The yield of 24-hour ambulatory electrocardiography in the assessment of symptomatic school-age children

Apport de l'enregistrement ambulatoire de l'électrocardiogramme de 24 heures chez les senfants d'âge scolaire symptomatiques

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Abstract

Introduction: Lightheadedness, syncope, dyspnea, chest pain, palpitation, loss of consciousness (LOC) or malaise are a frequent reason for consultation in school-age children (SAC). The yield of holter monitoring (HM) in the investigation of these symptoms in SAC is still controversial given the scarce studies.
Aim: To determine the prevalence of baseline ECG abnormalities and those detected in HM in SAC, and to assess the predictive factors of abnormal HM test.
Methods: We conducted a retrospective descriptive study in which we had included all the consecutive SAC (6 to 12 years) presenting: syncope or lightheadedness or palpitation, dyspnea, or chest pain, malaise, LOC and referred to our department for HM
Results: We included 366 children. Mean age was 9.7 ± 1.88 years. The major symptoms experienced by the patients were: palpitation (50.7%), chest pain (16.9%), lightheadedness (11.9%), syncope (6.9%), LOC (5.3%), ECG was abnormal in 8.7%. The two most common baseline ECG abnormalities were premature ventricular contractions (PVCs) (1.8%) and right bundle branch block (1.6%). HM was positive in 101 (26.6%) patients. The most common abnormalities in HM were vagal hypertonia in 61 patients (16.1%), PVCs in 29 patients (7.7%), Malignant abnormalities were encountered in 16 patients (13.9%) whereas benign abnormalities in 99 patients (86.1%). In the multivariate analysis: Age≥10 years, mean heart rate <94 beats per minute, the presence of syncope, LOC, malaise and the presence of PVCs in baseline ECG were identified as independent risk factors of abnormal holter.
Conclusion: HM has an important diagnostic value in symptomatic SAC. It allows the identification of benign as well as malignant arrhythmias, which require urgent management.

Keys words: holter monitoring, children, arrhythmia

Résumé

Introduction: Les lipothymies, les syncopes, la dyspnée, les douleurs thoraciques, les palpitations, les pertes de conscience ou les malaises sont des motifs fréquents de consultation chez les enfants d'âge scolaire. L'Apport de l'enregistrement ambulatoire de l'électrocardiogramme de 24 Heures ou holter rythmique (HR) dans l'investigation de ces symptômes chez cette population est encore controversé étant donné vu le manque d'études
Objectif: Déterminer la prévalence des anomalies sur l'ECG de base et de celles détectées par le HM chez les enfants scolarisés et les facteurs prédictifs d'un holter de 24 heures anormal.
Méthodes: Nous avons mené une étude descriptive rétrospective dans laquelle nous avons inclus tous les enfants en âge scolaire entre (6 à 12 ans) présentant l'un des symptômes cardiaques suivants : syncope, étourdissement, palpitation, dyspnée, douleur thoracique, malaise, perte de connaissance et référés à notre service pour holter rythmique de 24heures
Résultats: Nous avons inclus 366 enfants. L'âge moyen était de 9,7±1,88 ans. Les principaux symptômes ressentis par les patients étaient les suivants : palpitations (50,7%), douleurs thoraciques (16,9%), étourdissements (11,9%), syncope (6,9%), perte de connaissance (5,3%), ECG anormal chez 8,7% d'entre eux. Les deux anomalies les plus fréquentes de l'ECG de base étaient les arythmies ventriculaires prématurées (1,8%) et le bloc de branche droit (1,6%). L'holter rythmique était positive chez 101 (26,6%) patients. Les anomalies les plus fréquentes dans l'HR étaient l'hypertonie vagale chez 61 patients (16,1%), les extrasystoles ventriculaires sont présentes chez 29 patients (7,7%), les extrasystoles auriculaires chez 7 patients (1,8%) et la préexcitation intermittente chez 7 patients (1,8%). Des anomalies malignes ont été observées chez Des anomalies malignes ont été rencontrées chez 16 patients (13,9%) et des anomalies bénignes chez 99 patients (86,1%). Dans l'analyse multivariée : L'âge≥10 ans, la fréquence cardiaque moyenne <94 battements par minute, la présence d'une syncope, d'une perte de connaissance, d'un malaise et la présence de PVC dans l'ECG de base ont été identifiés comme des facteurs de risque indépendants d'un holter rythmique anormal.
Conclusion: l'holter rythmique de 24 heures à une valeur diagnostique importante chez les enfants en âge scolaire et symptomatiques. Il permet de détecter des arythmies bénignes et malignes qui nécessitent une prise en charge urgente

Mots clés: holter rythmiques, enfants, arythmie.

