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Case report

Connected health: Ventricular tachycardia detection with Apple Watch–A case report

Gianluca Guarnieri [a,b], Massimo Mapelli [a,b,*], Massimo Moltrasio [a], Piergiuseppe Agostoni [a,b], Claudio Tondo [a,b]

[a] Centro Cardiologico Monzino IRCCS, 20138, Milan, Italy
[b] Department of Clinical Sciences and Community Health, University of Milan, 20122, Milan, Italy

A R T I C L E I N F O

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2 . A B S T R A C T

Background: Traditional screening methods, such as 12-lead electrocardiograms (ECGs) and Holter monitors, often fall short in detecting transient arrhythmias. However, advancements in wearable technology, like the Apple Watch®, enable real-time rhythm monitoring and specific arrhythmia detection through dedicated algorithms.

Case description: A 60-year-old man with a history of arrhythmogenic cardiomyopathy and an implanted cardioverter-defibrillator (ICD), during a walk, experienced palpitations and dizziness; the Apple Watch® alerted him of an elevated heart rate. He recorded a single-lead ECG with the watch, recognizing an abnormal electrocardiogram, then he sought for immediate medical assistance. After few minutes ICD delivered a shock. The patient underwent further evaluation and radiofrequency ablation to successfully treat the ventricular tachycardia.

Discussion: Wearable technologies, like the Apple Watch®, hold a promise in detecting arrhythmias, as demonstrated by the Apple Heart Study's high sensitivity and specificity for atrial fibrillation detection. This case emphasizes the importance of correlating symptoms with smartwatch-recorded ECGs, especially when receiving a elevated heart rate alert. Limitations include reliance on user activation and potential challenges in recognizing artifacts in single-lead ECGs. However, in high-risk patients, smartwatches may complement existing devices, potentially reducing mortality by aiding in early intervention and optimizing ICD programming.

Conclusion: The presented case emphasizes the potential of smartwatches in identifying ventricular arrhythmias, especially in high-risk individuals. Despite the existence of many challenges, the integration of wearable technologies into clinical care could enhance arrhythmia detection, reduce unnecessary shocks, and therefore improve patient outcomes. Future research could explore the role of smartwatches as a non-invasive alternative to implantable rhythm monitoring devices.

* Corresponding author. Heart Failure Unit, Centro Cardiologico Monzino, IRCCS, Milan Via Parea 4, 20138, Milano, Italy.
E-mail address: massimo.mapelli@cardiologicomonzino.it (M. Mapelli).

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1. Main text

1.1. Background

Cardiac arrhythmias encompass various conditions in which heart beats too quickly or too slowly. Morbidity and mortality can be associated with rhythm abnormalities. For instance, the most common arrhythmia, atrial fibrillation (AF), is linked to an increased risk of stroke [1].

However, most of cardiac arrhythmias are transient events and conventional screening tools used in clinical practice, particularly 12-lead electrocardiograms (ECGs) and Holter monitors, often fall short in their detection [2]. Nevertheless, advancements in wearable electronic devices enable real-time rhythm monitoring and certain smartwatches are able to detect specific arrhythmias through specific algorithms [2].

Smartwatches are designed to detect deviations in heart rate and rhythm by analyzing pulse waveforms and electrical signals. Through algorithms validated in clinical studies, smartwatches can identify patterns of irregular heartbeats, such as the rapid, disorganized electrical activity characteristic of AF or the slow conduction rates seen in bradyarrhythmias. Several studies have confirmed their sensitivity and specificity in detecting AF, with promising results for other arrhythmias such as ventricular tachycardia (VT) and supraventricular tachycardia [3].

The clinical relevance of arrhythmia detection through smartwatches lies in their ability to provide real-time alerts to users, prompting them to seek medical attention or perform an ECG directly from the device. This immediacy can lead to the early diagnosis of potentially life-threatening conditions, especially in asymptomatic individuals or those with transient arrhythmias that may otherwise go unnoticed. In particular, the detection of VT by smartwatches, although less commonly reported, underscores the importance of these devices in capturing clinically significant events [4].

