



Can Pediatric Practitioners Correctly Interpret Electrocardiograms?

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Objectives To assess the impact of participation in an educational presentation on electrocardiogram (ECG) interpretation in children on pediatric practitioners' ability to accurately interpret ECGs.

Study design Pediatric healthcare providers at a pediatric clinic with >65 000 visits/year were eligible to participate. A 1-hour ECG educational module that provided a systematic approach to ECG interpretation was presented to 8 providers who consented (6 pediatricians, 2 pediatric nurse practitioners). A test on 11 ECGs (normal, normal-variant, and abnormal ECGs) was given before and 2 weeks after the educational module. Outcomes included correct interpretation of each ECG as normal or abnormal and correct identification of specific ECG findings. Data analysis was descriptive and included χ^2 and Student *t* test.

Results Mean score (SD) for correct interpretation of ECGs as normal or abnormal improved from 35% (48%) (95% CI 25.0-45.4) to 77% (42%) (95% CI 68.3-86.2) after the ECG educational module ($P < .001$). Mean (SD) pretest score for correct identification in the normal ECG category improved from 45% (50%) (95% CI 28.9-61.1) to 68% (47%) (95% CI 52.3-82.7) ($P = .003$). In the abnormal ECG category, correct identification improved from 31% (47%) (95% CI 17.6-44.9) to 83% (5%) (95% CI 72.4-94.3) after the module ($P < .001$).

Conclusions Education of pediatric practitioners on ECG interpretation significantly improves their ability to distinguish normal from abnormal and to identify specific abnormalities. Limitations included small sample size and short-term follow-up. (*J Pediatr* 2019;206:113-8).

Sudden cardiac arrest (SCA) in the young accounts for at least 2000 childhood deaths each year in the US.¹ Conditions commonly associated with SCA include hypertrophic cardiomyopathy, dilated cardiomyopathy, arrhythmogenic right ventricular dysplasia/cardiomyopathy, coronary artery anomalies, long QT syndrome, Wolff-Parkinson-White (WPW) syndrome, and others.² Many of these conditions are associated with underlying electrical or structural cardiac alternations that result in electrocardiographic abnormalities. In this population, it is reasonable to use an electrocardiogram (ECG) to identify at-risk youth with a goal to prevent SCA. Although it is accepted that there are effective treatments for these specific cardiac conditions, the efficacy of screening tools for those at risk for SCA, particularly with an ECG, is widely debated.^{3,4} Several barriers to implementing ECG screening have been described, including logistics and infrastructure, workforce limitations, costs, and a variety of knowledge gaps.⁵

Studies on the proficiency of ECG interpretation of pediatricians, residents in pediatrics, and other specialties have shown limitations in expertise.⁶⁻⁸ Some suggest this lack of skill serves as a barrier to implementing ECG screening in the pediatric home.⁴

Drezner et al demonstrated that providing standardized criteria to physicians can significantly improve the accuracy of ECG interpretation.⁹ Although a few studies assessing ECG interpretation among pediatric providers have been performed, no studies have examined the use of an educational module presentation to improve accuracy rates for ECG interpretation among pediatric providers.^{10,11}

A number of pediatric criteria have been used to aid in the interpretation of ECGs, notably the Davignon criteria and the recent Pediatric Heart Network study.^{12,13} Criteria for ECG screening and interpretation in athletes include the Seattle and International Criteria.^{14,15}

The objective of our study was to address limitations in ECG interpretation as a barrier to implementing ECG use in pediatric practices to screen for potentially threatening conditions by determining the effectiveness of an educational module presentation on ECG interpretation in children and adolescents. We hypothesized that attending our educational module would improve the ability of pediatric practitioners to accurately interpret ECGs.