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INTRODUCTION

Arrhythmias in the young are common and usually benign but may be life altering or lethal [1]. It may begin at any age, from in utero up to the later teenage years [1].
School-age children (SAC) often present with symptoms of probable cardiac origin like palpitations, syncope, lightheadedness, chest pain, transient loss of consciousness, shortness of breath or malaise [2]. These symptoms represent terrifying events for them, a significant cause of concern for their family and a common reason of referral to a pediatric cardiologist.
Cardiac rhythm recorders devices have enhanced our ability to detect and treat arrhythmias [3]. Holter monitoring (HM) is one of the most widely available and economic non-invasive methods for detecting arrhythmias in children and it is independent of need for child's absolute cooperation [3].
The diagnostic value of 24-hour HM in the investigation of these symptoms in SAC is still controversial. It is sometimes challenged by the uncertainty surrounding its capacity to assign the cause of symptoms, defined strictly as the correlation of symptoms with arrhythmias during monitoring [4].
The aim of this study was to determine the prevalence of baseline ECG and HM abnormalities in SAC and to determine the predictive factors of abnormal HM test in order to better target its indications.

METHODS

This was an observational descriptive and retrospective mono-centric study that was carried out at the pediatric cardiology of la Rabta hospital over one year from January 2021 to January 2022.

Inclusion criteria

All consecutive SAC from 6 to 12 years who presented symptoms of probable cardiac origin from this list: syncope, palpitations, shortness of breath, chest pain, lightheadedness, transient loss of consciousness or unexplained malaise and underwent 24-hour HM were included in the study. Referring physicians were pediatricians and school doctors.

Non-inclusion criteria

Asymptomatic patients and children younger than 6 years or older than 12 years when the HM was performed as well as children with abnormal structural heart were not included.

Exclusion criteria

Patients whose recordings were less than 21 hours of analyzable data or whose medical files were not found or were incomplete were excluded of the present study.

Reporting data

We collected for each patient the following data: age, gender, family history of arrhythmia, the presence of cardiac disease, the presence of comorbidity and the chief symptom. We gathered only one symptom per patient. In case of many symptoms, the most disquieting symptom was retained.
We also collected data of physical examination, 12-lead ECG, transthoracic echocardiography and HM.
We defined a positive HM test as a Holter study considered to be diagnostic, with one of the following arrhythmias during monitoring that could be correlated to the symptom of the child.
We divided the findings into:
• Benign arrhythmias: they are usually hemodynamically well tolerated and do not warrant urgent therapy. These findings are:
Marked vagal hypertonia, frequent premature atrial contractions (PACs): more than 1% of total Heartbeats, frequent premature ventricular contractions (PVCs): more than 1% of total heart beats, paroxysmal supraventricular tachycardia (PSVT) in the absence of ventricular preexcitation, multifocal atrial tachycardia (MAT), non-sustained ventricular tachycardia (NSVT).
• Malignant arrhythmias: they are usually worrisome and prompts the need for urgent management such as introducing new therapy, withdrawal or change of current therapy or further investigation. These findings are:
second-degree atrio-ventricular (AV) block Mobitz type II or third-degree AV block, sinus pauses ≥3 s, sustained VT, SVT in the presence of preexcitation or intermittent preexcitation even in the absence of reentrant tachycardia.
We divided the study population into 2 groups: group A with normal HM test and group B with positive HM test and then we compared different parameters in both groups to identify the yield of HM in each subgroup.

Statistical methods

Data were analyzed using IBM SPSS statistics 23.0 software.
Frequencies and percentages were calculated for qualitative variable including gender, comorbidities, history of structural heart disease, family history of arrhythmia, the main symptom, ECG abnormalities and HM abnormalities.
Comparisons were made using the $\chi 2$ statistic test of Pearson for categorical variables and if not valid Fisher test was used instead.
A student's t-test was used for continuous variables. A p value <0.05 was considered significant.
Logistic regression analysis was used to study the effects of baseline characteristics on the outcome. Univariate logistic regression models were fitted for each of the potential predictors. A p value of <0.0.5 was used to select covariates included in the multivariate logistic regression. OR and 95% confidence interval (CI) were calculated.