In this case report, we present an unusual identification of VT thanks to an Apple Watch®, as a result of which the patient decided to seek medical attention.

1.2. Case description

A 60-year-old man, with a history of surgical repair for an interatrial defect and arrhythmogenic right ventricular cardiomyopathy, experienced an out-of-hospital cardiac arrest. Previously, the patient had two cardiac arrests. The first took place in 2015, presenting as polymorphic VT at 190 bpm without pulse, treated with a single dual shock in the emergency department. A cardiac magnetic resonance revealed right ventricle (RV) dilatation with late gadolinium enhancement of the intramyocardial areas of septum and a coronary angiography showed a normal appearance of the coronary arteries. Subsequently, the patient underwent an implanted cardioverter-defibrillator (ICD) implantation for secondary prevention and was discharge on antiarrhythmic drugs (amiodarone and bisoprolol). The second episode took place in 2018, and it was a VT at 185 bpm without a pulse, which was appropriately interrupted by an ICD shock in the context of hypokalemia (K^+ 3 mmol/L).

During an evening walk in late summer (August 2023), the patient began experiencing dizziness and palpitation.

An alert message of ‘Elevated Heart rate’ from his Apple Watch ® prompted him to record a single-lead ECG using the smartwatch. Recognizing the wide complex tachycardia, he decided on the same day to seek for help. While awaiting medical assistance, he

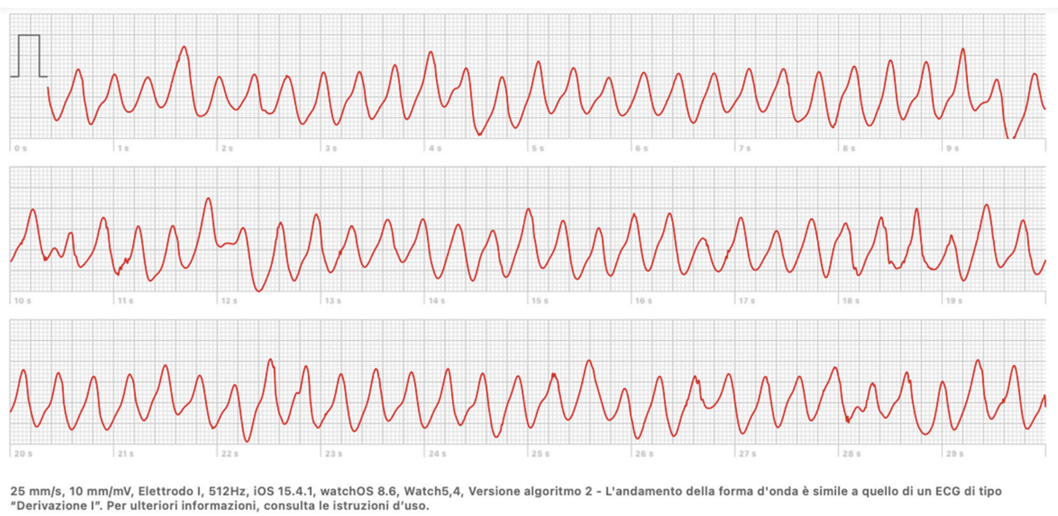

Fig. 1. Apple Watch® ECG
One derivation-ECG recorded by Apple Watch® series 5, 25 mm/s, derivation I. The ECG shows a wide-QRS tachycardia, suggestive of VT. Abbreviations: VT: Ventricular Tachycardia.

received a shock from his ICD. The single-lead ECG recorded by his Apple Watch® is shown in Fig. 1. In the emergency department, an ICD interrogation revealed 16 minutes of sustained VT at 183 bpm. The antitachycardia pacing (ATP) did not terminate the arrhythmia. Electrolyte values were normal ($K+$ 4 mmol/L) and troponin level was slightly elevated (hsTnI 55 ng/L, reference range <53 ng/L). The patient, upon admission, admitted not taking bisoprolol that morning. Transthoracic echocardiography demonstrated RV dilatation with hypokinesia of the free wall and global disfunction of RV (TAPSE 14 mm, S′ TDI 6 cm/s, FAC 30 %). The left ventricle had a normal dimension and preserved ejection fraction, while no relevant valve diseases were noted.

