Mini Review

Interventional Cardiology

A novel tool in cardiology: Smartwatches and the detection of acute ischemic heart disease

Abstract

Smartwatches have experienced a notable expansion in their health applications to the integration of Electrocardiographic (ECG) tracing recording. Some of these devices have received approval for the detection of Atrial Fibrillation (AF). However, in ischemic heart disease, the main cause of cardiovascular mortality, their role is not established. Small studies suggest that smartwatches may be useful for detecting ischemic changes, which could have significant implications for patient management and care. Obtaining a 9-lead ECG using smartwatches may help in this field by obtaining limb and precordial leads ECG. In this article, we review the existing evidence in ischemic heart disease, the methodology for obtaining a 9-lead ECG with the smartwatch, and future expectations in this field.

Keywords: Electrocardiographic; Smartwatches; Ischemic heart disease

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Received date: 12-Sep-2023, Manuscript No. FMIC-23-113404;
Editor assigned: 14-Sep-2023, PreQC No. FMIC-23-113404 (PQ);
Reviewed date: 29-Sep-2023, QC No. FMIC-23-113404;
Revised date: 06-Oct-2023, Manuscript No. FMIC-23-113404 (R);
Published date: 13-Oct-2023, DOI: 10.37532/1755-5310.2023.15(S19).484

Introduction

The integration of Electrocardiographic (ECG) tracing recording into smartwatches has expanded their applications in ways previously unforeseen. In this context, a "smartwatch" is defined as any wearable device running a high-level operating system with the capability to install third-party applications. These electronic devices currently enjoy widespread societal acceptance to the extent that their sales volume reached 127.5 million units sold in 2021 [1].

The primary application of these devices in the field of cardiology is heart rate measurement through ECG tracing. Some of them have already been approved for the detection of Atrial Fibrillation (AF) [2], even being used for electrocardiographic assessment [3], in athletes before and during exercise. However, their role in Ischemic Heart Disease (IHD), the leading cause of cardiovascular mortality worldwide, has not been adequately established. Current literature includes isolated studies with small sample sizes [4], or employs various devices such as smartphones [5].

Literature Review

Current scenario with smartwatches

Leading technology brands offer medical devices composed of dedicated software and hardware. Most of these devices analyze data obtained through photoplethysmography sensors to identify episodes of irregular heart rhythm indicative of atrial fibrillation and notify users if such an episode is detected. This software is intended to create, record, store, transfer, and display a single-channel ECG similar to Lead I electrocardiogram. ECG data is meant solely for informational purposes. Users should not interpret or make clinical decisions based on device recordings without consulting a qualified healthcare professional. These tracings are intended to complement heart rhythm classification, aiming to distinguish atrial fibrillation from sinus rhythm, and are not

intended to replace traditional diagnostic or treatment methods.

Most ECG applications are not designed for use by individuals under 22 years of age or by those previously diagnosed with atrial fibrillation. One of the primary clinical validation studies for these applications was conducted in the Smart Heart Study, a prospective single-arm study aimed at evaluating the Smart Watch's irregular heartbeat detection algorithm's ability to detect atrial fibrillation [6].

The study included 419,297 participants, and over an average follow-up period of 117 days, 2,161 participants (0.52%) received notifications of irregular pulse. Among participants who received a notification of irregular pulse, the positive predictive value for detecting AF on simultaneous ECG with a subsequent irregular pulse notification was 0.84 (95% CI, 0.76 to 0.92). For the observation of AF on simultaneous ECG with a subsequent irregular tachogram, the positive predictive value was 0.71 (97.5% CI, 0.69 to 0.74).

Similarly, other studies assess the quality of ECG and clinical performance of some of the major available software options for atrial fibrillation detection. Among these, Scan Monitor and Fitbit Irregular Rhythm Notifications deserve special mention. The clinical study results of Campo, et al., [7] evaluating scan monitor software, showed sensitivity data of 96.3% and specificity of 100% (95% confidence interval lower limits: 89.4% and 96.7%, respectively) in detecting atrial fibrillation [7].

Fitbit irregular rhythm notifications presented results equivalent to Smart Inc. Irregular rhythm notification [8], with a positive predictive value of 98.2% (95% CI lower limit: 96.4% to 97.5%).

Obtaining a 9-Lead ECG using smartwatches

We begin with the fundamental principles of electrocardiography applied to a smartwatch for obtaining an electrocardiogram. The polarity of the leads is determined by the placement of electrodes on the smartwatches [9].

There are six limb leads or frontal plane leads, consisting of three limb leads (I, II, III) and three augmented limb leads (augmented Vector Right (aVR), Arteriovenous Fistula (aVF), and augmented Vector Left (aVL)). The limb leads are the original leads chosen by Einthoven in 1901 [10], for recording electrical potentials in the frontal plane. Electrodes are placed on the Left Arm (LA), Right Arm (RA), and Left Leg (LL).

