

Diagnostic yield of ambulatory cardiac monitoring in pediatric patients with palpitations

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ABSTRACT

- Background** : Palpitations are a frequent reason for referral to pediatric cardiology providers and diagnostic workup includes ambulatory cardiac monitoring. While common practice, the diagnostic yield is unknown in the pediatric population. The objective is to evaluate the diagnostic yield of 24-h Holter and extended ambulatory cardiac monitoring in pediatric patients with palpitations.
- Methods and Results** : All pediatric patients aged 10–18 years who had ambulatory cardiac monitoring (1–30 days) through the Pocket Electrocardiogram (PocketECG™) system (Medi-Lynx) between January 2016 and July 2020 were included. Patients with an International Classification of Diseases-10 diagnosis code of palpitations (R00.2) during enrollment were evaluated separately. Tachyarrhythmia diagnoses included atrial fibrillation (AF), nonsustained supraventricular tachycardia (nSVT), supraventricular tachycardia (SVT), nonsustained ventricular tachycardia (nVT), and ventricular tachycardia (VT). Age, heart rates, arrhythmia type, and symptomatic transmission data were collected and analyzed. A total of 2388 patients (mean age 11.6 years, 58% F) with the R00.2 code had ambulatory cardiac monitoring (28% 24-h Holter, 72% extended) performed during the study period and there were 6287 total patients (mean age 13.9 years, 54% F) that underwent ambulatory cardiac monitoring (42% 24-h Holter, 58% extended) during that time. Of 2388 patients, 321 (13%) were diagnosed with tachyarrhythmia: AF (9), nSVT (192), SVT (59), and nVT (61). In the overall cohort, 764 (12%) patients were diagnosed with tachyarrhythmia: AF (22), nSVT (478), SVT (85), nVT (177), and VT (2). Symptomatic transmissions with normal cardiac rhythm were common in the R00.2 ($n = 1697, 71\%$) and overall ($n = 3848, 61\%$) groups. No episodes of nSVT, SVT, nVT, or VT were associated with symptomatic transmissions.
- Conclusion** : Ambulatory cardiac monitors are an integral part of the diagnostic workup for pediatric palpitations patients and have demonstrated a high yield of combined positive arrhythmia diagnoses and symptomatic normal transmissions. Further prospective study of this population with the integration of clinical information is warranted.
- Keywords** : Ambulatory cardiac monitors, Holter monitoring, pediatric palpitations, tachyarrhythmias

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INTRODUCTION

Palpitations in children are a common reason for referral to pediatric cardiologists,^[1-4] yet accurate histories can be difficult to elicit from many patients, especially children. The sensation associated with “palpitations” can be difficult to describe and it can be challenging to build associations with the circumstances surrounding the events.^[2] Palpitations can be associated with multiple diagnoses, including arrhythmias and noncardiac etiologies such as stress and anxiety, so it is important to distinguish concerning conditions from those that are benign.^[5,6]

The evaluation of pediatric patients presenting with palpitations includes a thorough history, physical examination, and usually an electrocardiogram (ECG). ECGs, however, only evaluate only a brief period of cardiac electrical activity and the patient often no longer has symptoms at the time of presentation. Cardiac monitoring, including Holter monitors and extended cardiac monitors, is often performed during outpatient pediatric cardiology visits to attempt to associate a cardiac rhythm with patient symptoms.^[3] In 2009, the ACC/AHA published guidelines that recommend ambulatory electrocardiography to correlate a symptom with a cardiac rhythm as a Class I recommendation.^[7]

Holter monitors often are limited to a 24-h period, while extended monitoring can range from 1 to 30 days. If a patient has a paroxysmal arrhythmia or infrequent symptoms that occur less than once per month,^[2] diagnosis can be more challenging, and longer-term implantable cardiac monitors may be indicated in certain scenarios.^[8,9]

The diagnostic yield of Holter and extended cardiac monitoring in pediatric patients with palpitations is not well known, and the literature so far has shown varied results regarding utility.^[3,10] In this study, we aim to evaluate the diagnostic yield of 24-h Holter and extended ambulatory cardiac monitoring in pediatric patients and those with symptomatic palpitations.

