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Short communication

Usefulness of wearable electrocardiography devices in patients experiencing paroxysmal cardiac-related symptoms: A case series of the "CardioSecur" system

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ABSTRACT

Background: Electrocardiograms (ECGs) recorded with wearable devices and additional smartphone apps play an increasing role in cardiology.
Case summaries: We present two cases in which it was possible to record an ECG during cardiac-related symptoms using the patients' smartphones. Previous standard resting and 24-hour ECGs had revealed no pathologies. In one case, AV nodal reentry tachycardia was detected and treated accordingly. In the second case, ischemic ECG changes were recorded in a young woman without cardiovascular risk factors during a chest pain episode. Suspecting a coronary vasomotion disorder, an invasive diagnostic procedure was performed. The acetylcholine spasm provocation test revealed coronary microvascular spasm and appropriate therapy was initiated.
Discussion: Smartphone-based ECG systems which can be used by the patient independently while experiencing cardiac-related symptoms are a modern diagnostic tool. Considering the use of these systems is beneficial for early diagnosis and appropriate treatment for paroxysmal arrhythmias and coronary vasomotion disorders.

1. Introduction

Technological advances in electrocardiography (ECG) led to new diagnostic capabilities through the development of mobile solutions like wearable smartphone-based ECG systems. An example which is widely used in Europe is "CardioSecur" (CS-ECG) (Fig. 1). It has been approved by the Conformité Européenne as a class IIa device and differs from a standard 12-lead ECG device because it requires only 4 (EASI) electrodes to generate a 15- or even 22-lead ECG with an implemented algorithm. Comparisons with conventional 12-lead ECGs yielded a high degree of congruence [1,2]. In addition to the localization of complex arrhythmias, the extra channels allow the detection of anterior, lateral and posterior wall ischemia as recommended by the European Society of Cardiology guidelines for the management of myocardial infarction [3]. Thanks to the sizes and simple communication features, patients can take those CS-ECG systems with them anywhere at any time, allowing them to use it during an event of suspicious symptoms. The CS-ECG can be uploaded to a secure server and shared with healthcare providers.

2. Case 1

A 67 year old woman presented to our outpatient clinic with paroxysmal palpitations, chest tightness and tachycardia (up to 220 bpm) for about three months. She reported having those symptoms at least once a month at rest, lasting about 3–20 min, and leading to repeated emergency department visits where Acute Coronary Syndromes could always be ruled out. Her only cardiovascular risk factor was a family history of a myocardial infarction and stroke in the mother at age 55 and 68, respectively, an aneurysm of the ascending aorta in the brother, and a sub-aortic stenosis in her own son. Her physical examination was normal. She had been taking levothyroxine for hypothyroidism and prophylactic cholecalciferol once daily. The resting electrocardiogram (ECG) showed sinus rhythm with a heart rate of 75 bpm. There were no ST-segment changes or T-wave inversions. An outpatient 24-hour-ECG revealed no relevant cardiac arrhythmias. Echocardiography showed normal results except for a mild mitral valve regurgitation, trace aortic valve regurgitation, and moderate tricuspid valve regurgitation. We recommended the CS-ECG system to allow self-

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recording an ECG on her smartphone during an episode of paroxysmal palpitations. Only a few weeks later the patient experienced another episode, recorded a CS-ECG and send it to us via email (Fig. 2). It showed a supraventricular tachycardia with a heart rate of 231 bpm which lasted about 20 mins and subsided spontaneously. Based on this ECG documentation the diagnosis of an atrioventricular nodal re-entry tachycardia (AVNRT) was made. The patient was referred to our electrophysiological team who successfully performed a catheter ablation. Subsequent inpatient telemetric monitoring and discharge resting ECG (Fig. 3) revealed no abnormalities. On outpatient visits throughout the next several months, the patient did not report recurrence of palpitations.