The patient underwent an urgent electrophysiology study and a VT from the anterior edge of the tricuspid valve was induced by ventricular stimulation (Fig. 2). Subsequent radiofrequency ablation (RFA) successfully interrupted the VT (Fig. 3). Following RFA, no other forms of VT were inducible, and the patient was discharged with an antiarrhythmic therapy (amiodarone and metoprolol).

2. Discussion

In this case we described the prompt recognition by a patient (together with his devices) of a sustained VT. This case is particularly noteworthy because, unlike most reports where the Apple Watch® is primarily used to detect supraventricular arrhythmias such as AF, it successfully identified a potentially life-threatening ventricular arrhythmia. This highlights the expanding role of wearable technology in the early recognition of a broader range of cardiac arrhythmias, including those with serious prognostic implications. This expands the potential utility of such devices, allowing individuals with known arrhythmias, when appropriately educated by their physicians, to better assess whether an ongoing arrhythmia detected by their devices warrants concern or immediate medical attention.

Wearable technologies are rapidly advancing, and their adoption is expected to continue growing.

Many smartwatches offer heart rate monitoring.

The Apple Watch® uses two main methods to detect arrhythmias: photoplethysmography (PPG) and ECG. PPG is an optical technique that continuously monitors heart rate using green LEDs and light-sensitive photodiodes to detect changes in blood volume beneath the skin. It passively tracks heart rate variability and identifies irregular heartbeats, such as those seen in AF. By using light beams and light-sensitive sensors on the smartwatch, changes in the blood volume passing through the wrist caused by the peripheral pulse are measured to generate a PPG, which is used to estimate the heart rate. The peak-to-peak distance of the waves created by each pulse can be interpreted as the R wave-R wave interval in the cardiac cycle [5]. Elevated resting heart rate (RHR) in individuals without