METHODS

This project was given exempt status by the Institutional Review Board at the Albert Einstein College of Medicine. A retrospective review of all patients ages 10–18 years who had PocketECG™ monitoring by Medi-Lynx (Medi-Lynx Cardiac Monitoring LLC, Plano, TX) at participating pediatric centers between January 2016 and July 2020 was performed. All patients that had cardiac monitors performed during this time period were evaluated, and patients with the “palpitations” International Classification of Diseases (ICD-10)

diagnosis code of R00.2 were evaluated and reported separately. The lower age limit of 10 years was chosen based on an arbitrary age cutoff where a typical child could subjectively describe the sensation of palpitations. Patient age, heart rates, arrhythmia type, and arrhythmia and symptomatic transmission data were collected and analyzed.

Ectopy was defined as an abnormal single premature beat or 2–3 consecutive abnormal beats, and diagnoses included supraventricular ectopy (SVE) and ventricular ectopy (VE). An SVE was distinguished from VE based on QRS morphology compared to the baseline sinus rhythm. Nonsustained tachyarrhythmias were defined as 4 or more consecutive beats lasting <30 s and sustained tachyarrhythmias were defined as lasting for 30 s or longer. Tachyarrhythmia diagnoses [Figure 1] included atrial fibrillation (AF), nonsustained supraventricular tachycardia (nSVT), supraventricular tachycardia (SVT), nonsustained ventricular tachycardia (nVT) and ventricular tachycardia (VT). The Medi-Lynx monitor algorithm distinguished supraventricular from VE and arrhythmia based on the morphology of the baseline QRS.

All calculations were performed using Python 3 libraries pandas, numpy, and scipy. The mean time to diagnosis of an arrhythmia was calculated by acquiring data on how many days was needed to diagnose the first arrhythmic episode in each patient and then averaging this data. Mean heart rates were compared using Student’s *t*-test due to the normal distribution, and minimal and maximal heart rates were compared utilizing nonparametric Mann–Whitney *U*-test.

RESULTS

Demographics

A total of 6287 patients (mean age 13.9 ± 2.1 years, 54% F) were placed on ambulatory cardiac monitoring during the study period. Of the total population, 42% had 24-h Holter monitoring and 58% had extended monitoring for up to 30 days. There were 2388 patients (mean age 11.6 years ± 2.1, 58% F) with the R00.2 ICD-10 code that had ambulatory cardiac monitoring. Of these patients, 28% had 24-h Holter monitoring and 72% had extended monitoring for up to 30 days.

Tachyarrhythmia diagnosis

Of the total 6287 patients, 764 (12%) were diagnosed with a tachyarrhythmia: AF (22), nSVT (478), SVT (85), nVT (177), and VT (2). Of the 2388 patients with the R00.2 ICD-10 code, 321 (13%) were diagnosed with a tachyarrhythmia: AF (9), nSVT (192), SVT (59), nVT (61). No patients were diagnosed with sustained VT in the R00.2 group.

Symptomatic transmissions

Symptomatic transmissions with normal cardiac rhythm and no ectopy were common in the overall (3848, 61%) group and the R00.2 (1697, 71%) group. In the overall group of patients with symptomatic normal transmissions, 2443 (63%) had evidence of SVE and 1350 (35%) had evidence of VE, but ectopy was not noted during symptomatic transmissions. In the R00.2 group with symptomatic normal transmissions, 1097 (65%) had evidence of SVE and 631 (37%) had evidence of VE without ectopy noted during symptomatic transmissions.

AF was symptomatic in 50% of patients in the overall group and in 56% of patients in the R00.2 group. No episodes of nSVT, SVT, nVT, or VT were associated with symptomatic transmissions.