Ethical considerations

We declare that we had no conflict of interest and that we respected medical confidentiality for all patients.

RESULTS

Flow chart

During the study period, 509 children whose age ranged from 6 to 12 years were referred to our unit for HM. 366 children (71%) were symptomatic and were included in our study (figure1)

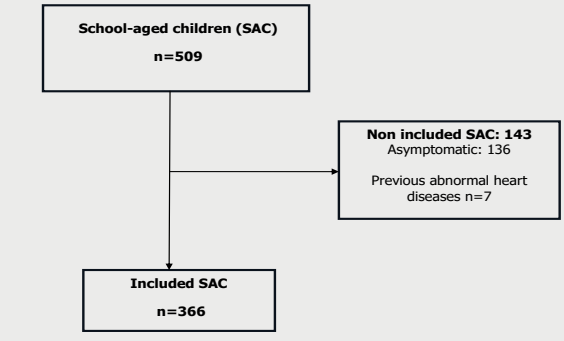

Figure 1. Flow chart of the study

Descriptive study

Table 1 and 2 summarize the demographic characteristics of our population and the prevalence of different symptoms.

Table 1. Baseline demographic characteristics of our study population

Characteristics	Number	Percentage (%)
Male gender	185	50.5
Age ≥ 11 (puberty)	158	43.2
Family history of arrhythmia	5	1.4
Comorbidity	8	2. 2

Table 2. Prevalence of symptoms in our study population

Symptoms	Number of patients	Prevalence (%)
Palpitations	186	50.8
Chest pain	61	16.7
Lightheadedness	43	11.7
Syncope	26	7.1
Transient loss of consciousness	20	5.5
Malaise	17	4.6
Shortness of breath	13	3.6

ECG was abnormal in 31 patients (8.7%). HM findings were positive in 109 (29.8%) patients. Arrythmia were benign in 86.1% of cases and malignant in 13.9% of children in 24 hours Holter monitoring

Table 3 and 4 summarize respectively the prevalence of ECG and HM abnormalities among our population.

Table 3. Prevalence of baseline ECG abnormalities in our study population

ECG abnormalities	Number of patients	Prevalence (%)
PVCs	7	1.9
RBBB	6	1.6
SVT	4	1.1
Sinus pause	3	0.8
Ventricular Preexcitation	3	0.8
Sinus bradycardia	2	0.5
RVH	2	0.5
NSVT	1	0.3
PACs	1	0.3
LBBB	1	0.3
LVH	1	0.3

LBBB: left bundle branch block; LVH: left ventricular hypertrophy; NSVT: Non-sustained ventricular tachycardia; PACs: premature atrial contractions; PVCs: premature ventricular contractions; RBBB: right bundle branch block; RVH: right ventricular hypertrophy; SVT: supraventricular tachycardia.

Table 4. Prevalence of Holter monitoring abnormalities in our study population

Holter monitoring abnormalities	Number of patients	Prevalence (%)
Vagal hypertonia	61	16.7
PVCs	29	7.9
Intermittent preexcitation	7	1.9
PACs	7	1.9
Sinus pause	2	0.5
Sustained VT	1	0.3
PSVT	1	0.3
MAT	1	0.3

AV: atrio-ventricular; MAT: multifocal atrial tachycardia; PACs: premature atrial contractions; PSVT: paroxysmal supraventricular tachycardia; PVCs: premature ventricular contractions; VT: ventricular tachycardia.

Comparative study

We compared the prevalence of symptoms, ECG and HM abnormalities in different ages. Regarding age, we chose 10 (the median age as the cut off). Only the symptom malaise was significantly more prevalent in children less than 10 years old. However, there was no significant difference in the prevalence of ECG abnormalities according to age (Table 5).

Table 5. Summary of comparative study findings by age

	Population (n=366)	Age<10 (n=149)	Age>=10 (n=217)	P
Palpitations	186	83 (55.7%)	103 (47.5%)	0.18
Chest pain	61	22 (14.8%)	39 (18%)	0.54
Lightheadedness	43	13 (8.7%)	30 (13.8%)	0.16
Syncope	26	9 (5.8%)	17 (7.6%)	0.5
Transient loss of consciousness	20	8 (5.4%)	12 (5.5%)	0.93
Malaise	17	11 (7.4%)	6 (2.8%)	**0.04**
Shortness of breath	13	3 (2%)	10 (4.6%)	0.18
Baseline ECG abnormalities	31	11 (7.4%)	20 (9.2%)	0.36
Holter monitoring (+)	109	42 (28.2%)	67 (30.9%)	**0.001**

We divided the study population into 2 groups: group A with normal HM test and group B with positive HM test and then we compared different parameters in both groups to identify the yield of HM in each subgroup (table 6).

