Using a Cardiac Event Recorder in Children with Potentially Arrhythmia-Related Symptoms

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Background: In this study, we reported our experience with the use of cardiac event recorders in pediatric patients.

Methods: We evaluated 583 patients fitted with an event recorder (15–30 days) between March 2010 and November 2014 at our clinic. Excluded from the study were 117 patients with no recorded events and six with records contaminated by electrocardiogram artifacts. All of the patients received electrocardiograms, Holter monitoring, and echocardiography before the cardiac event recording.

Results: The patient sample consisted of 460 patients (64% female). The mean age was 12.8 ± 4.1 years. The median number of recorded events was 7. The indications included palpitations in 336 (73%) patients, syncope in 27 (6%) patients, and chest pain and palpitations in 97 (21%) patients. Whereas 64 patients (14%) had structural heart disease according to echocardiographic examination, the remaining patients had normal echocardiographic examination results. The most frequent cardiac comorbidities were mitral valve prolapse (6%), operated tetralogy of Fallot (1.5%), and complicated congenital heart diseases with single ventricle physiology (1%). The recorded events were sinus tachycardia in 113 (25%) patients, supraventricular tachycardia in 35 (8%) patients, ventricular extrasystole in 20 (4%) patients, supraventricular extrasystole in nine (2%) patients, and ventricular tachycardia in two (0.4%) patients. Based on the event recorder and follow-up electrocardiogram findings, 46 patients received an electrophysiology study/ablation. The symptom-rhythm correlation was 39%.

Conclusion: In the presence of possible arrhythmia-related symptoms in children, a cardiac event recorder can be considered a useful primary diagnostic method. More research on this topic is needed.

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The 12-lead electrocardiogram has served as the "gold standard" for arrhythmia diagnosis for more than 100 years. However, the limitations inherent in an electrocardiogram also have been recognized

for a similar amount of time. Arrhythmias can be paroxysmal and asymptomatic; thus, a baseline-resting electrocardiogram may be insufficient for diagnosis. Holter monitoring remains the most

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widely used technology for the continuous recording of electrocardiograms. Yet, the short duration of conventional Holter monitoring, which is limited to a 24-hour period of recording, can be inadequate if cardiac symptoms are infrequent.¹ Hegazy et al. confirmed the low diagnostic yield of this instrument among pediatric patients with transient palpitations, chest pain, and syncope, which are common indications for Holter monitoring, in a large study population.² Since the development of the Holter monitor in the 1940s, there has been progressive development in ambulatory external electrocardiogram monitoring technology. The inability to diagnose patients with suspected arrhythmia using traditional methods, such as 24-hour Holter monitoring, is an important clinical problem. Remote monitors, transtelephonic or external loop recorders, cardiac event recorders, and implantable loop recorders are additional devices that may increase the diagnostic yield in such patients. However, few studies relating to this topic focus on the childhood period.

In this study, we reported our experience with the use of cardiac event recorders in pediatric patients. To the best of our knowledge, as gained from the literature in English, this is the largest second series performed to measure the diagnostic value of a cardiac event recorder for pediatric patients.

PATIENTS AND METHODS

Study Population

Between March 2010 and November 2014, 43,554 patients who varied in ages and backgrounds were seen at the pediatric cardiology clinic. The presentation symptoms of these patients included palpitations (4480 patients), syncope (896 patients), and chest pain and palpitations (224 patients). A cardiac event recorder was applied to 583 of these patients (aged <18 years) between the specified dates. Excluded patients included 117 with no recorded events and six with records contaminated by electrocardiogram artifacts. All patients underwent electrocardiogram, 24-hour Holter monitoring, and echocardiography before the use of the cardiac event recorder.