Types of monitors and monitor length

The breakdown of Holter and extended cardiac monitors and the average length of monitoring for tachyarrhythmia and symptomatic normal transmissions are presented in

Table 1. The majority of patients, both in the overall and R00.2 groups, had extended cardiac monitoring (>1 day) and the mean duration of monitoring was >14 days in all arrhythmia and symptomatic normal groups. While the monitoring length was more than 2 weeks in many patients, the mean time to diagnosis of arrhythmia or symptomatic normal transmission was <10 days in all groups.

Heart rates and International Classification of Diseases-10 codes

The average, minimum, and maximum heart rates for various tachyarrhythmias are shown in Table 2. The maximum heart rate in the R00.2 group was significantly higher than the overall group, though the difference was only 4 beats/min. Patients diagnosed with tachyarrhythmia along with the R00.2 code had significantly higher average and minimum heart rates, but the mean difference was only 2 and 3 beats/min, respectively. There was a difference across arrhythmias with regard to the maximum heart rates, though this may be due to the effect of SVT on the heart rate measurements.

Table 1: Comparing types of tachyarrhythmias by monitor type, mean duration of monitoring, and mean time to diagnosis

Type of arrhythmia	Overall				R00.2			
	24 h Holter (%)	Extended (%)	Mean duration (days of monitoring)±SD	Mean time to diagnosis (days)±SD	24 h Holter (%)	Extended (%)	Mean duration (days of monitoring) ±SD	Mean time to diagnosis (days)±SD
Total group	42	58	12±12	-	28	72	15±12	-
All arrhythmia	21	79	18±12	6.5±7.2	13	87	20±11	7.8±7.2
Symptomatic normal	24	76	16±12	2.4±3.6	17	83	25±7	2.5±3.5
AF	15	85	18±12	6.4±8.3	14	86	16±11	2.7±2.1
nSVT	21	79	18±11	6.8±7.2	11	89	18±11	8.2±7.0
SVT	5	95	22±11	2.0±1.3	3	97	22±11	3.0 (n=1)
nVT	28	72	19±13	7.3±8.4	12	88	21±14	9.1±8.8
VT	50	50	17±23	2.0±1.3	-	-	-	-

AF: Atrial fibrillation, SVT: Supraventricular tachycardia, nSVT: Nonsustained SVT, VT: Ventricular tachycardia, nVT: Nonsustained VT, SD: Standard deviation

Table 2: Heart rate data comparing overall population and tachyarrhythmias

Overall population	Number of patients	Average HR (bpm)	Minimum HR (bpm)	Maximum HR (bpm)
All patients (n=6287)	6287	83.8±11.2	54.6±10.1	165.2±26.2
Patients with R00.2 ICD-10 code (n=2388)	2388	84.2±9.9	54.2±9.2	169.8±24.3
Patients without R00.2 ICD-10 code	3899	83.4±11.8	54.8±10.6	162.4±26.9
P		0.0015	0.119	<0.0001
P		0.125	0.0915	<0.0001
Patients with tachyarrhythmias (n=764)	679	83.2±9.9	52.1±8.2	172.4±24.6
Patients with tachyarrhythmia and R00.2 ICD-10 code (n=321)	277	83.3±8.8	51.4±7.2	178.3±21.4
Patients with tachyarrhythmia without R00.2 ICD-10 code	402	83.1±10.6	52.6±8.8	168.3±25.8
P		0.793	0.0653	<0.0001
P		0.0004	<0.0001	0.747
Tachyarrhythmias				
AF	22	82.5±9.2	50.6±8.6	172.2±17.7
nSVT	478	83.2±9.9	51.9±8.1	172.9±24.8
SVT	85	83.5±9.9	51.3±8.9	182.3±18.7
Nvt	177	83.0±10.5	52.5±8.4	169.5±24.5
VT	2	81.0±2.8	53.5±0.7	143±1.4
P		0.987	0.739	0.001

