ORIGINAL ARTICLE

Usefulness of long-term telemetric electrocardiogram monitoring in the diagnosis of tachycardia in children with a medical history of palpitations

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KEY WORDS
cardiac arrhythmias, children with palpitations, Holter electrocardiogram monitoring, long-term telemetric electrocardiogram recording, PocketECG system

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ABSTRACT

BACKGROUND In children, palpitations, which may result from a life-threatening tachyarrhythmia, are one of the most common causes of cardiac visits and hospitalizations. Effective diagnosis is essential in this population of patients.

AIMS This study aimed to assess the usefulness of long-term telemetric electrocardiograms compared with Holter monitoring in the diagnostic workup in children with palpitations.

METHODS A total of 350 children with undocumented palpitations were examined in a multicenter study. In 167 patients (47.7%), the TELE group, month-long continuous telemetric electrocardiogram monitoring (using the PocketECG system) was performed. In 183 patients (52.3%), the HOLT group, 24-hour Holter electrocardiography was carried out and repeated after a month if tachyarrhythmia was not recorded.

RESULTS A total of 152 children (43.4%) reported palpitations, and 36.2% of them had sinus tachycardia during palpitations. Tachyarrhythmias were recorded in 68 patients (40.7%) in the TELE group and in 7 (3.8%) in the HOLT group after the second examination (P <0.001); the mean time to record tachycardia was 15.8 (8.7) days versus 25.4 (11.1) days (P = 0.004). In the TELE group, we noted a greater number of children with palpitations during recording (62.9% vs 18%), tachycardia with normal QRS complexes (21.6% vs 1.6%), ventricular tachycardia (11.4% vs 0.5%), and asymptomatic arrhythmias than in the HOLT group.

CONCLUSIONS In children, long-term telemetric electrocardiogram monitoring using the PocketECG system is well tolerated and has a high diagnostic efficacy. In young patients with palpitations, telemetric cardiac monitoring lasting up to a month increased the number of patients with recorded tachyarrhythmia by almost 10-fold compared with the analysis of 2 Holter electrocardiograms. We found that a large number of children have asymptomatic cardiac arrhythmias.

INTRODUCTION In children, rapid heartbeat attacks or palpitations are one of the most common causes of cardiac visits and hospitalizations. These symptoms usually occur periodically, at various frequencies, and are not long-lasting. The occasional occurrence of episodes significantly hampers the diagnosis and proper therapeutic management, particularly given the fact that no abnormalities are observed in the time interval between incidents in most subjects. Among patients with palpitations, there are children with mild sinus rhythm acceleration, but there are also those with life-threatening tachyarrhythmia causing syncope or cardiac arrest, in whom

WHAT'S NEW?

We examined 350 pediatric patients with undocumented palpitations. For the first time, telemetric continuous electrocardiogram monitoring prolonged to 30 days was performed in 167 (47.7%) of them, using the PocketECG system. A total of 152 children (43.4%) reported palpitations at the time of electrocardiogram recording, and in 55 (36.2%) of them no cardiac arrhythmias were found during palpitations, apart from the accelerated sinus rhythm. The number of patients with tachycardia detected by the PocketECG system was almost 10-fold greater compared with two 24-hour Holter electrocardiograms. The mean time to diagnose was 15.8 (8.7) days. Long-term telemetric electrocardiogram recording showed asymptomatic cardiac arrhythmias: supraventricular and ventricular ectopic beats, bradycardia incidents, and atrioventricular conduction disorders, which were found in a greater number of children than in the case of the analysis of two 24-hour Holter electrocardiograms. Of note, children with asymptomatic arrhythmias also require periodic cardiac care.

it is very difficult to document the incident. It has been estimated that, in 10% to 15% of children with palpitations, symptoms correlate with those of supraventricular tachycardia. Early, reliable, and noninvasive diagnostic workup that enables the implementation of the appropriate and most effective therapeutic management is extremely important in children.[1-4] Commonly applied standard and Holter electrocardiogram recordings have poor diagnostic efficacy.[5-9] It is essential to optimize diagnostic workup, especially in view of the fact that the recently developed technological solutions allow for long-term remote monitoring of heart rhythm and automatic diagnosis. A noninvasive modality that prolongs monitoring time for electrocardiogram recording in children with periodically occurring symptoms increases the probability of detecting incidents and clinically dangerous arrhythmias.[10,11] This may significantly facilitate the diagnosis and early implementation of an appropriate (non)invasive therapeutic management.[1,3,4,12]

The aim of this study was to assess the usefulness of long-term continuous telemetric electrocardiogram monitoring as compared with the standard 24-hour Holter recording, currently applied for the diagnosis of children with a history of palpitations.