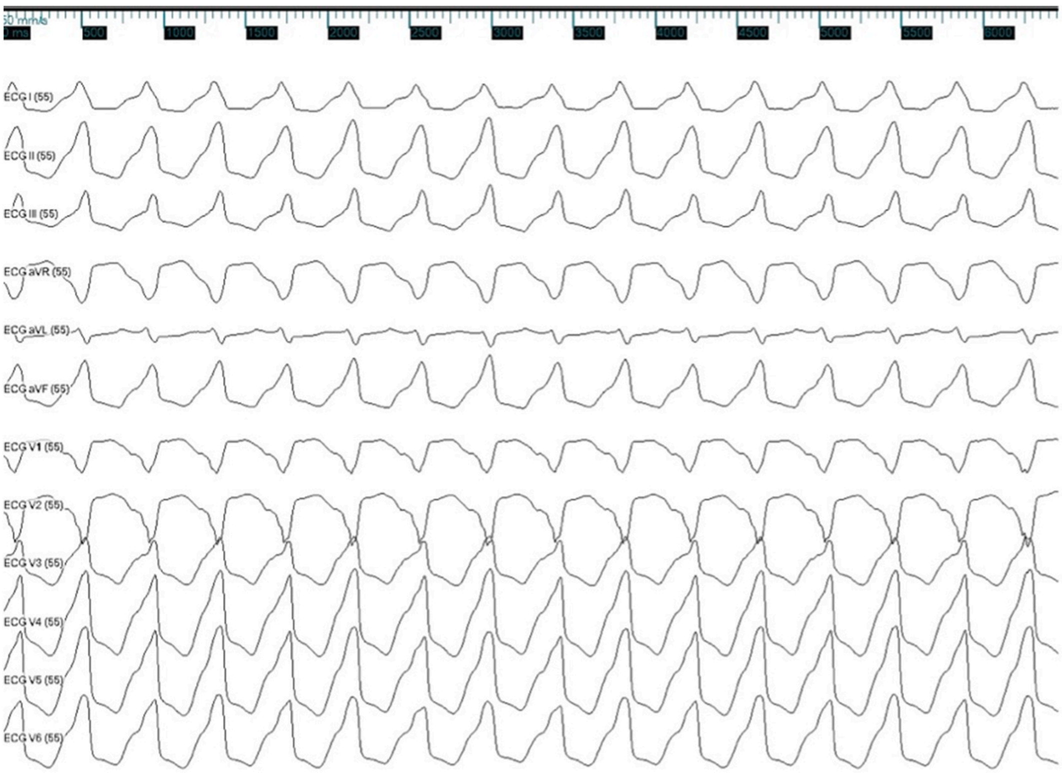

Fig. 2. Induced VT at electrophysiology study.
The figure shows the VT induced during the electrophysiology study (inferior axis and left bundle branch block pattern). The VT morphology (see lead I) appears to be analogous to that recorded by the device.
Abbreviations: VT: Ventricular Tachycardia.

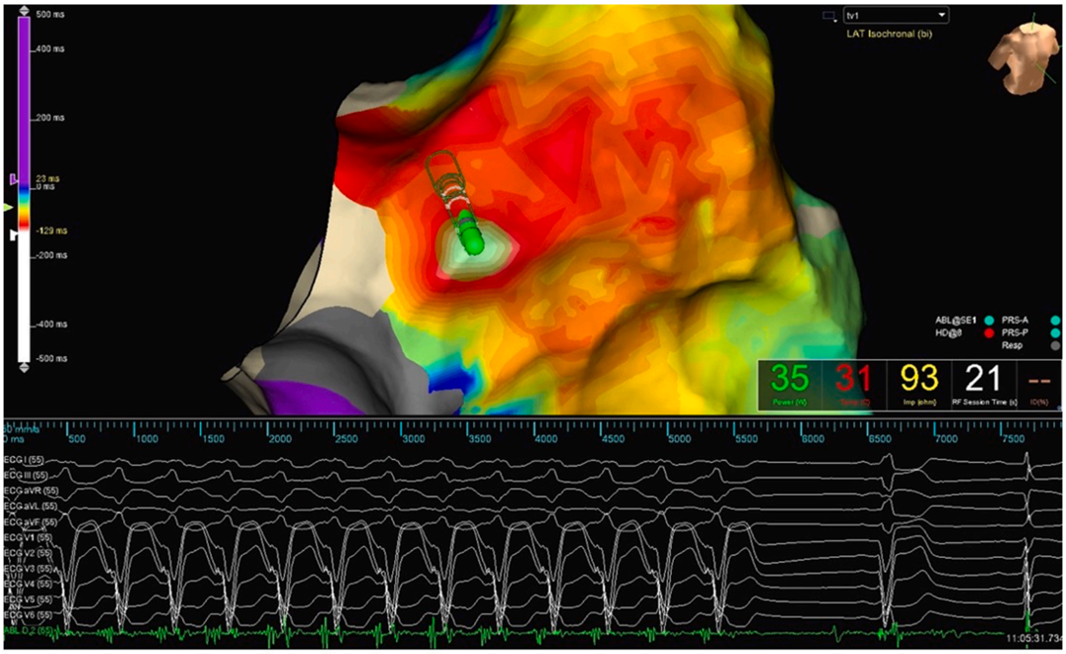

Fig. 3. VT ablation by RFA.
The figure shows the electroanatomical mapping and the position of the ablation catheter (top part), along with the ECG tracings (bottom part), highlighting the interruption of the VT during RFA (green tracing).
Abbreviations: RFA: Radiofrequency Ablation; VT: Ventricular Tachycardia.

cardiovascular disease is associated with higher blood pressure, body mass index, impaired pulmonary function, and subclinical inflammation [6]. Consistent evidence shows an independent association between elevated RHR and increased cardiovascular event and mortality risks in general population [6]. While most research relies on single HR measurements, few studies explore temporal changes in HR, relevant to wearable technologies. An increase in HR over time signals health deterioration, associated with adverse events in conditions like heart failure, chronic obstructive pulmonary disease, diabetes, and rheumatoid arthritis [6].