HR: Heart rate, AF: Atrial fibrillation, SVT: Supraventricular tachycardia, nSVT: Nonsustained SVT, VT: Ventricular tachycardia, nVT: Nonsustained VT, ICD-10: International Classification of Diseases-10

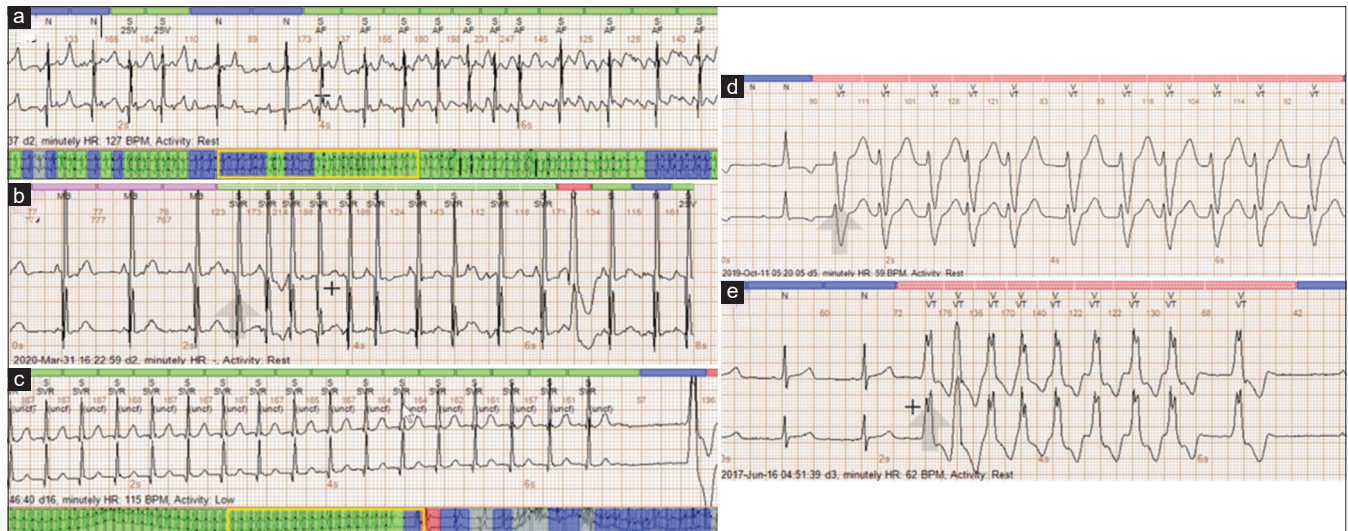


Figure 1: Monitor strips showing tachyarrhythmias including (a) Atrial fibrillation, (b) Nonsustained supraventricular tachycardia, (c) Sustained supraventricular tachycardia, (d) Sustained ventricular tachycardia, (e) Nonsustained ventricular tachycardia

DISCUSSION

Ambulatory cardiac monitoring is frequently performed for pediatric patients for palpitations, but the utility and diagnostic yield has not been well described. Since pediatric patients may have difficulty describing symptoms and there is seldom correlation between the severity or frequency of symptoms and arrhythmia diagnosis, ambulatory cardiac monitoring has diagnostic importance. In our cohort of more than 2000 pediatric patients aged 10–18 years, the majority (84%) of patients with palpitations had either a negative or positive diagnosis: 13% with a tachyarrhythmia and an additional 71% with a symptomatic transmission demonstrating normal cardiac rhythm. While the diagnosis of tachyarrhythmia in a pediatric patient has treatment implications, the additional correlation of symptoms with a normal cardiac rhythm can have a significant impact on the mental health and quality of life of pediatric patients.^[6] In addition to the impact for the patient and family, practitioners are more likely to discharge patients from cardiology care and avoid further workup and follow-up that could lead to the financial burden on families.