FIGURE 1 PocketECG system

METHODS The study was conducted as a multicenter trial. The Bioethics Committee of the Institute of Cardiology (IK-NP.-0021-48/1139/09 as of April 6, 2009; permission to continue the trial granted on April 14, 2014) approved the study.

The PocketECG system (MEDICALgorithmics, Warsaw, Poland), a new technological solution for long-term remote heart rate monitoring and automatic diagnostic workup, was used for telemetric electrocardiogram monitoring (FIGURE 1). The system enables real-time noninvasive long-term 2-channel electrocardiogram monitoring. Data are collected from 3 electrodes placed on the patient's chest. The electrocardiographic signal is transmitted through the mobile phone network. A full recording is transmitted, including each beat during the examination, even for up to 30 days. The device automatically records and recognizes the morphology of electrocardiographic waveforms: P waves, T waves, and QRS complexes. Advanced algorithms used in the system analyze and recognize various types of arrhythmias including ventricular arrhythmia, supraventricular arrhythmia, atrial fibrillation, and single ectopic beats. The beginning and the end of each arrhythmia type is marked, and all heartbeats are classified in real time. It is possible to directly correlate the patient's symptoms with the rhythm recorded at a given time, assess the impact of effort on changes in rhythm frequency, or check the effectiveness of antiarrhythmic drugs used. During monitoring, the recording can be assessed on an ongoing basis and relevant fragments can be printed out. After monitoring has been completed, a Holter-like diagnostic report is generated, which provides a full statistical and graphical presentation of arrhythmia, heart activity, and symptoms (FIGURE 2).[13,14]

Twenty-four–hour Holter electrocardiography was performed by means of 3-channel recorders: MR45 with the Medilog Excel analysis system (Oxford Medical, Ltd., Abingdon, United Kingdom) or DMS 300-7 with the Cardioscan 12 system (DM Software, Stateline, Nevada, United States).

Patients who visited pediatric cardiology clinics were selected for the study based on their medical history and standard 12-lead electrocardiographic recordings. The inclusion criteria were as follows: 1) age of up to 18 years; 2) medical history of the incidence of palpitations occurring not less frequent than 4 times a year; 3) incidents not documented on electrocardiography; 4) single supraventricular and / or ventricular ectopic

