Predictors of abnormal electrocardiograms in the pediatric emergency department

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ABSTRACT

Background : **Electrocardiograms (ECGs) are ordered in the pediatric emergency room for a wide variety of chief complaints**

Objectives : **Criteria are lacking as to when physicians should obtain ECGs. This study uses a large retrospective cohort of 880 pediatric emergency department (ED) patients to highlight objective criteria including significant medical history and specific vital sign abnormalities to guide clinicians as to which patients might have an abnormal ECG.**

Methods : **Retrospective review of Pediatric ED charts in all patients aged < 18 years who had ECG performed during ED stay. Pediatric ED physician interpretation of the ECG, clinical data on vital signs and past medical history was collected from the medical record for analysis.**

Results : **Of 880 ECGs performed in the ED, 17.4% were abnormal. When controlled for medical history and demographic differences, abnormal ECGs were associated with age-adjusted abnormal ED vital signs including increased heart rate (odds ratio [OR] 1.85, 95% confidence interval [CI] 1.1–3.09) and increased respiratory rate (OR 1.74, CI 1.42–2.62). In a logistic regression analysis, certain chief complaints and history components were less likely to have abnormal ECGs including complaints of chest pain (OR 0.38, CI 0.18–0.80) and known history of gastrointestinal or respiratory condition (i.e., asthma) (OR 0.48, CI 0.29–0.79).**

Conclusions : **In this cohort of patients, those with a chief complaint of chest pain or known respiratory conditions and normal age-adjusted vital signs in the ED have low likelihood of an abnormal ECG.**

Keywords : Chest pain, children, electrocardiogram, syncope, resource utilization

INTRODUCTION

Electrocardiograms (ECGs) in the pediatric emergency department (PED) can be an important tool to diagnose emergent cardiac conditions for a variety of presentations. Children with or without significant medical history may present with chest pain, shortness of breath, syncope, or palpitations, often requiring an ECG for further differentiation. However, since most patients do not have a cardiac etiology to these complaints, most ECGs in the PED are normal or clinically insignificant.[1] Furthermore, ECGs can be costly, time-consuming, and distressing to family members; these consequences are amplified in the case of false positives, which are common in pediatric patients.

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Chest pain is a concerning indicator of myocardial ischemia or myocardial infarction for adult patients in the emergency department; however, children with chest pain rarely have a cardiac etiology.[1] Studies examining previously healthy children with a chief complaint of chest pain show that a cardiac problem is found in only 0.3%–1% of children who present to the PED with chest pain and the most common cause of pediatric chest pain is musculoskeletal disorders.[1-4] Other common noncardiac diagnoses for chest pain include respiratory infections such as pneumonia or pharyngitis, gastrointestinal (GI) problems including esophagitis or gastritis, psychological problems, and idiopathic etiologies.[1,3,5] Therefore, there is a low likelihood that a child will have an abnormal ECG.[1] In addition, Sert *et al.* concluded that medical history and physical examination are the only procedures necessary for diagnosing the cause of chest pain in pediatric patients, not ECG.

One of the most common reasons PED physicians obtain an ECG is syncope in children.[6] Sanatani *et al.* developed a decision rule for pediatric patients presenting with syncope, which distinguishes the most common type, vasovagal syncope, from cardiac or neurologic causes of loss of consciousness. The authors concluded that ECGs are not necessary for diagnosing cardiac causes of syncope; only five of 480 pediatric patients with syncope were found to have a cardiac cause.[7] Similar to chest pain, a detailed history and physical examination without an ECG are sufficient to determine if syncope can be diagnosed as vasovagal or requires follow-up with a cardiologist or neurologist.[7]

There are several well-known criteria developed for children in the PED such as Pediatric emergency care applied research network (PECARN) rules that risk stratifies children with head injuries and provides options for management and the Ottawa ankle rules, which help physicians determine if a patient has an ankle or foot fracture that requires imaging.[4,8-10] Recent studies have evaluated the indications for echocardiograms given specific historical and clinical data using validated quality metrics.[11-18] These studies have demonstrated a reduction in utilization of echocardiograms by following the proposed algorithm.[11-18] There are no similarly widely accepted decision rules or criteria that risk stratify children to guide pediatric emergency physicians in when to obtain ECGs. Because ECGs are used to evaluate a variety of chief complaints, it is challenging to develop universal guidelines regarding the need for ECGs in the PED setting.

The objective of this study was to determine a specific set of clinical variables that are predictive of abnormal ECGs to risk stratify children presenting to the PED. All chief complaints were included, details regarding medical and family history were obtained, and both PED and cardiology interpretations were used.

METHODS

Cohort

Data were retrospectively collected from the electronic medical record for all patients who received an ECG in the PED from January 1, 2010, to December 31, 2010. Patients were included if they had an ECG performed in the PED, were ≤18 years of age, and had the ED physician's ECG interpretation documented in the medical record. All study data were extracted from the medical record by one of the authors (S.G.); 10% of the charts were randomly selected for secondary review by another author (M.L.) to confirm whether there were data entry errors. This study was approved by the Institutional Review Board at the study institution.

