IMAGES IN CARDIOLOGY

Portable/Wearable ECG Recording Gadgets

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Abstract

Several portable devices for ECG acquisition are already available in the market and have provided valuable information regarding various cardiac arrhythmias, most commonly atrial fibrillation (AF). Such gadgets are easy to use and can impact health care for both diagnosis and management in a variety of clinical settings, such as in patients complaining of palpitations, patients presenting with unexplained presyncope or syncope, patients with heart failure and suspected tachycardiomyopathy, those afflicted by cryptogenic stroke, and/or patient groups who are at high arrhythmic risk (e.g., older persons, individuals with obesity, sleep apnea, hypertension, diabetes or structural heart disease). ***Rhythmos 2022; 17(3):58-61.***

Key Words: portable ECG recording; event monitor; loop recorders; arrhythmias; presyncope; syncope; atrial fibrillation

Abbreviations: AF = atrial fibrillation; ECG = electrocardiogram; PPG = photoplethysmography

For heart rate monitoring, there are several wearable devices available which use photoplethysmography (PPG) technology; they are inherently less accurate than conventional ECG monitoring techniques. Accuracy of various devices varies, with correlation to reference standard ECG monitoring ranging from 0.76 to 0.99. [1] Technology in wearable ECG acquisition has advanced to include use of direct electrode recording via a device that generates a lead I like rhythm strip, facilitating arrhythmia detection.

Although these gadgets are intended for personal use promoting health and physical activity, wearable technologies can enhance healthcare delivery, with data collection providing answers to health issues pertaining to cardiac arrhythmias in various settings (patients' complaints, including palpitations, presyncope or syncope; older persons with increased prevalence of AF; unexplained cryptogenic stroke; patients with heart failure and suspected tachy-cardiomyopathy; [2] patients with obesity, hypertension, diabetes, sleep apnea or structural heart disease, all more vulnerable to AF and/or other arrhythmias). Health care providers may also see these wearable gadgets as accessible risk stratification tools for detection of AF in high-risk cohorts (such as high $CHADS_2$-$VASC_2$ score patients). [1] The recent Apple Heart Study attests to such a perspective, wherein 419,297 persons were recruited into an AF screening study that used a PPG-based algorithm followed by a 7-day patch if AF was suspected. [3] Employing a complex tachogram algorithm, 2126 individuals were notified of irregular pulse recordings and were advised to proceed with a telemedicine visit and 7-day ECG patch. A positive predictive value of 84% was reported for each irregular pulse notification, and 71% for each irregular tachogram. Similarly, the Huawei Heart Study assessed 187,912 persons who used smart devices for their cardiac rhythm monitoring; 424 participants were notified of suspected AF. [4] A strong relationship was found between advancing age and detecting AF. The predictive value of the algorithm was 87% in the 62% of notified persons, who subsequently proceeded with medical evaluation.

Studies evaluating PPG-based wearables in conjunction with machine-learning algorithms have been found promising in arrhythmia detection, such as AF. [5] Studies to date have not focused on ventricular arrhythmia detection. Cardiac monitoring via wearables has the potential to significantly impact our healthcare delivery, and to affect management and outcomes of patients, or how risk scores derived in other populations such as the CHA_2DS_2VASc score apply in these previously undetected individuals.

ECG recording gadgets are portable ECG monitors, handheld or wearable; they can record lead I, lead II or a chest lead (**Fig**. 1-4); they provide instant ECG analysis with an application with no subscription required; recording duration may range from 30 sec to 15 min.

Figure 1. Most gadgets can record lead I, e.g., by touching the two electrodes with the finger(s) of each hand

Figure 2. Single lead ECG recording is easy to obtain by touching the two electrodes with either the finger(s) of the two hands (lead I, left panel) or combining right hand and left leg (lead II).