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ECG Electrocardiogram
SCA Sudden cardiac arrest
WPW Wolff-Parkinson-White

Methods

The institutional review board of The Children's Hospital of Philadelphia approved our prospective feasibility study. Eligible subjects included all pediatricians and pediatric nurse practitioners employed by a large, urban pediatric clinic with >65 000 pediatric visits per year. Pediatric providers were recruited from the clinic faculty by written and verbal communication. Providers who agreed to participate and provided written informed consent were included in the study. Participants who enrolled were assigned a unique study ID to complete the study testing anonymously.

We evaluated the practitioners' ability to interpret ECGs as normal or abnormal as well as to identify common specific ECG findings and abnormalities both before and after attending the ECG educational presentation. We selected 11 ECGs consisting of normal, normal-variant, and abnormal ECGs for interpretation by the pediatric health practitioners ([Supplement 1](#); available at www.jpeds.com). The normal and normal-variant ECGs were chosen as a representative sample of ECGs commonly encountered in the pediatric population and were collectively classified under the normal/normal-variant ECG category. The abnormal ECG category included findings consistent with some of the conditions associated with sudden cardiac death, such as WPW syndrome, hypertrophic cardiomyopathy with left ventricular hypertrophy, and long QT syndrome. All of the 11 ECGs were reviewed and interpreted as the stated diagnosis by both of the pediatric cardiologists, based solely on the ECG ([Table I](#)). It is the standard for 15-lead ECGs to be obtained at our institution, but all of the findings discussed and used for interpretation apply to 12-lead ECGs as well.

All patient identifiers and computer-generated interpretations except for patient age, race, and sex were removed from the ECGs to avoid biasing study participants. A checklist for ECG interpretation was created to standardize interpretations among the pediatricians and pediatric nurse practitioners and to ensure completeness ([Supplement 2](#); available at www.jpeds.com). The ECG interpretation checklist asked participants to determine the rhythm, calculate the rate, and assess PR, QRS, and QTc interval lengths. Participants were expected to determine the axis, evaluate for signs of

atrial or ventricular hypertrophy, and to evaluate ST-segment and T-wave morphology. An overall interpretation as either normal or abnormal was required on the interpretation checklist.

A 1-hour educational module on ECG interpretation in children and adolescents was prepared to provide a systematic approach to ECG interpretation ([Supplement 3](#); available at www.jpeds.com). This was presented to the pediatric practitioners in a small classroom setting with slides and handouts provided and opportunities for questions, discussion, and clarification. The module focused on rate and rhythm assessment, interval and axis determination, and waveform analysis. Normal, normal-variant, and abnormal ECGs were used to demonstrate this systematic approach. Conduction abnormalities, such as atrioventricular block, intraventricular conduction delay, and bundle branch blocks were reviewed using example ECGs from each respective category. QRS amplitude abnormalities were depicted to demonstrate electrocardiographic changes representing ventricular hypertrophy, myocarditis, and pericardial effusions. Waveform morphology, focusing on ST-segment and T-wave changes, was reviewed to demonstrate signs of early repolarization, myocardial infarction, pericarditis, and dilated and hypertrophic cardiomyopathies. Two representative slides selected from the ECG module are shown in [Figure 1](#).

Before attending the ECG educational module, pediatricians and pediatric nurse practitioners enrolled in the study anonymously took a pre-test that required interpretation of the 11 ECGs. They were asked to complete the ECG interpretation checklist for all 11 ECGs. Two weeks after attending the educational module and before feedback on their original ECG test, the practitioners used their study ID and the checklist to anonymously interpret the 11 post-test ECGs provided as a paper document. Although not specifically stated to the practitioners, the post-test featured the same 11 ECGs as in the pre-test but presented in a different random order. The ECGs shown in [Table I](#) were classified as either normal (5), which included normal (3) and normal variant (2), collectively, or abnormal (6). The primary outcome was correct interpretation of each ECG as normal or abnormal. A score in which 3 of 11 ECGs were identified correctly as normal or abnormal would be 27% and a score in which 8 of 11 ECGs were correctly identified would be 73%. Secondary outcomes included correct interpretation of specific ECG abnormalities, including right bundle branch block, WPW, left ventricular hypertrophy, and others.