Limb leads are bipolar because they represent an electrical potential difference between two poles, positive and negative, with the lead axis being the line connecting both poles (each line is divided into two halves, one positive half near the positive pole and one negative half near the negative pole).

- Lead I: Potential difference between the Left Arm and Right Arm (LA-RA).
- Lead II: Potential difference between the Left Leg and Right Arm (LL-RA).
- Lead III: Potential difference between the Left Leg and Left Arm (LL-LA).

Using these electrocardiography principles as a basis with a smartwatch, only the limb leads (I, II, III) can be obtained directly. The augmented leads (aVR, aVF, aVL) are calculated mathematically. It's not possible to calculate them directly due to the inability to generate the central terminal (Wilson Central Terminal, 1931) [11], which is essentially the barycenter of Einthoven's equilateral triangle with a potential very close to infinity (zero). To obtain them, the following approach is used:

The smartwatch's electrocardiogram recording is obtained using its integrated electrodes. The digital crown/button (negative) and the back crystal (positive) serve as electrodes.

To obtain Lead I, the watch is placed on the left wrist (back crystal, positive electrode), and the right index finger touches the digital crown (negative electrode).

Leads II and III are obtained with the back of the watch (back crystal, positive electrode) against the lower left abdomen and the right index (Lead II) or left index (Lead III) finger touching the crown (negative electrode).

To obtain the precordial leads with the smartwatch, the back of the watch is placed in the classic positions for precordial leads or horizontal plane V1-V6, with the right index finger touching the crown/button (Figure 1).

Similar to the augmented leads, the absence of the central terminal should theoretically prevent the recording of precordial leads. In this case, smartwatches create a closed positive/negative circuit at each of the positions from V1 to V6, allowing the recording of each of the leads in the horizontal plane.

Smartwatches for the diagnosis of ischemic heart disease

In the context of ischemic heart disease, only small studies, clinical cases [12], or case series support the use of ECGs taken by smartwatches. Table 1, summarizes the currently published evidence. In the study by Carmen AM. Spaccarotella, et al., [13], which included patients with ischemic heart disease and healthy controls, and compared conventional ECGs with the 9-lead ECGs obtainable from smartwatches, the use of smartwatches for diagnosing a normal ECG showed a sensitivity of 84% and a specificity of 100%. Moreover, the degree of correlation was very high (Cohen κ coefficient, 0.90; 95% CI, 0.78-1.00). For ST-segment elevation, the sensitivity was 93% and the specificity was 95%, and for ischemic heart disease without ST-segment elevation, the sensitivity was 94% and the specificity was 92% [13].