Many devices, such as Apple Watch®, can record a single-lead electrocardiogram, thanks to the circuit between the two electrodes—one located on the back of the watch in contact with the skin and the other on the digital crown—providing valuable health information to general population [7]. The Apple Heart Study showed over 98 % sensitivity and over 99 % specificity for the detection of AF(3). In this study, the detection of AF was based on continuous heart rate monitoring through plethysmography.

2024 ESC guidelines of AF now carry a **Class I recommendation** for the diagnosis of AF with smartwatches equipped with single-lead ECG. This means that ECG recordings from devices such as the Apple Watch® are considered both appropriate and reliable when reviewed by a healthcare professional. The accuracy of these devices for detecting AF has been well established, and they are now part of the formal diagnostic pathway [8].

The Apple Watch® can alert the user (i.e., in case of AF) by different mechanisms: firstly, it can recognize AF and send a rhythm notification recommending contacting emergency department. Secondly, it allows to download a PDF file of the one-lead ECG just recorded, facilitating analysis by physician of arrhythmic events [3].

However, the endorsement of wearable devices for detecting ventricular arrhythmias has not yet been granted by major international societies like The Heart Rhythm Society. Nevertheless, the identification of supraventricular and ventricular arrhythmias by the clinician on the ECG-Apple Watch®-PDF has been described [9]. Our case highlights the crucial role of correlating symptoms with the ECG recorded by smartwatch. While the Apple Watch® did not directly identify VT, our patient, with a history of ventricular arrhythmias, recognized the abnormal wide complex QRS pattern and thus sought for medical attention. Of course, this represents a limitation as well. In this case, as well as in another previous similar report [8], the identification of the ventricular arrhythmias was based on the ability of the patient to recognize symptoms and start single lead-ECG registration. However, ventricular arrhythmias can often be asymptomatic, and an alternative could be the automatic recording of a predefined number of ECGs by smartwatches, similar to the identification of AF. Otherwise, it could be feasible to design an algorithm that, upon detecting any irregularities in heart rate, both in terms of rhythm and speed, would prompt the smartwatch to send a notification suggesting the user record an ECG.

Moreover, a single-lead ECG approach, while useful and easy to apply, also carries the risk of interpretative and diagnostic challenges. Some authors, such as Cobos Gil et al. [9], have therefore suggested a 'multi-lead' approach to overcome these limitations and improve diagnostic accuracy, as described in their article that proposes the use of standard and precordial leads with an Apple Watch®. Countless devices are available on the market for patients' self-monitoring, often with multiple ECG leads [10]. These devices, designed for use by non-medical personnel, can be connected to computers or smartphones. However, the more bulky and 'external' they are, the less likely they are to be practical or effective for 24-h monitoring, which is one of the undeniable advantage of wearables like the Apple Watch®.

The ESC position paper emphasizes the importance of defining a clinically relevant populations that would particularly benefit from the use of wearable devices for heart rate and arrhythmias monitoring [6]. Various types of bradyarrhythmias and tachyarrhythmias can be identified using smartwatches equipped with advanced cardiac monitoring features. Bradyarrhythmias, such as sinus bradycardia and atrioventricular block, can be detected by measuring prolonged pauses or slow heart rates below normal physiological thresholds. Similarly, tachyarrhythmias, including AF, supraventricular tachycardia, and VT to even ventricular fibrillation, are recognized through the detection of elevated heart rates and irregular rhythms [4].

