Title

Incidental electrocardiogram abnormalities in children undergoing polysomnography.

Journal

The Journal of Clinical Sleep Medicine, 17(12)

Authors

Amin, Ankit
Mogavero, Maria
Ferri, Raffaele
et al.

Publication Date

2021-12-01

DOI

10.5664/jcsm.9440

Peer reviewed

https://doi.org/10.5664/jcsm.9440

JCSM | Journal of Clinical Sleep Medicine

SCIENTIFIC INVESTIGATIONS

Incidental electrocardiogram abnormalities in children undergoing polysomnography

Ankit Amin, MD[1]; Maria Paola Mogavero, MD[2]; Raffaele Ferri, MD[3]; Lourdes M. DelRosso, MD, FAASM[1]

[1]University of Washington Department of Pediatrics and Seattle Children's Hospital Seattle, Washington, USA; [2]Istituti Clinici Scientifici Maugeri, IRCCS, Scientific Institute of Pavia, Italy; [3]Sleep Research Centre, Oasi Research Institute – IRCCS, Troina, Italy

Study Objectives: Monitoring electrocardiogram is an integral component of pediatric polysomnography (PSG). There are limited data regarding arrhythmia and conduction disturbances in the pediatric population undergoing a PSG. In this work we present abnormal electrocardiogram findings during PSG in our sleep center.

Methods: A retrospective chart review from children who underwent PSG read by a single sleep medicine physician in the last year was carried out. Findings in children without cardiac disease and with first or second degree atrioventricular block were compared to those from children with premature ventricular contractions.

Results: A total of 1,235 PSGs were included. Twenty-four children (9 girls and 15 boys) aged 2–17 years (median 9 years) were identified with arrhythmias or conduction disturbances (1.9%). Nineteen out of 24 of these children (79.2%) had obstructive apnea-hypopnea index > 1 event/h; this frequency was not significantly different from that found in the whole group of 1,235 children. No statistically significant difference was found between children with atrioventricular block or premature ventricular contractions. Seven out of 9 children with atrioventricular block and 7 out of 10 with premature ventricular contractions had obstructive apnea-hypopnea index > 1 event/h, while 8 children with atrioventricular block out of 9 and 4 out of 10 with premature ventricular contractions were males (Fisher's exact test $P = .04$). None of the children were found to have a structural or conduction abnormality when referred to cardiology.

Conclusions: Our study supports that electrocardiogram abnormalities are rare in PSGs of children and not associated with cardiac disease or sleep disorders but appear more commonly in males.

Keywords: children, polysomnography, electrocardiogram, first-degree atrioventricular block, second-degree atrioventricular block, premature ventricular contractions

Citation: Amin A, Mogavero MP, Ferri R, DelRosso LM. Incidental electrocardiogram abnormalities in children undergoing polysomnography. *J Clin Sleep Med*. 2021;17(12):2393–2398.

BRIEF SUMMARY

Current Knowledge/Study Rationale: Data regarding arrhythmia and conduction disturbances in the pediatric population undergoing a polysomnography are scarce. The aim of this study was to assess, retrospectively, the eventual presence of abnormal electrocardiographic findings during polysomnography in a large number of children recorded in a single sleep center.

Study Impact: Electrocardiographic abnormalities were found in 1.9% of children undergoing polysomnography. None of the children were found to have abnormal findings after cardiology referral. This study supports that electrocardiographic abnormalities are rare in polysomnographic recordings of children suspected to have a sleep disorder and are not usually associated with severe cardiac disease or specific sleep disorders, but appear to be more common in males than in females.

