [8], where sensitivity reached 98%. The authors emphasised that the discrepancy between the two studies may be related to Chan et al. using a newer version of the application.

Handheld devices

Handheld devices allow the recording of a single-lead ECG. An example is the Beurer ME90 [9]. The tracing is

obtained by placing the index fingers on the sensor, which enables acquisition of lead I. The built-in algorithm performs real-time analysis of the recording and, through messages displayed on the screen, informs the user whether the tracing is normal ("OK") or whether an arrhythmia ("Rhythm"), a pause ("Pause"), or an abnormal QRS morphology ("Wave") has been detected. Additionally, it provides information on the heart rate. The device allows results to be displayed on a smartphone via Bluetooth and enables data export to a computer via USB (Universal Serial Bus).

A study conducted by Brito et al. evaluated the effectiveness of the Beurer ME90's built-in algorithm in detecting atrial fibrillation and atrial flutter compared with a standard 12-lead ECG. An alternative device placement was also tested by positioning it parasternal on the left side to obtain a modified V4 lead. It was shown that for lead I recordings, sensitivity was 88.9% and specificity was 61.9%, with false-negative results occurring exclusively in cases of atrial flutter. The use of the modified V4 lead in combination with lead I increased specificity to 84.3% [10].

KardiaBand

KardiaBand is an optional accessory for the Apple Watch that enables single-lead ECG recording. It is a wristband that can replace the standard watch strap. It contains a sensor that records an ECG tracing when the user places a finger from the opposite hand on its surface. The band connects to the smartwatch via Bluetooth and can also be paired with an iPhone [11].

Bumgarner et al. compared the effectiveness of distinguishing sinus rhythm from AF in patients scheduled for electrical cardioversion [12]. Each participant underwent a standard ECG recording, followed by a KardiaBand recording. Each tracing was then evaluated by two physicians, who classified the rhythm into one of four categories: sinus rhythm, AF, atrial flutter, or unclassified. The interpretation generated by the device's automatic algorithm was also compared with the physicians' assessments.

Overall, the algorithm achieved a sensitivity of 93% and a specificity of 84%. However, a substantial proportion of KardiaBand tracings (57 out of 169) remained unclassified by the algorithm. According to the authors, this was primarily due to insufficient recording duration, low P-wave amplitude, or the presence of artifacts. A clinician-led review of these unclassified recordings provided further insight: AF was confirmed in all 14 AF cases, but 5 out of 25 sinus rhythm recordings were incorrectly classified as AF (80% specificity). When all KardiaBand recordings were interpreted by clinicians and compared with a standard ECG, the sensitivity for detecting AF increased to 99%, with a specificity of 83%.

The authors note that the demonstrated efficacy of the band in detecting AF is comparable to that of implantable loop recorders, and they highlight the strong correlation between KardiaBand tracings and standard 12-lead ECG recordings. They conclude that the KardiaBand is highly effective for AF detection; however,

final interpretation of the recordings should still be supported by clinician review.

Kardia Mobile

Kardia Mobile is a device designed to work with smartphones and tablets. It is shaped like a small plate with metal electrodes on both sides. To record an ECG, the user opens the dedicated Kardia app and selects the recording option. The tracing is then obtained by placing the index and middle fingers of both hands on the electrodes, producing a recording comparable to lead I of a standard ECG. The recording time is 30 seconds, after which the tracing is wirelessly transmitted to the connected smart device. The app's automatic algorithm analyses the recording and generates one of the following messages: "interference," "normal," "AF," or "unclassified" if the tracing is unsuitable for interpretation. Data export in PDF format is also available. The device is compatible with most Apple and Android systems [13, 14].

Kołtowski et al. compared the effectiveness of AF detection using ECG recordings from the Kardia Mobile device with that of a standard 12-lead ECG [14]. The sensitivity for detecting AF was 92.8%, and the specificity was 100%. It is worth noting that the study did not assess the performance of the automatic algorithm, as the recordings were interpreted by physicians based on printed exports of the data.

Apple Watch

The Apple Watch Series 4 is a smartwatch equipped with two electrodes that enable single-lead ECG recording. One electrode is located beneath the watch face, and the other on its lateral surface. Recording is performed by resting the arm wearing the watch on a stable surface and touching the side electrode with a finger of the opposite hand. The resulting tracing is analysed by an algorithm, after which the user receives one of four feedback messages: sinus rhythm (if the heart rate is between 50–100 beats/min), AF (irregular rhythm 50–120 beats/min), low or high heart rate, or inconclusive (when the tracing cannot be reliably interpreted). Similar to the Kardia Mobile device, results can be presented on an iPhone screen and exported in PDF format. It is worth noting that when the heart rate is below 50 beats/min or above 120 beats/min, algorithmic interpretation may be impaired, resulting in an inconclusive outcome [15].