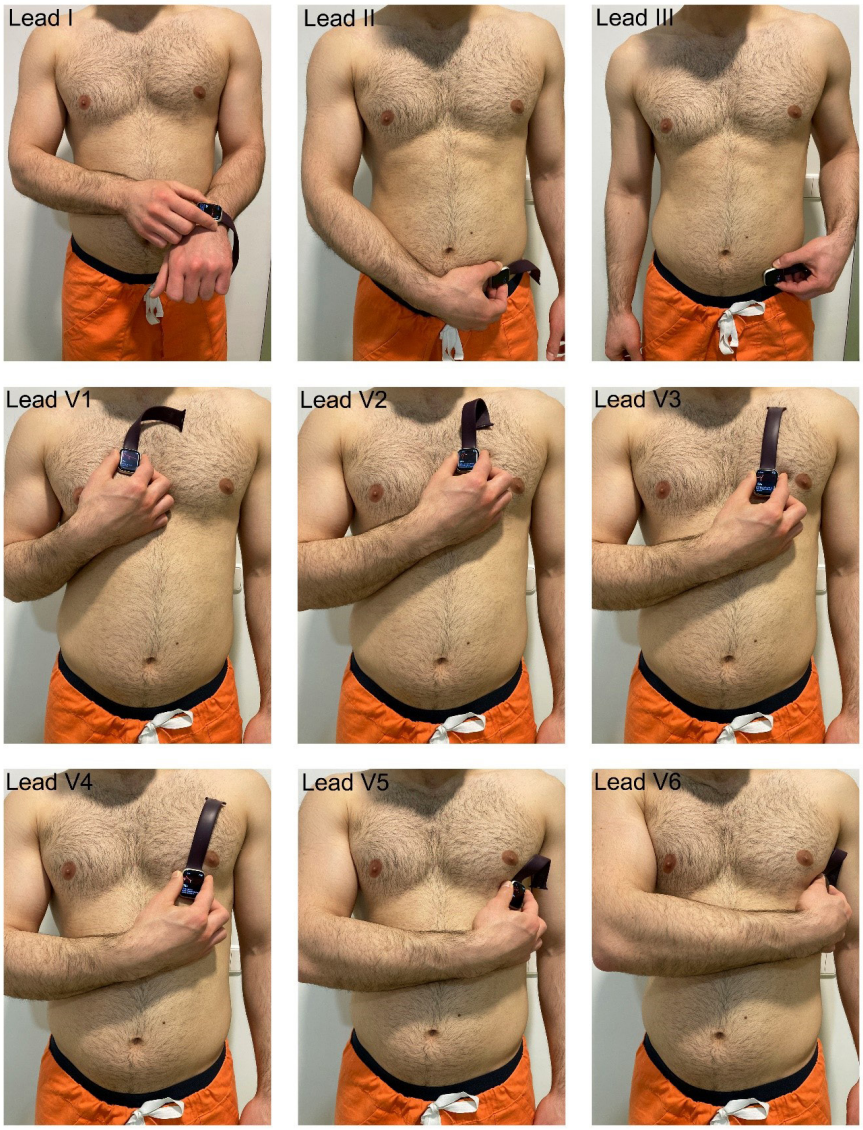

Figure 1: Detailed methodology lead by lead for obtaining a 9-Lead ECG using a smartwatch

Table 1: Published evidence on the use of smartwatches in ischemic heart disease.

Study details	Study design	Sample size	Outcome measures	Summary of findings
Buelga Suarez et al. 2022. Spain [12]	Case series. Conventional 12-leads ECG Vs 9-leads Smartwatch tracing	3 patients	Overlay of Electrocardiograms in 3 Cases.	Smartwatch recording is identical to the conventional electrocardiogram recording
Spaccarotella CAM et al. 2020. Italy [13]	Concordance test validation study. Conventional 12-leads ECG Vs 9-leads Smartwatch tracing	100 patients (54 STEMI, 17 NSTEMI, 19 healthy individuals)	Quantitative and qualitative comparison	ST-segment changes on ECG shown with use of a smartwatch agree with those determined with standard ECGs
Buelga Suarez et al. 2023. Spain [14]	Concordance test validation study. Conventional 12-leads ECG Vs 9-leads Smartwatch tracing	25 ACS patients	Quantitative and qualitative comparison	In ACS, smartwatch ECG tracing is reliable. Inferior myocardial infarctions may be missed and require a conventional 12-lead ECG to rule them out.

Note: ACS: Acute Coronary Syndrome; ECG: Electrocardiogram; NSTEMI: Non-ST segment elevation myocardial infarction; STEMI: ST segment elevation myocardial infarction.

In the ACS Watch Study, which quantitatively compared tracings obtained by smartwatches with those from conventional ECGs in 25 patients with acute coronary syndrome with and without ST-segment elevation, there were no differences in the Q wave, R wave, ST segment, or T wave. There was a very strong correlation in the ST segments, a strong correlation in the Q and R waves, and a moderate correlation in the T wave. Additionally, these tracings were qualitatively compared in a second phase by specialists in the acute treatment of acute coronary syndrome (cardiologists, intensivists, emergency physicians, or primary care physicians), and the level of agreement between both ECGs for diagnosis was almost perfect (kappa=0.96). There was only poor correlation in one case with inferior ischemia because, although the smartwatch was capable of obtaining augmented leads, the ischemia seen in aVF could not be detected [14].

In light of these publications and given the versatility of using a simple watch for electrocardiographic recording, Han C et al. developed an artificial intelligence-based model capable of detecting cardiomyopathies with just 3 leads, with the most accurate model utilizing leads I, II, and V2 [15].

Practical implications of smartwatch use for early diagnosis in ischemic heart disease

The practical implications of these results could be significant. Firstly, the use of smartwatches to detect ST-segment elevation in patients with chest pain symptoms could be a valuable tool for early detection of acute myocardial infarction, improving its treatment and prognosis. Secondly, the use of smartwatches to rule out ST-segment elevation in patients with chest pain symptoms who do not present this electrocardiographic sign could reduce the number of unnecessary tests and expedite diagnosis.

In summary, the validation of electrocardiographic recording by smartwatches in acute coronary syndrome could significantly enhance the management and care of patients with this condition.

Conclusion

Smartwatches due, among other reasons, to the plausibility of obtaining 9-lead ECGs, may potentially detect ischemic highlights in ECG. It appears a bright future within the field of early diagnosis of cardiopathies, but their clinical use still needs to be carefully assessed before considering them as conclusive diagnostic tools. Currently, they should be considered as complementary tools to professional medical evaluation.

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