INTRODUCTION

Monitoring electrocardiogram is an integral component of pediatric polysomnography (PSG). The American Academy of Sleep Medicine scoring manual technical specifications for cardiac rules outlines use of single modified electrocardiography (ECG) lead II and torso electrode placement. ECG is important to monitor during PSG as abnormal findings including significant arrhythmias should be reported to physicians and may warrant further investigation and work up. Although sinus rates may vary according to age in children, it should be noted that children tend to have faster heart rates than adults.[1]

Nevertheless, mindful consideration should be given to remember that although single-lead ECG may be useful for monitoring heart rate and cardiac pauses, it may have a decreased capacity to detect myocardial ischemia and define cardiac intervals.[2] There is limited data regarding arrhythmia and conduction disturbances in the pediatric population, with even fewer studies reporting on the prevalence of arrhythmias in children with sleep-disordered breathing. In children, it has been shown that heart rate variability parameters increase as they age due to the progressive maturation of the autonomous nervous system, and studies have suggested that sleep-disordered breathing may profoundly disrupt this normal maturation process of autonomic control and the positive association between autonomic control and cerebral oxygenation.[3,4] Therefore, an important question that should be postulated involves whether sleep disorders, in particular obstructive sleep apnea, pose as risk factors for arrhythmias in children and adolescents.

Table 1—Prevalence of arrhythmias and conduction disturbances in the PSG studies analyzed and comparison with their prevalence reported by Niwa et al.

	Current Case Series (Total n = 1,235)		Niwa et al 2004[6] (Total n = 152,322)
	n	%	%
Premature ventricular contractions	10	0.810	0.515
Premature atrial contractions			0.106
Atrioventricular block, first and second degree	9	0.729	0.134
Atrioventricular block, third degree			0.002
Right bundle branch block	1	0.081	0.828
Wide QRS tachycardia	2	0.162	0.13
Sinus tachycardia	2	0.162	
QT interval prolongation			0.024
Total	24	1.943	1.815

PSG = polysomnography.

Our study aims to present abnormal ECG findings in children without prior diagnosis of cardiac disease during PSG in our sleep center and shed light on how common ECG abnormalities are in PSGs of children and whether they are associated with cardiac disease or sleep disorders.

METHODS

This was a retrospective chart review of children without previous cardiac history, at Seattle Children's Hospital, looking for patients that were found to have abnormal ECG findings. Inclusion criteria were children age 1–19 years and completed PSG. Exclusion criteria: infants from birth to 11 months, patients with known structural heart disease (heart transplant, congenital heart disease). Data collected included patients' age, sex, medical history, medications, PSG findings, and PSG-ECG abnormalities. The study was approved by the institutional review board of Seattle Children's Hospital study number 00002782.

PSG was recorded following the American Academy of Sleep Medicine standards[5] and included electroencephalogram (at least 1 frontal, 1 central, and 1 occipital channel, referred to the contralateral mastoid); electrooculogram, electromyogram of the submentalis muscle, electromyogram of the right and left tibialis anterior muscles, respiratory signals, effort signals for thorax and abdomen, oximetry, capnography, a single-lead ECG (with the positive lead on the fifth intercostal space, midclavicular line, and the negative lead on the manubrium of the sternum). Calibrations were performed per routine standard by the sleep technician. Epochs and all sleep parameters were scored by a certified sleep technologist and board certified sleep physician, according to standard criteria.[5] All PSG recordings were screened for the presence of arrhythmias and conduction disturbances in the single-lead ECG available, as reported by a single sleep medicine physician (LMD).

Statistical analysis

The frequency of the different ECG abnormalities found was reported as a percentage of the total sample. Due to the low number of patients found, nonparametric statistics were used with the chi-square test and the Fisher's exact test to compare frequencies, as appropriate, and the Mann-Whitney test for the comparison of independent variables.