Figure 3. A precordial lead can be recorded with use of a chest strap

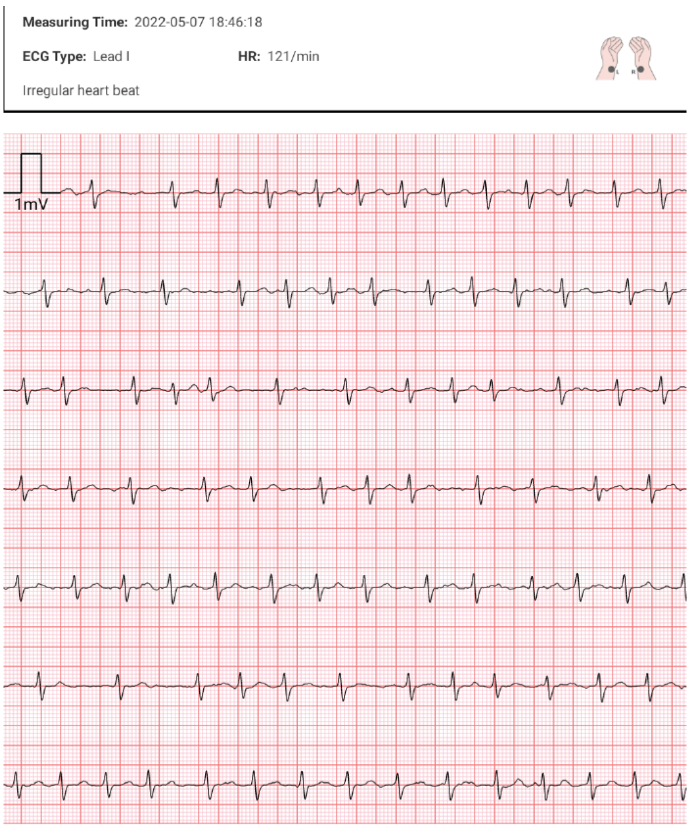

Figure 4. Data from the ECG recording (here lead I) and report generated by the device can be synchronized, reviewed and shared by connecting to the respective App via bluetooth; the ECG can be viewed and shared with the patient's physician

Apps are available for both iOS and android devices; a pdf report is generated and can be shared; these devices have built-in memory, and a rechargeable battery.

The ECG recording can be tested with the fingers before finalized; one can observe real-time ECG on the App dashboard; the gadget can record ECG stand-alone even when not connected to the App.

There are two types of wearable ECG gadgets:

1. A looping memory monitor is a small device about the size of a pager that can be programmed to record the ECG for a period of time, e.g., 5 minutes. One must push a button to activate it, and it stores the ECG for the period before and during one's symptoms. If one faints and pushes the button after recovery, the device will record the ECG during the time of syncope, and right after the button is pushed.
2. A symptom event monitor can be either a hand-held device or worn on the wrist. When one develops a symptom or irregular heartbeat, one can place the monitor on the chest and activate a recording button. The back of the device has small metal discs that function as the electrodes. If the monitor is worn on a wrist, one can press the button to record. This stores the ECG in memory. Unlike the looping memory monitor, the device will not store the ECG before one activates it.

Advanced 6-lead technology (KardiaMobile 6L): with 2 sensors on top, a third on the bottom; has 2 electrodes on the top for one's fingers or thumbs and one on the bottom to contact the skin of the left leg; thus, it records ECG leads I, II, III, aVL, aVR, and aVF (**Fig**. 5 & 6).

Figure 5. KardiaMobile 6L records a 6-lead ECG with 2 sensors on top and 1 sensor on the bottom (**Error! Hyperlink reference not valid.**)

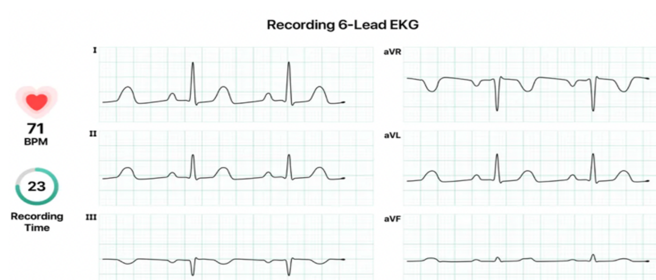

Figure 6. 6-lead ECG recording.

Prices for these gadgets range between 50€ and 300€ or more depending on the brand and model. One should look for a monitor that is compatible with all smartphones; small compact size; easy to use, with no leads; a gadget that records ≥30 sec of ECG and can store it, review and share heart health data on a smartphone and/or personal computer (**Fig**. 7).