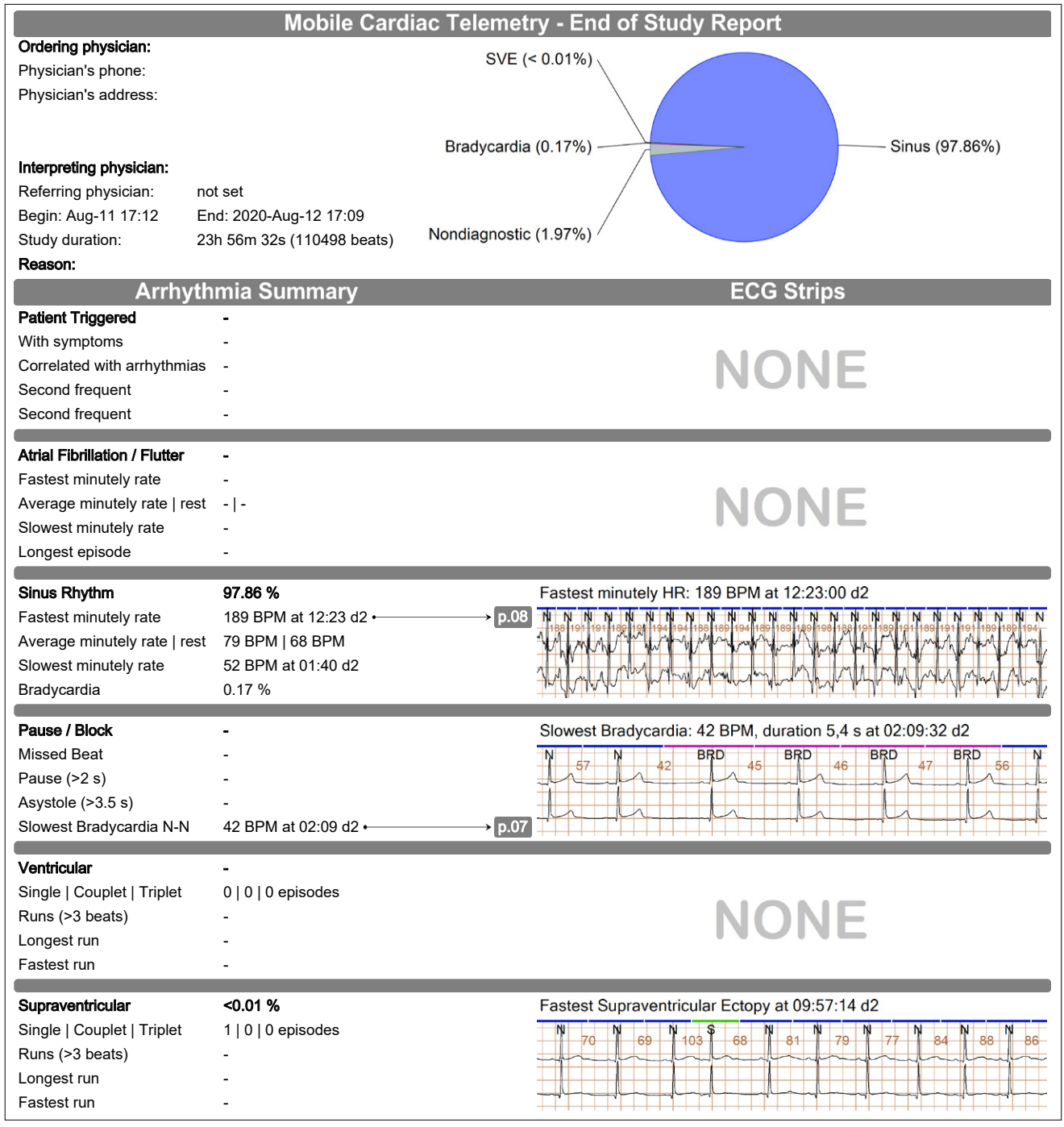

FIGURE 2 First pages of a summary report of a 9-year-old boy, obtained from the PocketECG system

beats, features of atrial or ventricular hypertrophy as well as atrioventricular conduction disorders on electrocardiography did not exclude the patient from the study; and 5) cooperation of parents and children regarding device operation was possible. Patients who had previously had tachycardia recorded on electrocardiography and those with overt preexcitation (Wolff–Parkinson–White syndrome) on electrocardiography were deemed ineligible for the study.

The patients were selected during their visits at pediatric cardiology outpatient clinics. In each center, they were assigned to one of the 2 study groups: 1) the TELE group including patients diagnosed using continuous telemetric electrocardiogram monitoring lasting a month or until the diagnosis was established, ie, palpitations and / or tachycardia were recorded; 2) the HOLT group including patients diagnosed using the commonly available 24-hour electrocardiogram Holter recording; the first recording was performed immediately after the inclusion in the study, and the second one, after a month, unless the patient reported palpitations and / or tachycardia was recorded during the first examination.

Parents (guardians) and patients were informed about the assumptions of the study and signed informed consent forms. Physicians completed a questionnaire for each patient, which included patients' details, medical history, findings from physical examination and electrocardiography, as well as the date of joining the study. Echocardiographic findings and exercise test results were added if available.

In the TELE group, continuous telemetric electrocardiogram recording was performed (the patient received a recorder for arrhythmia detection for home use). If palpitation occurred and/or tachyarrhythmia was recorded during telemetric monitoring, the patient completed their participation in the program. Otherwise, the study was completed after 30 days of telemetry recording.

In the HOLT group, 24-hour Holter electrocardiography was used. Patients with tachyarrhythmia recorded during the first examination ended their participation in the study and were further treated according to the protocol adopted in their cardiology centers. Other patients had the second Holter electrocardiogram performed a month later and their participation in the project was completed, regardless of whether arrhythmia was recorded or not.

The results of continuous telemetric and Holter monitoring were passed to the supervisory center. The recordings were analyzed at a paper speed of 25 mm/s with a standard feature of 0.1 mV = 1 mm and interpreted by 2 experienced pediatric cardiologists dealing with cardiac arrhythmias on a daily basis.