RESULTS

A total of 1,235 full-night PSG recordings obtained in children (469 girls and 766 boys) aged 1–19 years (median 8 years) were screened for the presence of arrhythmias and conduction disturbances in the single-lead ECG available. In 806 of them (65.3%) an obstructive AHI > 1 events/h was found. Among the whole sample, 24 children (9 girls and 15 boys) aged 2–17 years (median 9 years) were identified with arrhythmias or conduction disturbances, as listed in **Table 1**; 19 out of 25 (79.2%) had obstructive AHI > 1 events/h; this frequency was not significantly different from that found in the whole group of 1,235 children (chi-square test $P = .16$). Eight children did not have any comorbidity, 6 had a neurodevelopmental diagnosis (delay, attention deficit hyperactivity, or autism spectrum disorders), 4 had a chromosomal syndrome (achondroplasia, trisomy 21, deletion), 2 had asthma, 2 had seizures, 1 had chronic kidney disease, and 1 had hypertension. Medications used and number of children taking medication included: methylphenidate (1), lisdexamphetamine (1) amphetamine (1), melatonin (3), antihistamine (3), sertraline (1), levetiracetam (1), topiramate (1), metformin (1), albuterol (2), inhaled steroids (2), no medication (13).

In **Table 1**, the prevalence of each form of arrhythmia and conduction disturbance found in a very large population study by Niwa et al[6] involving 152,322 children is also reported for comparison. While no statistical comparison is possible, it is

evident that in our group of children there is a much higher prevalence of atrioventricular block (AVB; first degree and second degree) than that reported by Niwa et al[6] with a 5.44-fold increase, while the prevalence of other abnormalities found in our children (and the overall rate of arrhythmias and conduction disturbances) is very similar. **Table 2** shows each patient included in the study, the type of arrhythmia and the BMI, BMI percentile and oxyhemoglobin saturation index, and time spent with saturation below 88%.

To identify eventual factors influencing the relatively high rate of atrioventricular block (AVB, first degree and second degree) in our children we compared their age and PSG parameters with those of children with premature ventricular contractions (PVC), used as a control group, as well as the number of children with obstructive AHI > 1 event/h in each group and sex composition of the group. **Table 3** shows the comparison of age and PSG parameters found in the 2 groups and none of them was found to be significantly different. Seven out of 9 children with AVB (first degree and second degree) and 7 out of 10 with PVC had obstructive AHI > 1 event/h (Fisher's exact $P = .56$), while 8 children with AVB (first degree and second degree) out of 9 and 4 out of 10 with PVC were males, and this difference was the only statistically significant difference found (Fisher's exact $P = .04$).

All children with AVB were referred for cardiology evaluation. While all children subsequently underwent 12-lead or 15-lead ECG. Five children with second degree AV block underwent further workup with Holter monitor. Second-degree AVB was confirmed in all 5 of the children who underwent further evaluation with Holter monitor. All children were discharged from cardiology evaluation without need for follow up.

DISCUSSION

The results of this study on a case series of 24 consecutive children with arrhythmias and conduction disturbances detected in their PSG recordings indicates that, similarly to what can be expected in the general population, these abnormalities affect up to 2% of children. Thus, in general, it does not seem that having a sleep problem (all children were referred for a sleep complaint, most often for a suspected sleep breathing disorder) represents a particular risk factor for arrhythmias or conduction disturbances in children; this agrees with a previous report in 124 children with obstructive sleep apnea (OSA).[7] However, the prevalence of AVB (first degree and second degree) was clearly higher than expected and highly associated with the male sex.

When children underwent cardiology evaluation, the AVB was confirmed in 100% of children for whom cardiology felt necessary to pursue further evaluation with Holter monitor. Upon cardiological follow-up, these confirmed AVBs were often attributed to increased vagal tone during sleep. It was noted that first-degree or second-degree AVB can be seen commonly in teenagers or well-conditioned athletes while asleep and that, when these individuals awaken and increase physical activity, their AVB resolves with reduction in vagal tone; resolution of AVB with appropriate chronotropic response during exercise is regarded as an indicator of low risk.[8] As such, some of the children were made to ambulate briskly in clinic and examination after physical exertion suggested no further reason for the cardiologist to be concerned about pathological changes in the AV node.