Table 6. Summary of comparative study findings related to the Holter monitoring result

Characteristics	Population (n=366)	Holter (+) (n=109)	Holter (-) (n=257)	P
Age	9.72±1.88	9.88±1.85	9.64±1.88	**0.001**
Male gender	185	56 (51.4%)	129 (50.2%)	0.79
Mean HR	90.69±10.04	87.53±10.02	92.04±9.76	**<0,0001**
Familial history of arrhythmia	5	0 (0%)	5 (1.8%)	0.33
Comorbidity	8	1 (0.9%)	7 (2.7%)	0.46
Symptoms				
Palpitations	186	42 (38.5%)	144 (56%)	**0.009**
Syncope	26	14 (12.8%)	12 (4.7%)	**0.005**
Loss of consciousness	20	12 (11%)	8 (3.1%)	**0.001**
Malaise	17	15 (13.8%)	2 (0.8%)	**0.002**
Lightheadedness	43	8 (7.3%)	35 (13.6%)	0,99
Chest pain	61	16 (14.7%)	45 (17.5%)	0,18
Shortness obreath	13	2 (1.8%)	11 (4.3%)	0,12
ECG abnormality	31	14 (12.8%)	17 (6.6%)	0,08
PVCs	7	7 (6.4%)	0 (0%)	**0.002**
RBBB	6	0 (0%)	6 (2.3%)	0.35

Analytical study

Univariate analysis

In the univariate analysis, the variables associated with a better diagnostic performance of the 24-hour HM were age, mean HR, the presence of syncope, transient loss of consciousness, malaise, the absence of palpitation and the presence of PVCs in baseline ECG (table 7).

Table 7. Univariate study of the predictive factors of positive yield of Holter monitoring

Variable	OR	95% CI	P
Age ≥10 years	1.87	1.28-2.80	0.001
Mean HR <94 bpm	2.52	1.54-4.11	<0.0001
Transient loss of consciousness	2.42	1.62-3.61	0.001
Malaise	2.32	1.52-3.64	0.002
Syncope	2.00	1.31-3.07	0.005
Absence of palpitations	1.57	1.11-2.21	0.009
PVCs in baseline ECG	3.36	2.39-4.76	0.002

Multivariate analysis

We included the seven variables that were significant in the univariate analysis (age, mean HR, the presence of syncope, transient loss of consciousness, malaise, palpitations and the presence of PVCs in baseline ECG).

In the multivariate analysis, the results showed that age≥10, mean HR<94 bpm, the presence of syncope, transient loss of consciousness, malaise and the presence of PVCs in baseline ECG were identified as independent risk factors of positive Holter test (Table 8).

Table 8. independent risk factors of positive Holter monitoring

Variable	Adjusted OR	95% CI	P
Age ≥10 years old	2.45	1.38 – 4.34	0.002
Mean HR <94 bpm	2.94	1.54 – 5.60	0.001
Loss of consciousness	6.97	2.60 – 18.76	<0.0001
Syncope	4.35	1.85 – 10.26	0.001
Malaise	9.69	3.33 – 28.19	<0.0001
PVC in baseline ECG	19.85	2.27 – 173.63	0.007

DISCUSSION

It emerges from our study that in symptomatic SAC, HM has three times more diagnostic yield than ECG and that almost one-eighth (13.9%) of arrhythmias identified in Holter are malignant and are missed in ECG.

In the multivariate analysis, the results showed that age≥10 years, mean HR<94 bpm, the presence of syncope, transient loss of consciousness or malaise and the presence of PVCs in baseline ECG were identified as independent risk factors of abnormal Holter monitoring . Thus, the presence of one of these factors increases significantly the yield of Holter.

We chose the category of SAC (from 6 to 12 years) because they can verbalize symptoms and because we have noticed from our experience that they represent the majority of children who were referred for HM. They also usually cooperate and the recording is usually of good quality.