3. Case 2

A 30 year old woman had been suffering from recurrent exertional and resting angina pectoris for 7 years accompanied by palpitations and syncopes. The symptoms aggravated during the last months and occurred several times per day. Extensive external diagnostics had ruled out epicardial coronary artery disease (CAD), myocarditis, and arteritis (which had been suspected because of chronically elevated C-reactive protein (CrP)). The patient's external ECG exercise stress test had been abnormal. Her family history consisted of a sudden cardiac death in her grandfather at age 49 and another grandfather with a heart disease. Physical examination was normal. Her daily medication included 2 × 120 mg verapamil hydrochloride for angina pectoris, 80 mg valsartan and 15 mg torasemide for hypertension. Due to additional chronic back pain she took ibuprofen and metamizole as needed, as well as sublingual glyceryl trinitrate as needed for angina pectoris. The resting ECG showed sinus rhythm with a heart rate of 80 bpm. There were no significant ST-segment changes or T wave inversions. We recommended the CS-ECG system to record an ECG during a symptomatic episode. Ten days later the patient sent a CS-ECG via email which clearly showed significant (>0.1 mV) ST-segment depressions in the inferior leads (II, III, aVF) while having exertional angina pectoris and tachycardia (Fig. 4). To test for coronary vasomotor disorders we performed an invasive diagnostic procedure (IDP) consisting of an acetylcholine (ACh) spasm provocation test and measurement of coronary flow reserve (CFR)

Fig. 1. Picture of the mobile "CardioSecur" ECG system.

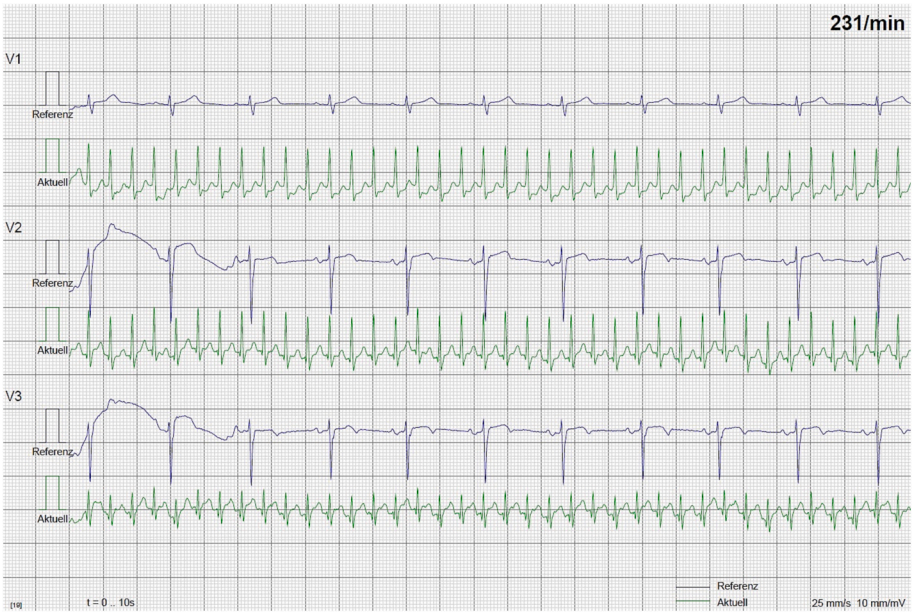

Fig. 2. CS-ECG showing supraventricular tachycardia.

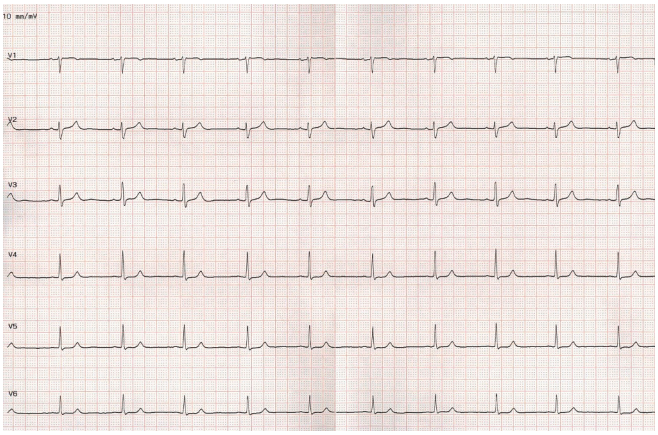

Fig. 3. Discharge resting ECG.

and hyperemic microvascular resistance (HMR) using a combined pressure/Doppler wire. Due to the ST-segment depressions in the inferior leads of the CS-ECG, acetylcholine provocation testing was performed in the right coronary artery (RCA) (Fig. 5) in addition to the left coronary artery. The patient reported familiar angina symptoms during the ACh-test along with ST-segment depressions on a 12-lead ECG (Fig. 6) but without epicardial coronary spasm. Therefore the diagnosis of coronary microvascular spasm was made. The ST-depressions seen during ACh injection into the RCA resembled the ECG changes seen on the CS-ECG in leads III and aVF. CFR and HMR were both normal (2.9 and 1.9 respectively). Due to the already long-existing, pronounced chest pain symptoms, and multiple drug intolerances in the past, we finally recommended spinal cord stimulation for improvement of symptoms.