Shahid et al. conducted a meta-analysis of studies evaluating the effectiveness of the Apple Watch compared with a standard 12-lead ECG [16]. The review included 11 studies with a total of 4,241 participants with diverse clinical profiles. The device demonstrated high accuracy in detecting AF, with a sensitivity of 94.8% and a specificity of 95%. The authors emphasised that despite the considerable heterogeneity of the study populations, restricting the analysis to patients with AF reduced this variability, supporting the consistency of the available evidence. However, they also highlighted the need for improved methodology in future research to better assess, among other aspects, the clinical utility and economic implications of using this technology.

Mobile recorders and stroke risk

A diagnosis of AF significantly increases the risk of ischaemic stroke. In patients with AF, the risk is estimated to be approximately five times higher than in the general population [17]. To prevent thromboembolic events, the ESC guidelines recommend initiating anticoagulation therapy in all patients with elevated risk, whenever possible [2]. This principle is reflected in the "CARE" strategy for AF management, in which "A" stands for "Avoid" (Avoid stroke and thromboembolism).

The growing popularity of self-recording ECG devices raises the question of whether they can contribute to reducing this risk and enable the timely initiation of therapy using direct oral anticoagulants (DOACs) or vitamin K antagonists.

Feldman et al. attempted to estimate the proportion of individuals using ECG-enabled devices who could benefit from anticoagulant treatment if the diagnosis of AF were based on these devices [18]. It was shown that only 0.25% of the subjects would be candidates for initiating such treatment. This means that out of 400 device users, only one would derive measurable benefits in the prevention of ischaemic events.

A significant concern involves the complications of anticoagulant treatment, specifically the increased risk of bleeding. Sunaga et al. are currently conducting research on the feasibility of using DOAC therapy based on patient monitoring with the Apple Watch Series 4 [19]. The study includes patients who have undergone ablation and subsequently returned to sinus rhythm. The primary premise is to continue DOAC treatment in the event of arrhythmia and to discontinue therapy in the absence of AF episodes. The initial observation period lasts 30 days. If no AF episode occurs during this time, anticoagulation is discontinued on the 31st day. If an AF episode occurs during the first month or after cessation, therapy is to be continued or reinitiated, respectively. The primary endpoint is the percentage reduction in the number of days on DOAC therapy during a 360-day observation period. Secondary endpoints include mortality, stroke, thromboembolic events, bleeding episodes, and device malfunction. The study aims to determine whether personalised DOAC therapy guided by Apple Watch monitoring can reduce DOAC use compared with conventional anticoagulation therapy.

Summary and practical implications

The growing popularity and accessibility of smart devices offer new opportunities to leverage their technology for health monitoring. The development of devices and applications dedicated to heart rhythm analysis and short ECG recording enables their use in the diagnosis and management of various conditions, including AF. A concise overview of the operating principles and effectiveness of individual methods, as reported across numerous studies, is presented in Table 1.

When considering the advantages of handheld or mobile ECG monitoring, ease of use, intuitive interfaces, and immediate, on-demand accessibility are particularly noteworthy. In the event of arrhythmia symptoms, users can instantly record a tracing and analyse the rhythm, unlike with a standard 12-lead ECG, which requires a visit to a medical facility. Collecting results, for example in the form of PDF files, enables subsequent medical consultation and, according to current guidelines, may support both the diagnosis of the disease and the initiation of treatment. However, it should be noted that the user decides when to activate the relevant function and perform the examination, which limits the detection of clinically silent arrhythmic episodes that do not prompt a recording.

Importantly, these devices may generate false-positive results, which can cause unnecessary anxiety among users and lead to redundant diagnostic testing. Another drawback is the difficulty in distinguishing between different arrhythmias, as some false-negative results may mask other rhythm disorders, such as atrial flutter. Furthermore, it is important to note the potential difficulties faced by elderly individuals when using such devices. This population represents the vast majority of patients affected by heart rhythm disorders, yet operating smartphone-based devices or applications can pose a significant challenge for them, often due to lower technological proficiency and difficulties in acquiring new digital skills. This may significantly limit the use of the methods discussed, which in turn would reduce their potential benefits.

In screening for AF, a significant challenge is the relatively high number of patients who must be screened to detect a single case, which entails potential costs related to the unit price of the device. The very need for active arrhythmia screening and for monitoring an asymptomatic individual – who, although considered healthy, carries certain risk factors – may not provide sufficient motivation for purchasing a smartwatch or smartphone.

Undoubtedly, however, the availability of this type of technology creates substantial opportunities for use in both the prevention and management of AF. The high sensitivity of these devices places them almost on par with the methods used to date. The ability to identify arrhythmia based on a single-lead ECG helps overcome the limitation of capturing arrhythmic episodes exclusively during standard ambulatory ECG. The continued advancement of this technology, together with improved accessibility and the reduction of current limitations and

Table 1. Sensitivity and specificity of selected mobile ECG monitoring methods [5, 7, 10, 12, 14, 16]

	Microlife WatchBP	Cardiio Rhythm	Beurer ME90	KardiaBand	Kardia Mobile	Apple Watch
Sensitivity	86%	93%	88.9%	93%	92.8%	94.8%
Specificity	96%	98%	61.9%	84%	100%	95%

drawbacks, will undoubtedly broaden the scope of benefits for patients with cardiac rhythm disorders in the future.

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