Continuous data are presented as mean and SD with 95% CIs and as frequency and percentages for categorical variables. Study outcomes included subjects' scores at pre-testing (before ECG module presentation) and post-testing (after ECG module presentation). Only subjects who completed both pre- and post-testing were included. Data analysis and comparisons between pre- and post-test scores were performed using a χ^2 /Fisher exact and Student *t* test. The data were analyzed as overall percentage of correct ECG interpretations, normal vs abnormal, and percentage of correct ECG interpretation for specific ECG findings using 2-sided tests of hypotheses and a

Table I. Selected test electrocardiograms

ECG categories	Interpretation
Normal ECGs	
Normal	Normal sinus rhythm Sinus arrhythmia Sinus tachycardia
Normal variant	Early repolarization Ectopic low right atrial rhythm
Abnormal ECGs	Right bundle branch block Left bundle branch block WPW Left ventricular hypertrophy Prolonged QTc interval Premature ventricular contractions

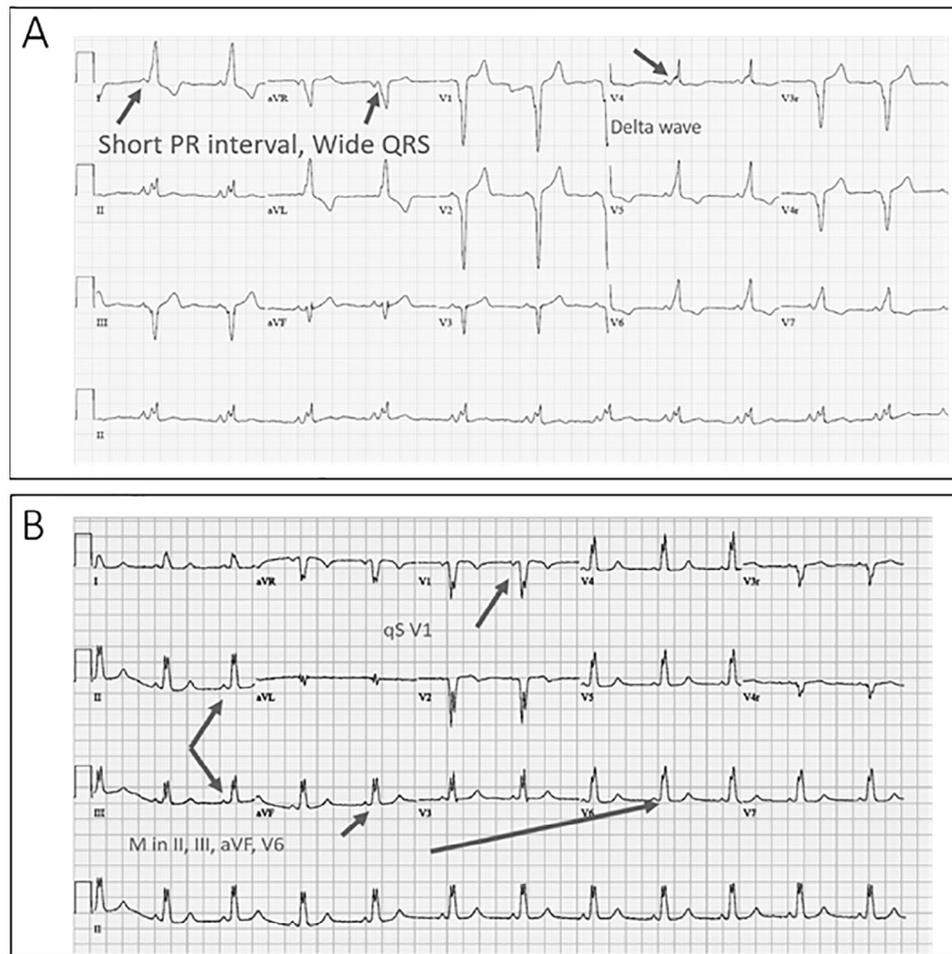


Figure 1. ECGs used in pre-test and post-test to evaluate for interpretation of ECG findings. **A**, WPW pattern (note short PR interval, delta wave, and wide QRS). **B**, Left bundle branch block (note wide QRS and dominant S wave in V1).