In accordance with the generally accepted criteria, the following arrhythmic events were considered significant: supraventricular tachycardia (with normal QRS complexes), atrial fibrillation/flutter, monomorphic ventricular tachycardia, polymorphic ventricular tachycardia/ventricular fibrillation, cardiac pauses longer than 3 seconds, advanced/complete atrioventricular block. The results obtained were entered into a database.

Statistical analysis Data were analyzed using the SAS software, version 9.4 (SAS Institute, Inc., Cary, North Carolina, United States). Study results were presented as frequency and percentages for categorical variables and mean (SD) or median (interquartile range) for continuous variables. The distribution of continuous variables was tested for normality with the Kolmogorov–Smirnov test. The study groups were compared using the χ^2 (Pearson) test or the Fisher exact test (when the number of expected events in cells was lower than 5) for categorical variables and independent *t* tests (Satterthwaite method) or Wilcoxon rank sum tests for continuous data, as appropriate. The strength of the relationship between measurable variables was analyzed with the Spearman rank-order correlation. Kaplan–Meier curves were used to present the time-to-event (tachycardia) outcome, and the 2 study groups (TELE and HOLT) were compared by means of log-rank tests. *P* values were 2-tailed and considered significant if less than 0.05.

RESULTS Thirteen pediatric cardiology centers participated in the study (TABLE 1). In total, 350 patients were examined (the largest number of 120 children [34.3%] in the Department of Cardiology at The Children's Memorial Health Institute), and telemetric recording was carried out in 167 patients (47.7%). A total of 183 children (52.3%) were included in the HOLT group, 135 (73.8%) of whom had a second Holter examination performed a month following the first one. Data on age and sex of the study patients as well as the mean time from the onset of palpitations are shown in TABLE 2.

Patients' medical history revealed that palpitations occurred since more than a year on average. The frequency of incidents varied from several attacks per hour to several incidents per year. The largest number of patients (152 [43.4%]) experienced several attacks during a month. The duration of attacks ranged from a few minutes to half an hour (median [interquartile range] time, 4 [2–10] minutes). Most children had attacks during the day, and the most frequent factors triggering the attacks included effort (36.3%), a sudden stressful situation (31.4%), and heavy physical exertion (15.1%). During palpitations, 44.3% of the study patients experienced irregular heart rhythm and 42.6% had chest pain. In 40% of cases, the incident was accompanied by anxiety, and 34.3% of the patients suffered from dizziness. Less frequently reported signs included excessive sweating, accelerated breathing, asthenia, and fatigue. The most alarming symptoms, such as collapse, were reported by 62 children (17.7%). A total of 10 children (2.9%) experienced syncopal attacks preceded by palpitations.

During the physical examination, all children were in good condition, with no symptoms of heart failure (New York Heart Association functional class I), and had a regular heart rhythm. In 78 children (22.3%), a quiet murmur was heard over the heart (1–2/6 on the Levine scale), usually along the left edge of the sternum.

Echocardiography was performed in 287 children (82%), 249 (86.8%) of whom had normal hearts. Congenital heart disease was diagnosed in 21 children (7.3%), mitral valve prolapse was found in 16 patients (5.6%), and a single patient suffered from dilated cardiomyopathy. The mean values of left ventricular ejection fraction and left ventricular fractional shortening were normal in 281 study subjects, while 6 children had slightly impaired left ventricular contractility (TABLE 3). The results of standard 12-lead

TABLE 1 Pediatric cardiology centers and researchers involved in the project

Pediatric cardiology centers	Researchers
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Department of Pediatrics, Endocrinology, Diabetology with Subdepartment of Cardiology, Medical University of Bialystok, ul. Waszyngtona 17, 15-274 Białystok, Poland	Joanna Tułwińska, Jerzy Wójtowicz
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Professor Stanisław Popowski Provincial Specialist Hospital in Olsztyn, ul. Żołnierska 18a, 10-561 Olsztyn, Poland	Iwona Szulc-Bugalska

TABLE 2 Characteristics of the study patients

Characteristics	TELE group[a] (n = 167)	HOLT group[b] (n = 183)	*P* value
Age, y, mean (SD)	14.4 (2.8)	13.7 (3.8)	0.03
Female sex, n (%)	102 (61.1)	125 (68.3)	0.16
Time from symptom onset, d, median (IQR)	378 (139–882)	364 (152–684)	0.18

a Patients examined using telemetric monitoring

b Patients examined using Holter monitoring

Abbreviations: IQR, interquartile range

electrocardiographic recordings were similar in both study groups (TABLE 4).