Of note, 1 of the children with AVB was noted to have a history of reactive airway disease with a diagnosis of asthma during follow-up with cardiologist. Since vagal tone increases during expiration and decreases during expiration, and increase in vagal tone could contribute to AVB. Vagal tone can increase during expiration and decrease during inspiration.[9]

Studies on the prevalence of arrhythmias in children are very few and report discordant data; a first study in 2004 showed a 1.25% prevalence of arrhythmias in primary school children and 2.32% in middle school children, with a higher prevalence in males, in particular bundle branch block seems to prevail in males, while PVC seems to be more frequent in females[6]; another more recent study has shown that AVB in pediatric age (diagnosed between the first month and the 18th year of life) has a prevalence of 1 in 15,000–20,000.[10]

According to another study carried out in 2005, PVC seems to be very common in children and adolescents in outpatient facilities, even in asymptomatic children, with an estimated prevalence between 18 and 50%.[11] Finally, in 2017, another study highlighted that early repolarizations are very frequent in the pediatric population, especially from the age of 8 years.[12] It is therefore necessary to conduct further studies to evaluate the prevalence of arrhythmias in children, especially of the various types (in fact there seem to be no other studies that have focused attention on the prevalence of AVB in pediatric age, apart from the report by Niwa et al. in 2004[6]).

However, it is generally believed that arrhythmias in the pediatric age should be kept under cardiological monitoring; in fact, according to some studies, PVC can frequently evolve into ventricular dysfunction.[13,14] Other studies have indicated a benign course in most cases, underlining, however, the importance of monitoring, especially in the case of symptoms or changes in the ECG.[15,16]

For this reason, specific recommendations have also been proposed, with indications for the execution of ECG, echocardiogram, and 24-hour ECG Holter, with checks every 6–12 months.[17] In consideration of the association found between cardiac arrhythmias (especially ventricular) and sudden death, even in the absence of cardiac structural anomalies,[18,19] specific guidelines to monitor them and avoid cases of sudden death have also been arranged.[20]

During non-rapid eye movement sleep there is a low heart rate and a reduction in blood pressure; in rapid eye movement sleep, an increase in vagal predominance and dynamic instability is observed due to sudden bursts of sympathetic activity with sudden changes in heart rate and peripheral resistance, which can cause arrhythmias at both the atrial and ventricular levels.[21]

An increase in vagal tone in children's sleep increases the risk of sinus arrhythmias[22]; moreover, in recent years, studies have been conducted to evaluate the correlation between respiratory disorders during nocturnal sleep and autonomic alterations, in light of the fluctuations of the autonomic nervous system related to OSA, characterized by greater parasympathetic activation during respiratory events and sympathetic peaks following them, which contribute to a greater propensity to arrhythmia.[23] One of

Table 2—Detailed description of BMI, ODI, time spent with < 88% O_2 peripheral saturation, and ECG findings in the participants reported in this study.

Participant	BMI	BMI for Age, %	ODI (3%)	Time Spent < 88%	Premature Ventricular Contractions*	Atrioventricular Block, First and Second Degree*	Right Bundle Branch Block*	Wide QRS Tachycardia*	Sinus Tachycardia*
1	17.4	92	1.5	0%		x			
2	17	42	4.7	0%				x	
3	17	88	1.2	0%	x				
4	14.4	7	12.1	0.9%		x			
5	32.5	97	9.9	0%		x			
6	15.7	41	3.1	0%		x			
7	15.1	38	3.9	0%		x			
8	32.4	99	8.6	0%				x	
9	15.7	51	3.6	0%			x		
10	18.5	81	0.6	0%		x			
11	16.6	31	2.7	0%					x
12	16.4	25	1.3	0%	x				
13	15.7	51	0.1	0%	x				
14	25	86	0.3	0%	x				
15	21	90	1.7	0%	x				
16	15.6	52	2.6	0%	x				
17	16.1	47	1.3	0%	x				
18	25	100	2.7	0%	x				
19	14	21	1.2	0%					x
20	34.7	99	1.4	0%	x				
21	15.4	19	1.1	0%		x			
22	18.1	5	7.1	0%		x			
23	18.2	75	5.2	0.1%	x				
24	26.2	98	2.9	0%		x			

BMI = body mass index, ECG = electrocardiogram, ODI = oxygen desaturation index, *X marks the presence of the EKG abnormality while empty cell represents absence of the particular EKG finding.