All patients referred with palpitations and syncope underwent a routine history collection, physical examination, 12-lead electrocardiogram,

laboratory investigation, echocardiography, and 24-hour Holter monitoring. Those with exercise-related symptoms were definitively assessed with an exercise test. The patients with congenital channelopathy and primary cardiomyopathy were excluded from the study. For patients without an identifiable etiology-related finding following these analyses, a cardiac event recorder was administered as an advanced test if their symptoms were above a certain frequency level (<1 month). In this study, patient data for those with which a cardiac event recorder was used due to palpitations, syncope, or chest pain and palpitations were retrospectively examined in the file recording system; obtained data were assessed in terms of symptom-rhythm correlation.

The Cardiac Event Recorder System

The CardioCall® (Spacelabs Healthcare Company, Snoqualmie, WA, USA) device was used for recording during symptoms. With this device, the patient presses the record button when he or she feels discomfort to start the recording. According to the already-designated recording protocol, an electrocardiogram is recorded for a specific period before and after the recording button is pressed (e.g., 1 minute before and 1 minute after) and saved in the memory with a record number and the recording date and time. The memory time of the device is 85 minutes for CardioCall^{ST80} (Fig. 1A) and 20 minutes for CardioCall²⁰ (Fig. 1B). The large memory of the device enables the continuation of recording electrocardiogram events if the symptoms recur. The direct input of the electrocardiogram results into the computer allows for the acquisition of digital electrocardiogram recordings of original quality. At our clinic, the device was used in its wired form for some patients and in its wireless form for other patients, which enabled direct-contact recording. Furthermore, we chose to set the device to be able to record for a period of 1 minute before and 2 minutes after the activation of the device.

Statistical Analysis

Statistics were calculated using the SPSS package. All values were expressed as percentages of the total or the mean $\pm$ standard deviation.

Figure 1. A view of the CardioCall device used as the cardiac event recorder system. (A) CardioCall^{ST80}. (B) CardioCall²⁰.

Figure 2. (A) A supraventricular tachycardia (SVT) record with a narrow QRS morphology. (B) The event recorder recording of a patient who had a wide QRS morphology and was observed to have posterior fascicular ventricular tachycardia (VT) in the electrophysiological study performed in the follow-up. SVT = supraventricular tachycardia; VT = ventricular tachycardia.

RESULTS

General Findings

The patient sample consisted of 460 patients ($n = 294$ females; 64%). The mean age was 12.8 ± 4.1 years. The median number of recorded events was 7 (range: 1–51). Indications included palpitations in 336 (73%) patients, syncope in 27 (6%) patients, and chest pain and palpitations in 97 (21%) patients. During Holter monitoring, performed before the use of the cardiac event recorder, the observed results included 15 patients (3%) with ventricular extrasystole, nine patients (2%) with supraventricular extrasystole, and 10 patients (2%) with preexcitation. The events recorded were sinus tachycardia in 113 (25%) patients, supraventricular tachycardia in 35 (8%) patients, ventricular extrasystole in 20 (4%) patients, preexcitation in 10 (2%) patients, supraventricular extrasystole in 9 (2%) patients, and ventricular tachycardia in two (0.4%) patients (supraventricu-

lar tachycardia and ventricular tachycardia records are shown in Figs. 2A and B). None of the patients with ventricular extrasystole on Holter monitoring showed ventricular tachycardia on the cardiac event recorder. However, supraventricular tachycardia was detected in two of nine patients showing supraventricular extrasystole on the Holter monitoring record. The rest of the patients had normal records. Based on the event recorder or follow-up electrocardiogram findings, electrophysiology study/ablation was performed in 46 patients.

The symptom-rhythm correlation was 39%. Pre-excitation was not accepted as positive regarding the symptom-rhythm correlation. Although 64 patients (14%) had structural heart disease according to the echocardiographic examination, the remaining patients had normal echocardiographic examination results. The most frequently identified structural heart diseases included mitral valve prolapse ($n = 27$; 6%), operated tetralogy of Fallot

Figure 3. Types of arrhythmia identified with Holter monitoring and the use of a cardiac event recorder, as sorted by the symptoms. n = number of patients; ST = sinus tachycardia; SVES = supraventricular extrasystole; SVT = supraventricular tachycardia; VES = ventricular extrasystole; VT = ventricular tachycardia.