In the TELE group, telemetric recording was well tolerated and no significant technical problems occurred that could lead to test discontinuation. Short interruptions resulted from the need to replace the electrodes. The generation of a report and its final evaluation were possible in all patients. In 90 patients (53.9%), recording was completed after the planned period of 30 days, while that time was shorter for the remaining patients. The examination did not confirm the hypothesis that more frequent palpitation attacks result in a shorter time to diagnosis ($r = -0.14$, $P = 0.25$). The mean time to record tachycardia was 15.8 (8.7) days in the TELE group and 25.4 (11.1) days in the HOLT group ($P = 0.004$). The Kaplan–Meier curves showed that the probability of survival without detecting tachycardia decreased very quickly in the TELE group (0.39 on day 33) and remained almost constant for a long period of time in the HOLT group (0.9 on day 50) (FIGURE 3).

TABLE 3 Echocardiographic findings in the study patients

Variable	TELE group (n = 167)	HOLT group (n = 183)	*P* value
Patients undergoing echocardiography	137 (82)	150 (82)	>0.99
Normal heart	105 (76.6)	128 (85.3)	0.06
Congenital heart disease	11 (8)	10 (6.7)	0.66
Dilated cardiomyopathy	1 (0.7)	0	0.48
Mitral valve prolapse	13 (9.5)	3 (2)	0.006
Contractility disorder	2 (1.5)	4 (2.7)	0.69
LVEF, %, mean (SD)	67.7 (7.9)	68.3 (5.8)	0.58
LVFS, %, mean (SD)	39.5 (6.9)	38.1 (4.9)	0.14

Data are presented as number (percentage) of patients unless otherwise indicated.

Abbreviations: LVEF, left ventricular ejection fraction; LVFS, left ventricular fractional shortening

TABLE 4 Results of standard 12-lead electrocardiographic recording in the study groups

Variable	TELE group (n = 167)	HOLT group (n = 183)	*P* value
Patients undergoing standard electrocardiographic recording	164 (98.2)	182 (99.4)	0.35
HR, bpm, mean (SD)	78.1 (15.5)	79.5 (16.4)	0.49
Sinus rhythm	163 (99.4)	181 (99.5)	>0.99
PQ interval, ms, mean (SD)	137.3 (24.1)	135.4 (21.6)	0.51
QRS complex, ms, mean (SD)	78.8 (14.7)	79.7 (11.8)	0.57
QT interval, ms, mean (SD)	343.1 (34.8)	346.9 (33.8)	0.39
QTc interval[a], ms, mean (SD)	389.0 (25.2)	393.3 (30.9)	0.23
Abnormal morphology of QRS complexes	15 (9.2)	19 (10.4)	0.69
Nodal escape rhythm and ectopic supraventricular beats	1 (0.6)	0	0.47
Ectopic rhythm	0	1 (0.5)	>0.99
Supraventricular ectopic beats	0	1 (0.5)	>0.99
Ventricular ectopic beats	3 (1.8)	0	0.11

Data are presented as number (percentage) of patients unless otherwise indicated.

a A QTc interval denotes a corrected QT interval calculated according to the Bazett formula.

Abbreviations: HR, heart rate

During long-term electrocardiogram monitoring in the TELE group, cardiac arrhythmias were recorded in 149 patients (89.2%). A total of 62 patients (37.1%) did not report any symptoms; however, arrhythmias were detected in 53 (85.5%) of them. In the HOLT group, there were 87 patients (47.5%) with arrhythmia and 136 asymptomatic patients (74.3%), 69 (50.7%) of whom had arrhythmia. The differences between the compared groups were highly significant (P <0.001). Further data obtained during electrocardiogram monitoring are presented in TABLE 5.