Ventricular arrhythmias are unpredictable events and the widespread use of smartwatches especially in patients with a history of major arrhythmic events or risk factors like coronary artery disease, could facilitate diagnosis by physicians. Consequently, unusual findings from these devices could be investigated more attentively. It is also important to consider the possibility of false positive results due to noise and artifacts, especially during physical exercise, which could lead to overdiagnosis and overtreatment.

Moreover, even in patients who still have an ICD or loop recorder, smartwatch technology could offer significant advantages. In our case, leading up to the ambulance call, the ICD had failed to treat this life-threatening arrythmia. If this VT had persisted at a rate of 160 bpm rate, the ICD would not have delivered a shock due to its programmed threshold rate (it was set between 180 and 200 bpm). Certainly, experimental studies have suggested that delivering shocks may lead to direct myocardial stunning, and it is well established that reducing shocks through ICD programming reduces mortality [10]. Therefore, the alert from his Apple Watch® could have helped prevent the ICD shock if the patient had reached the emergency department on time.

In the future, smartwatches may identify VT even in asymptomatic patients and potentially replace internal implanted rhythm monitoring devices like implantable loop recorders (ILR) [11–13]. Although ILRs don't require patient activation, wearable technology with continuous PPE and prompt notification of irregular rhythm could offer 24-h rhythm monitoring like ILRs.

Furthermore, ILRs require subcutaneous implantation, posing a risk of infections, local pain and bleeding while wearables do not necessitate invasive procedures.

Certainly, the analysis of VT alerts from smartwatches by an expert clinician will remain crucial to rule out false positives or artifacts that may elevate the risk of anxiety, unnecessary hospitalization, or inappropriate treatment [14]. Identifying artifacts in a 12-lead ECG is feasible by comparing signals in two or more derivations; if certain waves are not present simultaneously in every lead, they are considered artifacts. However, in the single-lead ECG provided by a smartwatch, recognizing artifacts could be challenging, potentially representing a limitation. This is undoubtedly a rapidly evolving field of scientific and technological innovation, where some new tools—starting with sophisticated artificial intelligence algorithms capable of identifying, recognizing, and classifying arrhythmias—seem poised to make a significant impact in the near future.

Moreover, even in patients with an ICD, this technology may enhance the detection of slower VT. Specifically, in cases where ICDs fail to detect VT or anti-tachycardia pacing is unsuccessful, patients can record an ECG during symptoms. This proactive approach may prompt physicians to adjust ICD programming and alert patients in a timely manner, so they can present themselves at the emergency department before ICD shock, potentially reducing the number of shocks and consequently mortality.

Therefore, for individuals capable of automatically recording an ECG with a smartwatch, any symptoms or detection of heart rhythm abnormalities should prompt the user to record an ECG, potentially through a notification.

CRediT authorship contribution statement

Gianluca Guarnieri: Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Data curation, Conceptualization. **Massimo Mapelli:** Writing – review & editing, Validation, Supervision, Software, Resources, Funding acquisition, Data curation, Conceptualization. **Massimo Moltrasio:** Validation, Supervision, Conceptualization. **Piergiuseppe Agostoni:** Validation, Supervision. **Claudio Tondo:** Validation, Supervision.

Consent

Informed consent was obtained from the patient for the publication of all the data and/or images in accordance with the Committee on Publication Ethics (COPE) guidelines.

Data availability

All data are incorporated into the article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] A.M. Alshehri, Stroke in atrial fibrillation: review of risk stratification and preventive therapy, J Family Community Med 26 (2) (2019) 92–97.