P value < .05 as the criterion for statistical significance. Analyses were performed using Stata 14.0 (Stata Statistical Software, Release 14; StataCorp LP, College Station, Texas).

Results

The study participants included 8 pediatric providers: 6 pediatricians and 2 pediatric nurse practitioners. The median time interval since completing training of the group was 7-9 years, ranging from 1 to >15 years. Most practitioners were female (88%).

ECG Test Scores Pre- and Post-Educational Module Presentation

The overall ECG interpretation scores are shown in **Table II**. The total percentages of correct interpretations of the 11 ECGs as normal or abnormal for each study participant before and after the educational module are shown in **Figure 2, A**. For the group, the mean (SD) pre-test score for correct interpretation of ECGs as normal or abnormal was 35% (48%) (95% CI 25.0-45.4), overall range 9%-82%. The mean (SD) post-test score

for correct interpretation of ECGs as normal or abnormal significantly improved to 77% (42%) (95% CI 68.3-86.2), overall range 64%-91% following the educational module (*P* < .001).

Scores for correct identification of specific ECG findings under the normal/normal-variant ECG category before and following the ECG module presentation are shown in **Figure 2, B**. The mean pre-test score for correct identification of specific ECG findings in the normal/normal-variant ECG category was 45% (505) (95% CI 28.9-61.1). The mean post-test score significantly improved to 68% (47%) (95% CI 52.3-82.7) after the educational module (*P* = .003).

Table II. ECG interpretation scores

ECG interpretation scores (% correct)	Normal vs abnormal (%)	Normal/normal-variant ECGs (%)	Abnormal ECGs (%)
Pre-test mean (SD)	35.2 (48.0)	45 (50.3)	31.3 (46.8)
95% CI	25.0-45.4	28.9-61.1	17.6-44.9
Post-test mean (SD)	77.3 (42.1)	67.5 (47.4)	83.3 (5.4)
95% CI	68.3-86.2	52.3-82.7	72.4-94.3
<i>P</i> value	<.001	.003	<.001