The yield of ambulatory cardiac monitoring has varied, especially within the pediatric population. Pradhan *et al.* reported ZIO patch monitoring compared with traditional 24-h Holter monitor and found that the diagnostic yield of arrhythmia was similar (9% by Holter and 10% by ZIO).^[11] In their cohort, surprisingly, 42% of patients with an arrhythmia diagnosis were diagnosed within 24-h by ZIO patch. An additional recent report found no difference in arrhythmia diagnosis in pediatric patients between traditional Holter monitor and ZIO patch monitoring.^[12] Begic *et al.* described a

cohort of pediatric patients with ambulatory cardiac monitoring and found that the most common diagnosis was an insignificant arrhythmia in 47.1%, but there is no mention of specific arrhythmia diagnoses.^[4] Hegazy and Lotfy reported 1319 pediatric patients with Holter monitors (mean age 6.7 years) and found an overall diagnostic yield of 10.7%, but the yield was only 5.7% in patients with palpitations as the primary complaint.^[3] They report that Holter monitors were most useful in postoperative patients and those with cardiomyopathies though a different report showed no impact of monitoring results on the care of pediatric patients with cardiomyopathies.^[10] Adult studies are scarce, but a report by Locati *et al.* reported a substantial diagnostic yield of ambulatory cardiac monitoring of 86% in patients with either palpitations or presyncope with a mean monitoring duration of 24 days. However, the mean age of the cohort was >60 years.^[13]

In our cohort, most patients that were diagnosed with either tachyarrhythmia or had a symptomatic normal transmission had monitoring for >14 days, though the time to the diagnostic transmission was <10 days in the majority. The authors cannot comment on the ideal monitoring length in pediatric patients, especially since symptom frequency can vary widely. Ambulatory cardiac monitors are most often wired and can be associated with decreased patient satisfaction and compliance, and many centers are evaluating patch monitors as an alternative to Holter and other monitors.^[12] There has been increasing interest in other cardiac monitoring options, such as cellular phone-based apps^[8] or implantable loop recorders,^[9] but the utility in pediatric patients has yet to be defined. Interestingly, there was a large portion of patients with either supraventricular or VE, but none of them were

associated with symptomatic transmissions. Ectopy is a frequent finding on baseline ECG in pediatric patients, and ambulatory monitoring may be an additional tool in reassuring both families and providers that ectopy is benign and asymptomatic.

There are limitations to our study. This is a retrospective review of a de-identified database of pediatric ambulatory cardiac monitors. There are no clinical data for review, so we cannot determine which patients were receiving therapy though the lack of significant difference between heart rates across groups does assume reasonable heterogeneity across the cohort. The abnormal tracings were identified based on a computer algorithm and do not include physician interpretations, so there is a possibility for false-positive diagnoses. Conversely, there is a potential for missed tachyarrhythmias based on subtle QRS or P wave morphologies.

Further, in the absence of clinical data, there is no follow-up available with regard to individual patients. The standard practice for our group typically includes discharging patients with symptomatic normal transmissions without repeating Holter or extended cardiac monitoring. However, this may not represent the clinical practice of all practitioners managing similar patients. For patients with documented tachyarrhythmia without symptoms, the decision to treat is based on the type of arrhythmia, length of arrhythmia, and additional clinical factors. Based on the potential variety of these patients, there is not a typical management strategy, and this will vary by center.

CONCLUSIONS

In a large cohort of pediatric patients with either 24-h Holter or extended ambulatory cardiac monitoring, there was a high yield of combined tachyarrhythmia and symptomatic normal transmission diagnoses. While clinical data were not available for review, this highlights the continued importance of both positive and negative diagnoses of pediatric patients with palpitations. Further correlation with clinical information and long-term follow-up may assist in the determination of the optimal timing of monitoring in pediatric patients.

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Conflicts of interest

There are no conflicts of interest.

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