The overall mean age was 9.7 years with 163 (43%) children older than 11 years which is in accord with many studies noted the high incidence of syncope, lightheadedness and palpitation during pubertal hormonal changes with a peak age of onset during puberty at age near 10–15 years; approximately one in three adolescents with syncope may experience recurrent and severe episodes [5,6]. In our study, few patients had structural heart disease 7 (1.8%). Therefore, the majority of our population consisted of apparently healthy children.

This was the main strength of our study since the majority of ancient studies enrolled children with structural heart disease. Thus, the diagnostic yield of HM in these studies was biased as arrhythmias are frequently seen in these children [7].

For example, in the study of Hegazy et al, 2.6% of the population consisted of children in the postoperative course of congenital cardiac surgery and 12.6% of children had cardiomyopathy. The highest contribution to diagnosis was in these two subgroups; postoperative assessment (32.4%) and in cardiomyopathy (19.9%) [8].

Palpitations was the leading chief of complaint. This is because it is used loosely to describe an unpleasant sensation in the chest of rapid, irregular or unusually strong heartbeats.

In our population, chest pain was three times lower than palpitations. This may be explained by the fact that chest pain is usually less related to arrhythmia than palpitations.

Malaise was the chief complaint in 19 patients of our population and was significantly higher in children <10 years (p=0.04). This may be due to the difficulty of awareness of symptoms and/or the difficulty to verbalize.

Shortness of breath was the least common symptom. This may be explained by the preponderance of asthma and respiratory problems as well as hyperventilation syndrome in this category of age [9].

In our study, HM had a high yield. 26.6% of patients had a positive Holter test.

This finding is in agreement with the study of Ali et al where HM was of positive contribution to diagnose 30 (37.5%) of their cohort patients and to provide a management in 19 (23.75%) of patients [10]. This disagrees with Hegazy et al study where the positive diagnostic contribution of HM was 10.9% [8]. This difference is probably due to the highly selective nature of the population in the study of Ali et al.

In the study of Aman et al, HM was positive in 40 (37%) patients. This study investigated the yield of HM in children with unexplained palpitations and other associated symptoms such as syncope, chest pain and shortness of breath. The higher yield may be explained by the duration of HM, which was up to 48 hours, and by the inclusion of children up to 18 years old. A 48-hour HM instead of conventional 24-hour HM increased yield by 10% [11].

In our study population, among Holter abnormalities, 86.1% were benign and 13.9% of malignant nature.

Frequent PVCs were found in 29 patients (7.7%). In the literature, PVCs are common, occurring in 20–30% of younger children and up to 40% of teenage boys on Holter monitoring [12].

In the study of Aman et al, frequent PVCs was the most common finding. Its prevalence was 11.2% [11]. Sustained VT was found in only one patient, 8-year-old boy who had complaint of episodes of shortness of breath during effort. His ECG showed PVCs. HM showed runs of sustained infundibular VT. In the study of Rocchini et al, VT was found in 17 patients without heart disease and only six of them were asymptomatic in comparison with children with heart disease (p <0.01).

PACs were found in seven patients. Isolated PACs are fairly common at all ages. In older children, PACs have been reported in between 15–40% of individuals studied [13]. These PACs may mimick atrio ventricular block. [14]

The originality of our study was the aim to determine the predictive factors associated with an increase in the yield of HM. Age ≥ 10 years was associated with higher diagnostic yield of Holter abnormalities. (P=0.002): adjusted OR= 2.45 and 95% CI [1.38 – 4.34]. This is probably related to puberty and adolescence and is the result of neurohormonal events, which are known and are consistent to results of other authors [5-6].

A mean HR lower than 94 bpm was associated with significant increase in diagnostic Holter yield (p=0.001, adjusted OR=2.94 and 95% CI [1.54 – 5.60].

Although tachycardia in adults is well recognized to have an important negative effect on cardio- and cerebrovascular morbidity and mortality in global population [15], this fact is questionable in young adults and children.

Many authors have reported that bradycardia could be worrisome, as it is associated with many hidden diseases such as congenital long QT syndrome, Brugada syndrome and catecholergic polymorphic ventricular tachycardia [16].

In our study, syncope was an independent predictive factor for abnormal Holter p=0.001, adjusted OR=4.35 and 95% CI [1.85 – 10.26].