[2] S. Nazarian, K. Lam, A. Darzi, H. Ashrafian, Diagnostic accuracy of smartwatches for the detection of cardiac arrhythmia: systematic review and meta-analysis, J. Med. Internet Res. 23 (8) (2021 Aug) e28974.
[3] M.V. Perez, K.W. Mahaffey, H. Hedlin, J.S. Rumsfeld, A. Garcia, T. Ferris, et al., Large-scale assessment of a smartwatch to identify atrial fibrillation, N. Engl. J. Med. 381 (20) (2019) 1909–1917.
[4] A. Provencio, M.Á.C. Gil, Smartwatch electrocardiogram records ST depression, premature ventricular complexes, and ventricular fibrillation, Lancet (London, England) 400 (10364) (2022 Nov) e12.
[5] N. Isakadze, S.S. Martin, How useful is the smartwatch ECG? Trends Cardiovasc. Med. 30 (7) (2020) 442–448 [Internet], https://www.sciencedirect.com/science/article/pii/S1050173819301495.
[6] M.T. Jensen, R.W. Treskes, E.G. Caiani, R. Casado-Arroyo, M.R. Cowie, P. Dilaveris, et al., ESC working group on e-cardiology position paper: use of commercially available wearable technology for heart rate and activity tracking in primary and secondary cardiovascular prevention - in collaboration with the European Heart Rhythm Association, Euro. Eur Hear J - Digit Heal. 2 (1) (2021) 49–59.
[7] J.M. Raja, C. Elsakr, S. Roman, B. Cave, I. Pour-Ghaz, A. Nanda, et al., Apple watch, wearables, and heart rhythm: where do we stand? Ann. Transl. Med. 7 (17) (2019), 417–417.
[8] K.V. Bunting, T. Force, C.U. Kingdom, H.J.G.M. Crijns, R. Casado-arroyo, TJR De Potter, et al., ESC Guidelines for the Management of Atrial Fibrillation Developed in Collaboration with the European Association for Cardio-Thoracic Surgery (EACTS) Developed by the Task Force for the Management of Atrial Fibrillation of the European Society of Cardiology (ESC), with the Special Contribution of the European Heart Rhythm Association (EHRA) of the ESC, 2024, pp. 3314–3414, 2024.
[9] J. Burke, M.C.P. Haigney, R. Borne, M.J. Krantz, Smartwatch detection of ventricular tachycardia: Case series. Hear Case Reports 6 (10) (2020) 800–804, https://doi.org/10.1016/j.hrcr.2020.08.003 [Internet].
[10] C.J. MacIntyre, J.L. Sapp, A. Abdelwahab, M. Al-Harbi, S. Doucette, C. Gray, et al., The effect of shock burden on heart failure and mortality, CJC Open 1 (4) (2019) 161–167, https://doi.org/10.1016/j.cjco.2019.04.003 [Internet].
[11] D. Glöckner, T. Zeus, M. Kelm, H. Makimoto, Recurrent nocturnal ST-T deviation and nonsustained ventricular tachycardias recorded with a smartwatch: a case report, J Cardiol Cases 26 (3) (2022 May 20) 169–172, https://doi.org/10.1016/j.jccase.2022.04.006. PMID: 36091616; PMCID: PMC9449772.
[12] Gil MÁ. Cobos, Standard and precordial leads obtained with an Apple watch, Ann. Intern. Med. 172 (6) (2020 Mar 17) 436–437, https://doi.org/10.7326/M19-2018. Epub 2019 Nov 26. PMID: 31766051.
[13] Z. Bouzid, S.S. Al-Zaiti, R. Bond, E. Sejdić, Remote and wearable ECG devices with diagnostic abilities in adults: a state-of-the-science scoping review, Heart Rhythm 19 (7) (2022 Jul) 1192–1201, https://doi.org/10.1016/j.hrthm.2022.02.030. Epub 2022 Mar 9. PMID: 35276320; PMCID: PMC9250606.
[14] C.J. MacIntyre, J.L. Sapp, A. Abdelwahab, M. Al-Harbi, S. Doucette, C. Gray, et al., The effect of shock burden on heart failure and mortality, CJC Open 1 (4) (2019) 161–167, https://doi.org/10.1016/j.cjco.2019.04.003 [Internet].