Figure 4. Arrhythmia conditions identified in the patient groups with and without congenital heart disease. n = number of patients; ST = sinus tachycardia; SVES = supraventricular extrasystole; SVT = supraventricular tachycardia; VES = ventricular extrasystole; VT = ventricular tachycardia.

Table 1. Certain Characteristic Features Pertaining to the Patients.

Variable	Value
Number of patients	460
Age (years)	12.8 ± 4.1
Gender (females)	294 (64%)
Event recorder indication	
Palpitation	336 (73%)
Chest pain + palpitation	97 (21%)
Syncope	27 (6%)
Echocardiographic findings	
MVP	27 (6%)
Operated TOF	7 (1.5%)
Single ventricle	5 (1%)
BAV	4 (0.8%)
The others	21
Holter findings	
VES	15 (3%)
SVES	9 (2%)
Event recorder result	
ST	113 (25%)
SVT	35 (8%)
VES	20 (4%)
SVES	9 (2%)
VT	2 (0.4%)

AV = atrioventricular; BAV = bicuspid aortic valve; MVP = mitral valve prolapse; ST = sinus tachycardia; SVES = supraventricular extrasystole; SVT = supraventricular tachycardia; TOF = tetralogy of Fallot; VES = ventricular extrasystole; VT = ventricular tachycardia.

(n = 7; 1.5%), and pathologies with single ventricle physiology (n = 5; 1%), respectively. Certain characteristic features and data of patients are

presented in Table 1. The types of arrhythmia detected with Holter monitoring and the cardiac event recorder are illustrated in Figure 3 per patient symptoms. Furthermore, the arrhythmia conditions identified in the patient groups with and without congenital heart disease are shown comparatively in Figure 4.

Patient Outcomes

We performed ablation procedure in 24 of 35 patients diagnosed as supraventricular tachycardia. Six out of the remaining nine patients are under follow-up for ablation while the other three patients were lost to follow-up after supraventricular tachycardia diagnosis. We performed successful ablation in two patients diagnosed as ventricular tachycardia. We initiated beta-blocker therapy in the two patients diagnosed as supraventricular extrasystole and in five patients diagnosed as ventricular extrasystole when arrhythmia frequency was high and patients were symptomatic. We followed seven patients with supraventricular extrasystole and 15 patients with ventricular extrasystole, without starting any medications. We did not identify an organic reason in any of the patients diagnosed as sinus tachycardia and we did not initiate treatment for these patients. We made the necessary referrals to ensure these patients to be evaluated by the child psychiatry clinic in the event that their symptoms would continue. In the

follow-up period of patients with normal event recorder records, six patients were identified to have supraventricular tachycardia (at presentation to emergency in five patients and in Holter record in one patient). In conclusion, the overall diagnostic yield was identified as 40%.

DISCUSSION

This study assessed the diagnostic value of using a cardiac event recorder compared with electrocardiogram and Holter monitoring data for the investigation of symptoms, such as palpitations and syncope, of child patients. The most important conclusions reached in this study are the following:

- (1) A cardiac event recorder seems to be able to offer more information to the clinician compared with other devices, such as an electrocardiogram and 24-hour Holter monitoring, with respect to symptom-rhythm correlation.
- (2) This practice may provide an important advantage in favor of cardiac event recorder use in selected patients in countries where the cost of cardiac event recordings and Holter monitoring are equal, such as in our country.