It is known that cardiac arrhythmias should be considered among the malignant causes of syncope in children [17]. Hence, syncope is a common cause of referral for Holter. However, many studies have reported a low yield of HM in syncope in children.

In the study of Hegazy et al, although abnormalities were detected in 14 (5.9%) of patients with syncope, only one patient with sick sinus syndrome had his diagnosis solely established according to HM which makes a low yield 0.4% [17].
In the study of Ali et al, of the 22 patients with syncope, Holter was useful in diagnosis of 10 (45.45%) patients and was useful in management of seven (31.82%) patients [10].
In our study, transient loss of consciousness had a high yield for abnormal Holter p<0.0001, adjusted OR=6.97 and 95% CI [2.60 – 18.76]. This was contrasting with literature data: most patients with transient loss of consciousness have infrequent symptoms and a small pre-test likelihood of blackout symptom–ECG correlation during recording. The diagnostic yield is around 1% for symptom–ECG correlation [18].
Palpitations was the most frequent symptom in all previous studies that had assessed the yield of Holter in children. In our study, palpitations was not associated with a higher diagnostic yield of HM. A main symptom otherwise than palpitation was significantly associated with positive Holter test instead. p=0.009, OR=1.57, 95% CI [1.11-2.21].
This is may be explained by the fact that palpitations usually occurs as a simple physiological response to factors like anxiety, fever, anemia, hypovolemia, hypoglycemia and orthostatic hypotension [19].
In the study of Aman et al, palpitation was associated with high yield of Holter, but in this study they included children with palpitation and associated symptoms and the recording lasted 48 hours [11].
Comparison of different symptoms in patients with positive Holter findings and those with normal Holter showed patients with complaints of color change/pallor and shortness of breath at the time of palpitations had significantly greater Holter yield (p=0.002) [11].
Besides, the first 24-hour record did have a lower yield of 27%. However, the extended duration improved the yield by 10%. Extended study for up to 48 hours has also shown better diagnostic results in previously published data [20].
Hegazy et al confirmed the low diagnostic yield of HM among pediatric patients with transient palpitations, which is a common indication for HM. The diagnostic yield of HM was identified to be 5.7% for palpitation [17].
The presence of PVCs in baseline ECG was an independent predictive factor of abnormal Holter test. p=0.007, adjusted OR=19.85, 95% CI [2.27-173.63].
In the study of Ali et al, an abnormal ECG was significantly associated with a higher diagnostic yield (p = 0.0001) [10]. However, to our knowledge there was no studies that have evaluated the association between PVCs in baseline ECG and the presence of Holter abnormalities.
The reported diagnostic yield of 24-hour HM ranges from 1-2% to 46% of cases [21,22].
Regardless of scarce direct comparative data, it can be assumed that both the type of indication and several underlying conditions (abnormal baseline 12-lead ECG, structural heart disease, advanced age and other) account to justify such highly variable diagnostic yield [10].

Limitations of our study

The definition of a diagnostic 24-hour HM is highly heterogeneous in the literature, with only a minority of series that find it compelling to establish a strict chronological relationship between symptoms and the 24-hour HM findings and/or to provide an unequivocal diagnosis with an impact on the patient's therapeutic management.
Although this study included a large sample, it was a retrospective, single-center study and without follow-up.
Yet, the short duration of HM, which was limited to a 24-hour period of recording in our study, can be inadequate if cardiac symptoms are infrequent.
On the other hand, cost-effectiveness is a major consideration in developing countries with low -budget programs and should be included in subsequent studies.

CONCLUSIONS

Our study highlighted that HM has an important diagnostic value in symptomatic SAC. It has three times more diagnostic yield than ECG and identifies malignant arrhythmias which could be missed in ECG. Although our findings may disagree with several studies, it can be assumed that both the type of indication and several underlying conditions (abnormal baseline 12-lead ECG, structural heart disease, advanced age and other) account to justify such highly variable diagnostic yield.
Despite our study input, further studies are still needed to establish clearer recommendations with regard to the appropriate criteria on the ambulatory ECG in pediatric cardiology.

Abbreviations:
HM: Holter monitoring SAC: school age children
PACs: Frequent premature atrial contractions
PVCs: Frequent premature ventricular contractions
PSVT: Paroxysmal supraventricular tachycardia
MAT: Multifocal atrial tachycardia
NSVT: Non-sustained ventricular tachycardia
AV: Atrio ventricular block
TTE: Transthoracic echocardiogram

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