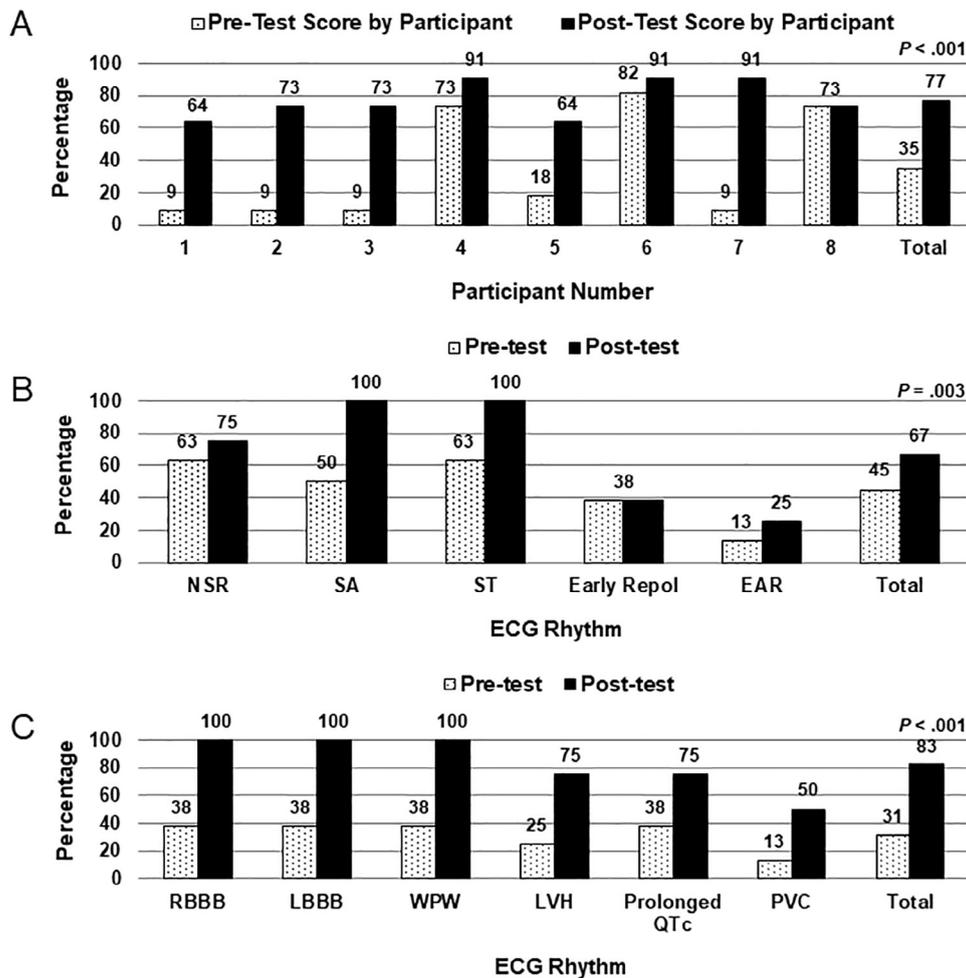


Figure 2. A, Pre- and post-test scores for correct interpretation of normal vs abnormal by participant. The *patterned bar* indicates pre-test scores and the *solid bar* indicates post-test scores. B, Pre- and post-test scores for correct interpretation of ECG findings categorized under the normal/normal-variant ECG category. The *patterned bar* indicates pre-test scores and the *solid bar* indicates post-test scores. EAR, ectopic low right atrial rhythm; Early Repol, early repolarization; NSR, normal sinus rhythm; SA, sinus arrhythmia; ST, sinus tachycardia. C, Pre- and Post-test scores for correct interpretation of ECG findings categorized under the abnormal ECG category. The *patterned bar* indicates pre-test scores and the *solid bar* indicates post-test scores. LBBB, left bundle branch block; LVH, left ventricular hypertrophy; PVC, premature ventricular contraction; RBBB, right bundle branch block.

Within the normal/normal-variant ECG category, pre-test scores for normal ECGs (normal sinus rhythm, sinus arrhythmia, sinus tachycardia) were greater than pre-test scores for normal-variant ECGs (ectopic atrial rhythm and early repolarization). The majority of the participants correctly identified normal sinus rhythm (63%) and sinus tachycardia (63%), but only 50% recognized sinus arrhythmia before the ECG educational module. Following the module, 75% of participants correctly identified normal sinus rhythm, and 100% correctly identified sinus tachycardia and sinus arrhythmia. Among the 2 normal-variant ECGs, low right atrial rhythm was correctly interpreted by only 13% of participants before the module and by 25% following the educational module. The accuracy rate for correct identification of early repolarization was 38% both before and following the educational module. Most

participants were able to correctly identify the presence of elevated ST segments, but labeled them as abnormal and did not associate these changes with the normal variant of early repolarization.

The ability of participants to correctly interpret specific ECGs classified under the abnormal ECG category improved significantly following the ECG educational module presentation. Scores for correct identification of specific ECG findings classified under the abnormal ECG category before and following the ECG module presentation are shown in **Figure 2, C**. The mean pre-test score for correct identification of specific ECG findings in the abnormal ECG category was 31% (47%) (95% CI 17.6-44.9). The mean post-test score significantly improved to 83% (5%) (95% CI 72.4-94.3) following the educational module ($P < .001$).

Correct identification of both right and left bundle branch block and WPW syndrome from pre- to post-test increased from 38% to 100%; for left ventricular hypertrophy from 25% to 75%; for prolonged QTc interval from 38% to 75%; and for premature ventricular contractions from 13% to 50%.