Palpitations and syncope are the most common symptoms necessitating pediatric arrhythmia consultation at a pediatric cardiology clinic. An electrocardiogram recording captured during the symptom is undoubtedly the gold standard for diagnosing the underlying arrhythmia. However, it is not very easy to obtain this recording, especially in a patient with intermittent symptoms. During Holter monitoring, which is able to record for 24–48 hours, patients are generally symptomatic; therefore, the diagnostic value of this test is low.^{3,4} Ayabakan et al. examined 2017 pediatric patients in which 67% were identified as experiencing palpitations, chest pain, and syncope and received Holter monitoring.⁵ In this study, the diagnostic value of Holter monitoring for the symptom-rhythm correlation was low; however, this test could have more diagnostic value, especially in the context of an underlying heart disease and symptoms developing in the postoperative process. Hegazy et al. conducted another study with pediatric patients where the diagnostic yield of Holter monitoring was identified to be 5.7% for

palpitation patients and 0.4% for syncope patients.² None of the patients who presented with chest pain in this study were identified as having an abnormal Holter monitoring recording.

In the rather comprehensive study conducted by Sulfi et al. on adults, 8973 Holter monitorings were performed on 7394 patients, and it was emphasized that 84.2% of patients with altered consciousness had normal Holter monitoring recordings.⁴ In this study, it was specified that the diagnostic yield of Holter monitoring was especially low for the patient group <50 years, whereas 93.1% of patients with syncope symptoms and 95.3% of patients with altered consciousness had normal electrocardiogram recordings. Similarly, a cardiac event recorder may be used for electrocardiogram recordings when symptoms are present. The major advantage of this device compared with traditional Holter monitoring is that it is small, allows for longer periods of electrocardiogram monitoring, and can provide nearly real-time data analyses when the patient transmits a recording in proximity to the symptomatic event.⁶ Finally, the cardiac event recorder offers more information in terms of symptom-rhythm correlation.¹

Still, the number of studies investigating the symptom-rhythm correlation with the use of a cardiac event recorder in the pediatric population is limited. Park et al. conducted a study of 30 patients aged between 4 and 16 years using an Omron HeartScan 801 cardiac event recorder system and obtained symptom-rhythm correlation in all patients.¹ The researchers reported that they identified supraventricular tachycardia in four patients and sinus tachycardia in the remaining patients. Furthermore, all of the patients in that study had palpitations, with two patients additionally experiencing presyncope; the average recording time during the symptom was 22.8 ± 16.5 days (range: 5–65 days). Another study comparing a standard cardiac event recorder system with a leadless portable electrocardiogram monitoring system (Omron HeartScan 801 cardiac event recorder) with 18 adult patients with palpitation symptoms reported that symptom-rhythm correlation was identified in 14 of the 18 patients (78%) with the standard recorder and in all of the patients with the Omron HeartScan 801 recorder.⁷ A study conducted using 43 patients with palpitation symptoms reported that the diagnostic value of a cardiac event recorder was higher than Holter

monitoring and was more efficient in terms of cost effectiveness.⁸

Additionally, a study conducted by Saarel et al.,⁹ the most comprehensive study in the literature about this subject, evaluated 495 patients suspected of having cardiac arrhythmia with a transtelephonic electrocardiographic monitor. In that study, supraventricular tachycardia was identified in 35 (15%) of 238 symptomatic patients. The symptom presented of all the patients with supraventricular tachycardia was palpitation. No other treatment-requiring arrhythmias were identified in the study. The researchers also found that the overall sensitivity rate of the transtelephonic electrocardiographic monitor for supraventricular tachycardia identification was 83% (35 of 42), and the negative predictive value for this device was 99%.

Finally, a study conducted with 184 patients with palpitation, presyncope, and syncope symptoms reported that the cardiac event recorder offered useful information in the assessment of patients with no underlying cardiac diseases and was cost effective, yet it offered fewer benefits and was more expensive for presyncope and syncope patients with an underlying cardiac disease, especially in those with previous nondiagnostic electrophysiological test results.¹⁰ In that study, the number of patients with symptoms and identified arrhythmias was 60 (33%), the number of patients with symptoms and no identified arrhythmias was 41 (22%), and the number of patients without symptoms was 83 (45%).