4. Discussion

24-hour-ECGs have long been used as standard care in the outpatient setting to detect sporadic arrhythmias such as paroxysmal atrial fibrillation. A major disadvantage of these ECGs is that there may be no arrhythmias present during the recording period if they are very sporadic. Mobile, wearable ECG systems which can be applied by the patient him- or herself can overcome these disadvantages [4]. Case 1 demonstrates how repeated episodes of palpitations could not be caught by a 24-hour-ECG or by ECGs in emergency rooms, because at the time either no arrhythmias occurred or they had already subsided. The independent application of the CS-ECG system made it possible to capture arrhythmias during a symptomatic episode. Fast data transfer via email to the treating physicians enabled an immediate reaction and ultimately an accurate diagnosis and targeted, successful therapy.

In case 2, a young woman presented with chest pain. Obstructive CAD is unlikely at this age without relevant cardiovascular risk factors. Nevertheless, ischemia had to be considered due to an abnormal ECG exercise stress test. The CS-ECG detected ischemic changes during an episode of angina, further emphasizing the suspected diagnosis of a coronary vasomotor disorder and justifying an IDP. Because the ischemic ECG changes had occurred in leads representing the inferior myocardial wall corresponding to the arterial supply area of the RCA, the RCA was additionally challenged with acetylcholine after the left coronary artery. Indeed, ST-segment changes equivalent to the CS-ECG could be induced by ACh provocation leading to a diagnosis of coronary microvascular spasm. This demonstrates that coronary spasms provoked by ACh induce the same ischemic changes as coronary spasms occurring spontaneously or by as yet unknown triggers in the everyday life of affected patients. The sometimes formulated criticism of the ACh test, that it creates an artificial situation which does not correspond to the real conditions during a coronary spasm, can thus be refuted. Even though ACh most likely does not play a pathophysiological role during a coronary spasm attack, it can be shown by our case report that it is a very well-suited agent to simulate the real processes during a coronary spasm.

Mobile ECG-recording technologies coupled with the ability to transfer digital data to the treating physicians are increasingly deployed in the clinical setting. A current development is that these technologies, with the help of artificial intelligence and big data analysis, may uncover even more diagnostic information from an ECG than is currently possible through human diagnosis by a trained physician [5]. However, even without artificial intelligence, these technologies are already an important diagnostic tool as we demonstrated here using the two cases of paroxysmal arrhythmias and myocardial ischemia without obstructive CAD.

In addition to their clinical performance, studies reported patient and medical staff preference for wearable compared to standard 24 h