Table 1. Individuals and Patients in Need for Portable/ Wearable Gadgets

- Patients with episodic palpitations / unexplained presyncope or syncope
- Older persons (>65 years)
- Patients with cryptogenic stroke
- Patients with heart failure / suspected tachy-cardiomyopathy
- Professional athletes (with or without symptoms / risk assessment)
- Patients with inherited rhythm disease
- Patients treated with catheter ablation

Discussion

Several portable devices for ECG acquisition are already available in the market. Smart watches and other wearable devices for heart rhythm assessment have increased in use in the general population. The Apple Watch and KardiaBand are such devices capable of obtaining single-lead ECG recordings, offering an opportunity for the detection of paroxysmal arrhythmias. [6] ECG tracings from such devices may be of sufficient quality, however, automated diagnosis alone is not sufficient for rendering clinical decisions about arrhythmia diagnosis and management.

Some of these devices are limited in assessing the heart rhythm and display inconclusive results when the heart rate exceeds 120 bpm or is under 50 bpm. Devices are also limited in recordings during exercise. [7]

In general, although smart watches demonstrate strong agreement in sinus rhythm, their utility in arrhythmias remains suboptimal. Tachycardic episodes recorded at rest may be suggestive of an underlying atrial tachyarrhythmia and warrant further clinical evaluation. [8] In general, these smartwatches demonstrate moderate diagnostic accuracy when compared with a 12-lead ECG (κ=0.60; [9] N.B.: Cohen's kappa coefficient (*κ*) measures inter-rater reliability and is a more robust measure than simple percent agreement calculation).

The AliveCor gadget can acquire a 30 sec single-lead ECG and transmit it through an audio channel to the associated app. Then, the signal is processed to remove noise and search for any anomalies. It is a two-electrode device to be attached to the backside of the smartphone. It is FDA approved and CE marked as a medical device. The output is a PDF file that can be shared by mail.

A case series of 6 patients, including one elite non-endurance athlete, two elite cricketers, one amateur middle-distance runner, and two semi-elite ultra-endurance runners (age range 16–48 years), indicated that an accurate arrhythmia diagnosis was obtained in 5 cases (atrial fibrillation/flutter and supraventricular tachycardias) using the smartphone ECG, which helped guide definitive treatment. [10] No arrhythmia was identified in the one case despite using the device during multiple symptomatic events, allowing the athlete to continue exercising.

Figure 7. Lead I (thumb) ECG recording

Acute ischemic stroke (AIS) patients are a difficult group to apply portable device monitoring. Nevertheless, a study using a portable ECG recorder (AliveCor KardiaMobile -KM) for detection of atrial fibrillation (AF) applying 30-second single-lead ECG recording on demand for 3 days indicated that the recruitment rate among AIS patients was 26.3%. [11] The withdrawal rate before the start of the intervention was 26%. The withdrawal rate after the start of the intervention was 6%. The KM device finally detected AF in 2.8% of AIS patients and in 2.2% of ECG records. Cardiologist confirmed the AF in 0.3% AIS patients. Sensitivity and specificity of KM for AF was 100% and 98.3%, respectively.

A validation study of a wrist-worn device dedicated to providing both continuous PPG-based rhythm monitoring and instant 6-lead ECG with no wires comprised 44 individuals including 121 patients in AF.[12] AF detection with PPG-based algorithm, ECG of the wearable and combination of both yielded high sensitivity and specificity of 94.2 and 96.9%; 99.2 and 99.1%; 94.2 and 99.6%, respectively, despite a significant amount of frequent single or multiple premature contractions.

In general, the use of wearable cardiac monitoring devices has shown significant symptom-rhythm correlation in various clinical settings, which has often resulted in a reduction in time to diagnosis and lower rates of visits to the emergency room.[13] These portable/wearable devices/gadgets are capable of recording ECGs of good quality, with a discernable P wave and distinguishable QRS morphology and their ability to detect cardiac arrhythmias appears significantly better than that of Holter monitoring, while a significant number of patients may receive therapeutic intervention based on ECGs recorded by such gadgets. [14]

Finally, empowering individuals to record their own ECG tracings in conditions such as for evaluation of symptoms (e.g., palpitations, presyncope or syncope), and for risk stratification of sudden death intuitively has important potential, but its value remains to be more vigorously and convincingly demonstrated.[15]

Conclusion

Digital technology provides tools for detecting, screening, diagnosis, and monitoring health-related parameters that have improved patient care and management. Wearable technologies have integrated sensors that can measure heart rate and record heart rhythm, but can also monitor physical activity and even measure glucose and electrolytes. [16] For individuals at risk, wearables or other portable devices may be useful for early detection of AF or other arrhythmias or sub-clinical states of cardiovascular disease, guide disease management of cardiovascular diseases such as hypertension and heart failure, and lifestyle modification.

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