The number of children who reported palpitations at the time of recording was higher in the TELE group than in the HOLT group. This finding was similar to the difference between the number of patients in whom the cause of the reported symptoms was established and the number of children with recorded both supraventricular (with normal QRS complexes) and ventricular tachycardias. The second 24-hour electrocardiogram was performed in 135 patients (73.8%) from the HOLT group, which increased the number of patients with the above-mentioned diagnoses yet did not affect the significance of the results. Tachycardia with normal and wide QRS complexes was recorded in 9 children (5.4%) from the TELE group, while no case of that tachycardia type was found on Holter electrocardiogram monitoring.

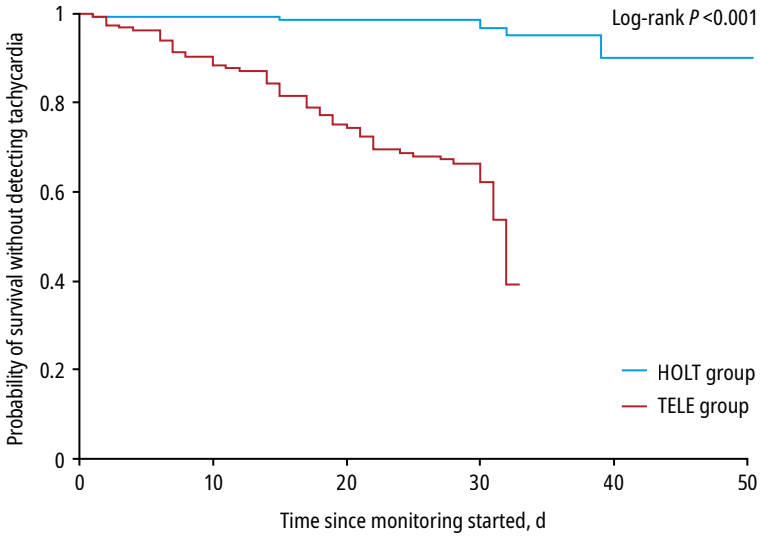

FIGURE 3 Kaplan–Meier curves for tachyarrhythmia recording in the study groups

In the HOLT group, there were 28 children (15.3%) with a history of collapse. In a single patient (3.6%) among those, tachycardia with normal QRS complexes was detected, and 5 children (17.9%) had palpitations with sinus tachycardia at the time of monitoring. Out of 3 patients (1.6%) with syncope, none had tachycardia at the time of recording, and a single patient reported rapid heartbeat with sinus tachycardia at that time. In the TELE group, 34 children (20.4%) reported collapse in their medical history. Tachycardia attacks were recorded in 14 (41.2%) patients (supraventricular in 11 patients [32.4%], ventricular in a single child [2.9%], and tachycardia with normal and wide QRS complexes in 2 patients [5.9%]), and 18 patients (52.9%) had a faster sinus rhythm at the time of reported palpitations. Out of 7 children (4.2%) with a history of syncope, a single child (14.3%) had tachycardia with normal and wide QRS complexes and another one (14.3%) had sinus tachycardia at the time of reported rapid heartbeat.

Palpitations were not recorded more frequently in patients with cardiac pathology. In both study groups, there were children with no cardiac arrhythmias found during palpitations (the TELE group: 31 [29.5%]; the HOLT group after the first examination: 16 [48.5%]; the HOLT group after 2 examinations: 24 [51.1%]), apart from the accelerated sinus rhythm that could cause such symptoms.

During long-term telemetric electrocardiogram recording in the TELE group, numerous study patients had cardiac arrhythmias manifested as supraventricular and ventricular ectopic beats as well as bradycardia incidents and