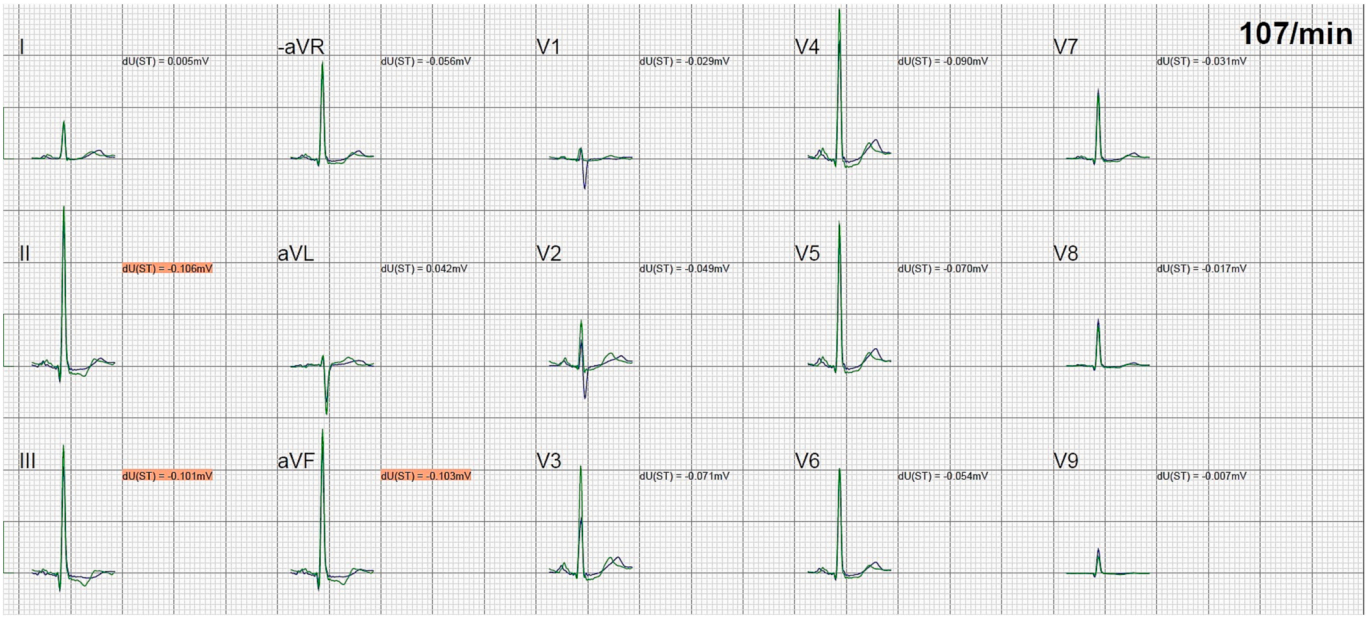

Fig. 4. CS-ECG showing ST-segment depressions in II, III, aVF; blue curve: baseline resting CS-ECG; green curve: CS-ECG recorded during an episode of chest pain.

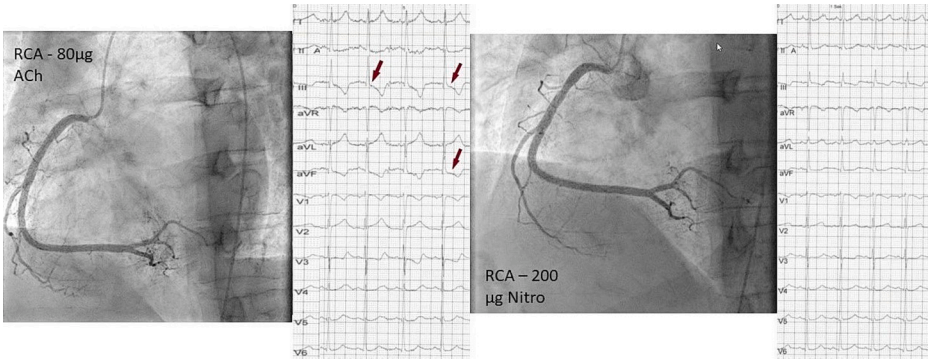

Fig. 5. Angiograms of the right coronary artery during acetylcholine provocation testing and after nitoglycerin i.c. and their corresponding 12-lead ECG recordings; red arrows indicate ST-segment depressions.

Fig. 6. ST-segment depressions on CS-ECG (arrows on the left side) versus ST-segment depressions during ACh provocation of the RCA (arrows on the right side).

monitoring devices due to their ease of use, which may result in greater compliance and eventually better health outcomes [6]. However, the utilization of wearable devices can be challenging in some populations like the elderly due to difficulties in correct handling [7] and limited availability of smartphones [8]. Furthermore, this new wave of multi-functional cardiac monitoring devices will require proof that tracings

are reliable and correspond to the curves obtained using a standard 12-lead ECG machine. Such proof is available for the CS-ECG system [9].

5. Conclusion

The amount of cardiac-related presentations in the emergency department setting points out a need for faster and more robust screening devices for patients experiencing cardiac-related symptoms. Rapid developments in the wearable ECG market have started a debate about their employment in patient care. Devices such as the CS-ECG have proved their efficacy in the outpatient care setting. Wearable ECG devices promise to become important new diagnostic tools as they are cost-effective, improve patient compliance, and enable fast availability during a symptomatic event. Moreover, as stated in our cases, wearable ECG devices may accelerate diagnosis and ultimately positively influence therapy and outcome, especially for patients with paroxysmal arrhythmias and those with coronary vasomotion disorders.

Ethics approval

Ethics approval not required.

Consent for publication

Consent for publication was obtained from the two patients.

Availability of data and materials

Not applicable.

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Conception and design: PO, US, AS.
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Drafting of the manuscript: JM.
Critical revision: PO, US, AS, RB, SF, CT.

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.

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