Discussion

Our study shows that education of pediatric practitioners on ECG interpretation, specifically focusing on distinguishing normal from abnormal and on identifying specific ECG findings, significantly improves their ability to interpret concerning ECG abnormalities.

In 1 study, the accuracy rate for correct ECG interpretation was only 64% for senior pediatric residents and 46% for interns.⁶ These results are similar to another study, which evaluated the ability of internal medicine and emergency medicine residents to interpret a variety of ECGs, including left ventricular hypertrophy and WPW syndrome; they reported that the overall competency score achieved by internal medicine and emergency medicine residents was low at only 60%.⁷ The study of Snyder et al showed that sinus arrhythmia and WPW syndrome were among the most frequently misinterpreted ECG findings for both pediatric interns and senior residents.⁶ Although our practitioners were attending-level pediatricians and nurse practitioners, we demonstrated that after education, accuracy rates for both of these ECG findings improved from a pre-test score of 50% (sinus arrhythmia) and 38% (WPW) to 100% for both.

In another prospective multicenter study of 61 family practice residents, the accuracy rates for correct identification of right bundle branch block (2 ECGs) was 80% and 74% and for left bundle branch block was 44%.⁸ In our study, pre-test scores for right and left bundle branch block increased from 38% to 100% for both ECG findings after the educational module. Although previous studies of pediatric, internal medicine, emergency medicine, and family practice residents have demonstrated low competency in ECG interpretation, our study shows that education can improve ECG interpretation skills.⁶⁻⁸

The greatest difficulty that our pediatric practitioners had was in recognizing specific normal variants such as low right atrial rhythms and early repolarization. This could be related to reader uncertainty in these instances and the desire to avoid missing a true abnormality or just to lack of understanding of the finding. The normal variant ECGs seemed to provide the greatest difficulty and responded least to the educational module. These types of findings should be better clarified and more effectively explained with more emphasis in future educational modules or refresher courses. More subtle ECG findings will require referral to a cardiologist. Summary points regarding identification of these entities should be provided in a slide at the end of the module to consolidate important facts about normal variants and other salient points regarding other specific ECG findings.

Inadequate workforce to interpret ECGs along with lack of ECG interpretation skills among pediatric providers are cited

as barriers to incorporating ECG screening in well-child or sports evaluation visits. We provide evidence that addresses improving ECG competency in pediatric practitioners.

The pediatric home could provide a pre-existing infrastructure for the directed use of the ECG in response to specific cardiac concerns. On-site ECG access could increase the likelihood that the practitioner would obtain contemporaneous ECGs on patients with concerning personal or family histories or abnormal physical examinations. By having the type of education that we provided, the pediatric practitioners could potentially identify abnormal ECG findings, resulting in prompt referral to pediatric cardiology specialists. This could result in early identification of those with potentially serious cardiac conditions.

A National Heart, Lung, and Blood Institute Working Group acknowledged that the performance of the ECG as a screening test has not been evaluated adequately in the US.⁵ To address this knowledge gap, the Working Group recommended that pilot ECG screening studies be performed to determine the test characteristics of the ECG in target populations. It is hoped that additional studies will fill in the identified knowledge gaps and allow for an evidence-based discussion regarding screening for sudden cardiac death in the young.⁵ Although a number of obstacles exist to conduct such studies, using pediatric offices could provide the opportunity to conduct such a study using a multicenter design.

There are several limitations to this study. First, the sample size was small with a limited number of pediatricians and pediatric nurse practitioners involved in the study. This could result in selection bias. Although improvement in ECG interpretation following the educational module was noted, we recognize that our study population was not a representative sample of the overall pediatric provider population. Second, we recognize that our study reassessed ECG interpretation skills only 2 weeks after the educational module, so we do not have information regarding long-term retention of ECG skills.

Our study provides data to inform the debate regarding the use of the ECG to screen for potentially threatening cardiac conditions and addresses some of the barriers to implementing ECG use in the pediatric home. The data from our study may provide insight into future pilot ECG screening studies. ■

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