TABLE 5 Events detected during electrocardiogram monitoring by study groups

Variable	TELE group (n = 167)	HOLT group (n = 183), test 1	*P* value (TELE vs HOLT, test 1)	HOLT group (n = 183 + 135), test 1 + test 2	*P* value (TELE vs HOLT, test 1 + test 2)
Palpitations	105 (62.9)	33 (18)	<0.001	47 (25.7)	<0.001
Established cause of palpitations	74 (44.3)	17 (9.3)	<0.001	23 (12.6)	<0.001
Recorded tachycardia	68 (40.7)	5 (2.7)	<0.001	7 (3.8)	<0.001
Supraventricular tachycardia	36 (21.6)	3 (1.6)	<0.001	5 (2.7)	<0.001
Fastest HR in SVT, bpm, median (IQR)	186 (157–214)	180 (105–271)	0.83	157 (142–180)	0.32
Ventricular tachycardia	19 (11.4)	1 (0.5)	<0.001	1 (0.5)	<0.001
Fastest HR in VT, bpm, median (IQR)	160 (145–175)	225	–	225	–
Polymorphic VT	4 (2.4)	1 (0.5)	0.2	1 (0.5)	0.2
Tachycardia with narrow and wide QRS complexes	9 (5.4)	0	0.001	0	0.001
Atrial fibrillation	2 (1.2)	0	0.22	0	0.22
Supraventricular ectopic beats	137 (82)	54 (29.5)	<0.001	61 (33.3)	<0.001
Ventricular ectopic beats	117 (70.1)	41 (22.4)	<0.001	55 (30)	<0.001
Ventricular bigeminy	13 (7.8)	3 (1.6)	0.006	4 (2.2)	0.01
Bradycardia <45 bpm, correlated with symptoms	8 (4.8)	0	0.003	2 (1.1)	0.053
Bradycardia <40 bpm	28 (16.8)	10 (5.5)	<0.001	12 (6.6)	0.003
Atrioventricular conduction disorders	27 (16.2)	12 (6.6)	0.004	18 (9.8)	0.08
RR pauses >3000 ms	2 (1.2)	0	0.23	0	0.23

Data are presented as number (percentage) of patients unless otherwise indicated.

Abbreviations: RR, interval between R waves; SVT, supraventricular tachycardia; VT, ventricular tachycardia; others, see TABLE 2

atrioventricular conduction disorders, which did not cause symptoms. Their number was higher than that after 2 sessions of 24-hour Holter monitoring in the HOLT group (TABLE 5).

DISCUSSION Rapid heartbeat attacks or palpitations reported by children are among the most common causes of cardiac visits and hospitalizations. Patients reporting such symptoms include children with accelerated sinus rhythm and also those with life-threatening tachyarrhythmia that may lead to loss of consciousness or cardiac arrest. Commonly used as the gold standard modality, Holter electrocardiogram recording is not very effective for the diagnosis of children, as demonstrated in numerous studies.[1-5,7-9] This is largely due to the fact that cardiac arrhythmias in children occur periodically and usually last for a short time. In addition, some children do not feel arrhythmias and, in some cases, it is difficult to obtain consistent data on symptoms.[1-5,7-9]

In the current study, we examined 350 children with reported and undocumented palpitations who were treated in 13 pediatric cardiology centers. On the first 24-hour Holter electrocardiogram monitoring performed in 183 children, tachycardia—being the cause of reported palpitations—was detected in 5 patients (2.7%). After the second Holter monitoring session in 135 patients, the number of children with documented tachycardia increased to 7 (3.8%). The percentage of diagnoses is slightly lower than the most commonly reported one, ie, approximately 5%.[7-9,15] This may result from the selection of participants: our study group did not include patients with patterns typical of Wolff–Parkinson–White syndrome or tachycardia on electrocardiography. Such exclusions were not made in the majority of studies evaluating the diagnostic efficacy of 24- or 48-hour electrocardiogram recordings.

Our study also confirmed the observation of other researchers who stated that a large percentage of children experiencing palpitations have sinus tachycardia (in our study, 8.7% of patients after the first 24-hour Holter electrocardiogram monitoring session and 13.1% after the second one).[7-9,15]

The prolongation of electrocardiogram monitoring in the TELE group, as it was intuitively expected, increased the percentage of diagnosed patients, while the mean time to record tachycardia was shorter than in the HOLT group. We showed that the rate of arrhythmia detection during long-term electrocardiogram monitoring in the TELE group was higher, and the differences between the study groups were significant. The number of patients in whom the cause of reported symptoms could be established was larger among those undergoing continuous monitoring compared with double 24-hour Holter electrocardiogram recording, used as the gold standard (74 versus 23 patients). The same applied to the documentation of supraventricular tachycardia attacks (36 versus 5 patients), particularly ventricular tachycardia (19 patients versus 1 patient). The results had a significant impact on further management, as children with recorded tachyarrhythmia were referred to centers performing invasive electrophysiological examinations and percutaneous ablation procedures; almost all of them underwent the therapy. Moreover, in the TELE group, the percentage of children (18.6%) who reported palpitations while the recording showed only a slightly accelerated sinus rhythm was also higher. The results obtained clearly prove that pediatric patients need long-term electrocardiogram monitoring, lasting at least 2 weeks, in order to diagnose cardiac arrhythmias. In this population, the use of telemetric electrocardiography—the PocketECG system in our study—has a very high diagnostic efficacy.