Table 3—Comparison of age and PSG parameters found in our children with atrioventricular block (first degree and second degree) or premature ventricular contractions.

	Atrioventricular Block (n = 9)			Premature Ventricular Contractions (n = 10)			Mann-Whitney Test	
	Median	Lower Quartile	Upper Quartile	Median	Lower Quartile	Upper Quartile	z	*P*
Age, years	9.0	6.0	10.0	7.0	4.0	11.0	0.327	.744
Total sleep time, min	470.5	444.5	497.0	454.3	434.0	478.5	0.694	.488
Sleep latency, min	23.8	11.8	31.6	18.1	5.0	52.9	0.286	.775
Sleep efficiency, %	90.4	82.9	92.5	91.2	86.8	94.7	−0.735	.462
SME	93.4	87.4	95.4	96.4	93.0	98.1	−1.388	.165
Arousal index, events/h	9.3	6.8	12.6	9.6	8.9	10.9	0.000	1.000
Stage N1, %	6.5	3.9	10.0	10.1	7.1	11.5	−1.184	.236
Stage N2, %	45.2	39.6	48.6	48.4	42.5	51.7	−0.531	.596
Stage N3, %	28.4	21.7	32.4	26.2	23.0	31.7	0.531	.596
Stage R, %	19.9	18.0	21.9	17.9	15.1	20.5	0.939	.348
oAHI, events/h	2.0	0.9	2.9	1.9	0.8	4.3	0.163	.870
cAHI, events/h	1.5	0.6	2.2	0.9	0.2	1.2	0.572	.568
tAHI, events/h	3.3	3.0	5.0	2.9	1.7	5.2	0.653	.514
O_2 saturation nadir, %	91.3	88.9	93.0	93.5	92.0	95.1	−1.592	.111
$CO_{2\%}$ above 50	0.0	0.0	0.0	0.0	0.0	3.3	−0.776	.438
PLMS index, events/h	0.0	0.0	4.5	1.3	0.0	3.5	0.082	.935

cAHI = central apnea-hypopnea index, oAHI = obstructive apnea-hypopnea index, PLMS = periodic leg movements during sleep, PSG = polysomnography, tAHI = total apnea-hypopnea index.

these studies used 24-hour ECG monitoring, confirming its importance during sleep;[24] however, only few studies have evaluated the presence of arrhythmias in children with OSA using PSG, an important topic in light of the different functioning of the autonomic nervous system during the different sleep stages.

One study evaluated cardiac arrhythmias in children with a mean age of 6.5 years, with a follow-up from 2002 to 2012, the mean AHI was 8.8 events/h, 26% of children had severe OSA, with an AHI > 10 events/h; 30% of children had arrhythmias and the most frequently encountered anomalies were PVC, furthermore cardiac alterations such as atrial and ventricular ectopy, tuberous sclerosis, and aortic and mitral insufficiency were very detected;[25] another study did not show any correlation between cardiac arrhythmias and OSA in pediatric age.[7]

There are no known sex differences in the literature regarding cardiac arrhythmias in pediatric age. However, 1 study on adults showed an effect of sex hormones on the onset of PVC and repolarization parameters; more precisely, there seems to be a protective effect of estrogen against ventricular arrhythmias,[26] which could explain a higher prevalence of this type of arrhythmias in males compared to females, as found in the present study and in another report in the general population.[6]