Contrarily, our study, which used a high number of patients comparatively and assessed patients on whom we performed cardiac event recordings, had a symptom-rhythm correlation of 39%, which is a high rate compared with the rates cited for Holter monitoring in the literature. It is an indisputable fact that the use of a cardiac event recorder in selected patients is a more cost-effective procedure in countries where cardiac event recording and Holter monitoring costs are equal. Therefore, the cardiac event recorder is advantageous for the conditions in our country because it is more cost effective in terms of symptom-rhythm correlation. The number of patients in our study with palpitation symptoms was 433, and we observed sinus tachycardia in 133 patients (26%) and supraventricular tachycardia in 35 patients (8%). We did not have any patients with identified pathologies when tested for the

underlying causes of sinus tachycardia. For the patients with supraventricular tachycardia, we performed an ablation procedure in line with clinical indications. For those patients with normal sinus rhythms according to electrocardiogram recordings obtained with the cardiac event recorder during experienced symptoms, advanced studies were not conducted, which helped prevent unnecessary medical expenses and mitigated anxiety for the families and their children.

A cardiac event recorder is a diagnostically more advantageous test compared with baseline electrocardiogram and Holter monitoring; however, its major disadvantages include the necessary activation of the electrocardiogram recording during a symptom by the patient or family, requiring patient compliance, the need for the leads to be placed on the skin during the symptom or the discomfort of the leads being constantly placed on the skin, and decreased patient motivation in the absence of symptom recurrence. These factors may limit the diagnostic value of the test. Furthermore, one-fourth of the patients using the cardiac event recorder experienced problems with the device activation during a symptom despite previous training.¹¹

In cases where no electrocardiogram recordings could be obtained during a symptom with the cardiac event recorder, an implantable loop recorder could be used as another method of offering valuable diagnostic information if an underlying rhythm problem is suspected.¹² The diagnostic value of an implantable loop recorder in pediatric patients presenting with palpitation and syncope symptoms ranges between 50% and 95%.^{3,12-16} In a current study published by our center relating to patients with recurrent syncope not able to be explained by noninvasive diagnostic tests, six of 12 patients implanted with an implantable loop recorder were observed to have developed symptoms.¹² However, the indications of this test should be kept limited despite its higher diagnostic value as compared with other noninvasive diagnostic tests. The determining factors for this limitation include the following: the need for invasive procedures in both implanting and explanting stages of the device, potential wound-site-infection risk, higher cost than other noninvasive diagnostic tests, and scar tissue creation at the implantation site. Because of all these factors, the implantable loop recorder's

recommended use is only for the diagnosis of high-risk and life-threatening arrhythmias in patients with structural heart disease, primary cardiac electrical abnormalities, or recurrent syncope, which cannot be explained despite wide-ranging conventional diagnostic tests.^{3, 12, 13}

STUDY LIMITATIONS

The study was neither randomized nor blinded. The advanced technology has now made it possible to have devices that provide longer recording and are able to stay in the patient for a longer time; however, the event recorder devices that we have in our center lack the most recently developed technological properties as in many centers in our country. This situation is a factor that may prevent the symptom-rhythm correlation to be at higher ratios. Furthermore, artifact-free records could have been achieved with the use of new devices having more developed technological properties in our six patients that had artifact with ECG examples who had to be excluded from the study as stated in our article. This fact has been added to the limitations section of the study. The number and extent of preevent recorder investigations were at the discretion of the clinician, which may have influenced the diagnostic yield of the device. However, this study provides an accurate view of the clinical management of patients with palpitations, chest pain and palpitations, and unexplained syncope in a tertiary referral pediatric cardiology unit.

CONCLUSION

A cardiac event recorder was useful in establishing a symptom-rhythm correlation in the significant proportion of children with unexplained syncope, palpitations, and chest pain and palpitations. Although the cardiac event recorder allows for prolonged ambulatory monitoring for approximately 1 month, its use is sometimes confounded by a high rate of noncompliance.

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