A method of prolonged monitoring of electrocardiogram recording has been sought for years. For a more effective diagnosis of symptomatic pediatric patients, data transfer via telephone was applied as early as at the end of the last century.[15] Karpawich et al[15] examined 202 children with suspected arrhythmia from a cardiology clinic. In 97 patients, 24-hour Holter monitoring was performed; 105 study subjects used an external recorder for a month and they could transfer data via telephone, which was done by 59 of them. The correlation between symptoms and arrhythmia was found in almost 32% of cases after the transmission of recordings via telephone and only in approximately 5% of cases at the time of Holter recording. In 30% of the recordings taken at the time of reporting symptoms (61% via telephone and 14% at the time of Holter electrocardiogram monitoring), normal sinus rhythm was recorded, with no signs of arrhythmia. Recently, daily telephone transmission has been applied with relatively good outcomes in newborns and infants with paroxysmal tachycardia.[16] Telephone transmission of data or external event recorders allow the user to take a 1-channel short-term electrocardiogram recording at the time of experiencing symptoms or just afterwards.[17-19] The newly available smartphone applications (eg, AliveCor Kardia) work in a similar way.[20-22] A continuous 1-channel recording of up to 14 days is possible with the recently distributed adhesive recorders that do not require additional electrodes (eg, the ZIO XT Patch system). The device is placed on the left side of the upper chest, directly on the skin, and data are collected by 2 sensors.[23-26] Vests with electrocardiographic sensors installed represent a modification of those rhythm monitors; the recorder is attached to the vest from the outside.[27-29] Implantation of a loop recorder is an invasive

method of electrocardiographic recording[30,31]; however, in children, this method should be used only if the possibilities of noninvasive diagnostic workup have been exhausted. The PocketECG system has an advantage over other tools discussed above, because the device transmits all electrocardiographic signals, including each heartbeat, throughout the entire examination time. A continuous 2-channel electrocardiogram recording is obtained in real time. That is why dangerous arrhythmias can be detected as soon as they occur, not only after the recording has been completed. This method makes it possible to extend the monitoring time for electrocardiographic recording to up to 30 days, which increases the probability of recording an incident and detecting clinically dangerous arrhythmias in individuals in whom symptoms occur periodically.[13,14] The use of continuous electrocardiographic recording for the period of up to a month significantly improved the diagnosis and facilitated the implementation of appropriate therapeutic procedures, such as percutaneous ablation. It applied to a large group of the study children who were still not properly diagnosed after undergoing standard 24- or even 48-hour Holter electrocardiogram monitoring and only their medical history indicated the possibility of arrhythmia. Therefore, a large group of children had the opportunity to fully recover and continue physical activity, which is so important in pediatric patients.

Prolonged continuous electrocardiogram monitoring also contributed to recording arrhythmias that did not manifest with symptoms in the study patients and, therefore, were not reported. The most frequent arrhythmias included supraventricular and ventricular ectopic beats as well as bradycardia incidents and atrioventricular conduction disorders. The number of patients with asymptomatic arrhythmia was higher in the group diagnosed with the use of long-term telemetric electrocardiogram monitoring. Our findings showed that longer electrocardiogram monitoring, lasting at least 2 weeks, in pediatric patients with arrhythmia, which is more frequently asymptomatic in this population than in adults, is of diagnostic value. We also demonstrated the advantage of the PocketECG system over cardiac event recorder systems, which require patients and/or their parents to activate the recording when symptoms occur. Based on the available literature, this is the first study in which such a long-term continuous electrocardiographic recording was used in children reporting palpitations.

Conclusions In pediatric patients, prolonged telemetric electrocardiogram monitoring using the PocketECG system is well tolerated and has a high diagnostic efficacy. In children and adolescents with palpitations, telemetric cardiac monitoring lasting up to a month increased the number of patients with recorded tachyarrhythmia by almost 10-fold compared with 2 standard 24-hour Holter electrocardiogram monitoring sessions. Using prolonged continuous telemetric electrocardiogram monitoring, we detected asymptomatic cardiac arrhythmias requiring cardiac care in a large percentage of pediatric patients.

ARTICLE INFORMATION

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CONFLICT OF INTEREST None declared.

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