Age differences may be related to cardiac strain (which refers to localized shortening, thickening, or lengthening of the myocardium as a measure of regional left ventricular function), which affects both contractility and ejection fraction and is involved in the mechanisms of myocardial ischemia and arrhythmias. Strain is strongly influenced by age, in fact in pediatric cardiology there are precise ultrasound data based on different age groups and a meta-analysis has shown that among newborns there is no difference between the longitudinal strain values at the level of basal, middle, and apical segments of the free wall and atrioventricular septum; however, with growth, and in particular starting from the age of 5 to 9 years, differences emerge such as to configure a real deformation gradient from the base to the apex.[27,28] Interestingly, this is the age group in which arrhythmias (especially ventricular) were found in both our study and other studies in the literature.[12,25] Specifically, 1 particular study showed that first-degree and second-degree AVBs were observed, especially during sleep, in kindergarten pupils aged 4–6 years, primary school pupils aged 9–12 years, and junior high school students aged 13–15 years; however, these AVBs were not observed in newborns and infants.[29] The age range in which AVBs were observed during that study is consistent with the age range of the children in whom we observed AVBs during our sleep studies.

In conclusion, cardiac arrhythmias and AVB are rare in children without structural heart disease during PSG. It appears that these findings are confirmed by full electrocardiogram and Holter but follow-up is not required in healthy children.

ABBREVIATIONS

AVB, atrioventricular block
ECG, electrocardiography
OSA, obstructive sleep apnea
PSG, polysomnography
PVC, premature ventricular contraction

REFERENCES

1. Fleming S, Thompson M, Stevens R, et al. Normal ranges of heart rate and respiratory rate in children from birth to 18 years of age: a systematic review of observational studies. *Lancet.* 2011;377(9770):1011–1018.
2. Caples SM, Rosen CL, Shen WK, et al. The scoring of cardiac events during sleep. *J Clin Sleep Med.* 2007;3(2):147–154.
3. Massin M, von Bernuth G. Normal ranges of heart rate variability during infancy and childhood. *Pediatr Cardiol.* 1997;18(4):297–302.
4. Walter LM, Tamanyan K, Weichard AJ, Davey MJ, Nixon GM, Horne RSC. Sleep disordered breathing in children disrupts the maturation of autonomic control of heart rate and its association with cerebral oxygenation. *J Physiol.* 2019;597(3):819–830.
5. Berry RB, Brooks R, Gamaldo CE, et al; for the American Academy of Sleep Medicine. *The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications.* Version 2.4. Darien, IL: American Academy of Sleep Medicine; 2017.
6. Niwa K, Warita N, Sunami Y, Shimura A, Tateno S, Sugita K. Prevalence of arrhythmias and conduction disturbances in large population-based samples of children. *Cardiol Young.* 2004;14(1):68–74.
7. Khositseth A, Chokechuleekorn J, Kuptanon T, Leejakpai A. Rhythm disturbances in childhood obstructive sleep apnea during apnea-hypopnea episodes. *Ann Pediatr Cardiol.* 2013;6(1):39–42.
8. Abela M, Sharma S. Abnormal ECG findings in athletes: clinical evaluation and considerations. *Curr Treat Options Cardiovasc Med.* 2019;21(12):95.
9. Warner MR, Loeb JM. Beat-by-beat modulation of AV conduction. I. Heart rate and respiratory influences. *Am J Physiol.* 1986;251(6 Pt 2):H1126–H1133.
10. Baruteau AE, Pass RH, Thambo JB, et al. Congenital and childhood atrioventricular blocks: pathophysiology and contemporary management. *Eur J Pediatr.* 2016; 175(9):1235–1248.
11. Massin MM, Bourguignont A, Gérard P. Study of cardiac rate and rhythm patterns in ambulatory and hospitalized children. *Cardiology.* 2005;103(4):174–179.
12. Maury P, Authenac C, Rollin A, et al. Réseau Francophone de Rythmologie pédiatrique et congénitale. Prevalence of early repolarisation pattern in children. *Int J Cardiol.* 2017;243:505–510.
13. Spector ZZ, Seslar SP. Premature ventricular contraction-induced cardiomyopathy in children. *Cardiol Young.* 2016;26(4):711–717.
14. Cohen MI. Frequent premature ventricular beats in healthy children: when to ignore and when to treat? *Curr Opin Cardiol.* 2019;34(1):65–72.
15. Sharma N, Cortez D, Imundo JR. High burden of premature ventricular contractions in structurally normal hearts: To worry or not in pediatric patients? *Ann Noninvasive Electrocardiol.* 2019;24(6):e12663.
16. Porcedda G, Brambilla A, Favilli S, Spaziani G, Mascia G, Giaccardi M. Frequent ventricular premature beats in children and adolescents: natural history and relationship with sport activity in a long-term follow-up. *Pediatr Cardiol.* 2020;41(1): 123–128.
17. Drago F, Leoni L, Bronzetti G, Sarubbi B, Porcedda G. Premature ventricular complexes in children with structurally normal hearts: clinical review and recommendations for diagnosis and treatment. *Minerva Pediatr.* 2017;69(5): 427–433.
18. Ip JE, Lerman BB. Idiopathic malignant premature ventricular contractions. *Trends Cardiovasc Med.* 2018;28(4):295–302.
19. Tsuda T, Fitzgerald KK, Temple J. Sudden cardiac death in children and young adults without structural heart disease: a comprehensive review. *Rev Cardiovasc Med.* 2020;21(2):205–216.
20. Priori SG, Blomström-Lundqvist C, Mazzanti A, et al. 2015 ESC Guidelines for the Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death. *Rev Esp Cardiol (Engl Ed).* 2016;69(2):176.
21. Bersano C, Revera M, Vanoli E. [Physiopathology of the autonomic nervous system activity during sleep]. *Ital Heart J Suppl.* 2001;2(8):840–844.
22. El-Sheikh M, Erath SA, Bagley EJ. Parasympathetic nervous system activity and children's sleep. *J Sleep Res.* 2013;22(3):282–288.
23. May AM, Van Wagoner DR, Mehra R. OSA and cardiac arrhythmogenesis: mechanistic insights. *Chest.* 2017;151(1):225–241.
24. Yilmaz O, Ciftel M, Ozturk K, et al. Assessment of heart rate variability in breath holding children by 24 hour Holter monitoring. *Cardiol Young.* 2015;25(2):317–323.
25. Baldassari CM, Beydoun HA, Peak J, Reed JH. Is cardiology evaluation necessary in children with electrocardiogram abnormalities noted on polysomnogram? *Otolaryngol Head Neck Surg.* 2014;150(4):684–688.
26. Dogan M, Yiginer O, Uz O, et al. The effects of female sex hormones on ventricular premature beats and repolarization parameters in physiological menstrual cycle. *Pacing Clin Electrophysiol.* 2016;39(5):418–426.
27. Castaldi B, Bordin G, Favero V, et al. Early modifications of cardiac function in preterm neonates using speckle tracking echocardiography. *Echocardiography.* 2018;35(6): 849–854.
28. Jashari H, Rydberg A, Ibrahimi P, et al. Normal ranges of left ventricular strain in children: a meta-analysis. *Cardiovasc Ultrasound.* 2015;13(1):37.
29. Nagashima M, Matsushima M, Ogawa A, et al. Cardiac arrhythmias in healthy children revealed by 24-hour ambulatory ECG monitoring. *Pediatr Cardiol.* 1987;8(2): 103–108.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication February 26, 2021
Submitted in final revised form May 13, 2021
Accepted for publication May 17, 2021
Address correspondence to: Lourdes DelRosso, Seattle Children's Hospital, 4800 Sand Point Way NE, Seattle, WA 98105; Tel: (267) 559 4515; Email: lourdesdelrosso@me.com

DISCLOSURE STATEMENT

All authors have seen and approved this manuscript. The authors report no conflicts of interest.