Variables for analysis

Demographic and clinical variables were extracted from the medical record for analysis. Demographic variables of interest included age, gender, race, and insurance type. Clinical variables included temperature, heart rate (HR), blood pressure, respiratory rate (RR), room air oxygen saturation, chief complaint, medical history, final ED diagnosis, and ED ECG physician interpretation as well as final pediatric cardiologist ECG interpretation. Medical history of cardiac disease was defined as known cardiac problem in the patient (either congenital or acquired) or a family history of early cardiac deaths under the age of 40 in close family members. Miscellaneous medical history was defined as significant noncardiac respiratory, GI, renal, oncologic, or psychiatric symptoms listed in the medical record. For children with multiple vital signs in the chart, the first entries were used for data analyses. The Harriet Lane Handbook was consulted to determine normal classifications for both HR and RR by age; entries outside of the 95% range were deemed abnormal.[19] Tintinalli's blood pressure guidelines were consulted to determine normal and abnormal classifications for both systolic and diastolic blood pressure by age.[9]

ECGs were classified as abnormal if the PED physician found supraventricular tachycardia (SVT), bradycardia, prolonged QTc interval, ST elevation (pericarditis), abnormal T-wave inversions, abnormal axis (structural heart disease), or left ventricular hypertrophy (LVH). Interpretations that were recorded in the chart as "assumed normal" were classified as normal. The "ED ECG" interpretation was recorded as the binary outcome for analysis. For children with a discrepancy between the ED and cardiologist interpretations, we used the ED interpretation because, in actual practice, the cardiologist reinterpretation may not be available while the child is still in the ED.

Data analysis

Clinical variables (temperature, HR, blood pressure, RR, room air oxygen saturation, chief complaint, medical history) were assessed for univariate association with an abnormal ECG. Rates of abnormal ECGs between groups were compared using Chi-squared analysis.

Logistic regression analysis was completed using SPSS Statistics for Windows, Version 22.0. (Armonk, NY: IBM Corp) with the binary outcome of abnormal ECG. Logistic regression analysis has been shown to successfully identify variables that show significantly high correlation and significantly low correlation with a specific outcome. In this study, the model assessed the odds of having an abnormal ECG in association with certain abnormal vital signs, presenting chief complaints, or medical history risk factors. This regression included the demographic variables noted above.

A recursive partitioning model was created using JMP software (SAS Institute, Cary, NC) that creates a decision tree based on dichotomous-dependent variables (patient characteristics and vital signs). Internal validation was performed using K-fold validation. Recursive partitioning is a type of multivariate analysis that helps users make decisions based on a hierarchy of binary variables. Using the dataset, a decision tree was formed by dividing the data into groups categorized by the presence or absence of one variable and then continuously dividing the data into smaller groups based on other variables. The statistical software determined which variables are most predictive for the targeted outcome and formulated a decision tree.

Table 1: Patient demographics

	Normal ECG (*n*=727) (%)	Abnormal ECG (*n*=153) (%)
Age (years), mean (SD)	11.8 (4.6)	11.2 (5.4)
Female	414 (56.9)	71 (46.4)
Male	313 (43.1)	82 (53.6)
Hispanic	203 (27.9)	41 (26.8)
Caucasian	335 (46.1)	72 (47.1)
African-American	115 (15.8)	29 (19.1)
Other	74 (10.2)	11 (7.2)
Public insurance	35 (4.8)	3 (2.0)
Private insurance	394 (54.2)	82 (53.6)
Self-pay	298 (41.1)	68 (44.4)

ECG: Electrocardiograms, SD: Standard deviation

RESULTS

During the study period, 902 children had an ECG performed in the PED. Of these, 880 had an ED ECG interpretation documented in the chart and met inclusion criteria. The mean age of the study patients was 11.7 years (6 months to 18 years), 44.8% were male, 46.1% were Caucasian, 27.7% were Hispanic, and 16.3% were African-American. The demographic characteristics were similar between those with and without abnormal ECGs [Table 1]. The most common chief complaints of patients who had an abnormal ECG were syncope (30/153), chest pain (29/153), cardiovascular (12/153), and respiratory complaints (18/153). Table 2 lists the frequency of abnormal ECGs for each chief complaint.

Twelve percent of children in the cohort had a significant congenital cardiac medical history, and 6.9% had a history significant for an acquired cardiac problem. Vitals sign abnormalities for age were present in a small portion of the cohort; abnormal HR was present in 12.4%, abnormal RR was present in 22%, and abnormal oxygen saturation was present in 2%.

Overall, 17.4% of patients in the study had an abnormal ECG read documented by the PED physician. The most

Table 2: Number and percent abnormal electrocardiograms per chief complaint

Chief complaint	Number of ECG Abnormal/total ECG per chief complaint	Percentage abnormal ECG (%)
Syncope	30/212	14.2
Chest pain	29/194	15.1
Overdose/ingestion	10/62	16.1
Respiratory	18/60	30.0
Seizure/shaking/weakness	5/51	9.8
Cardiovascular	12/48	27.3
GI (vomiting, diarrhea, abdominal pain)	7/35	20.0
Behavioral	6/35	17.1
Dizziness	2/33	6.1
Other (dehydration, abnormal labs/films, rash)	8/29	27.6
Fever	7/20	35
Eating disorder/anorexia/weight loss	5/17	29.4
AMS	1/17	5.9
Abuse/trauma	2/16	12.5
Musculoskeletal (sickle cell with pain)	2/16	12.5
Headache	1/14	7.1
Fall	5/13	38.5
ALTE	3/12	25

GI: Gastrointestinal, AMS: Altered mental status, ALTE: Apparent life-threatening event, ECG: Electrocardiograms

common abnormalities documented were SVT (48/880), bradycardia (39/880), prolonged QT interval (29/880), and left ventricular hypertrophy (18/880). The pediatric cardiologist interpretation agreed 95.6% of the time with the ED physician interpretation. Discrepancies included mild ST elevations, tachycardia, and bradycardia. None of these were clinically significant.

Univariate analysis demonstrates that abnormal findings are more likely in patients with an elevated or slow age-adjusted HR ($P < 0.005$). Patients with a known medical history significant for respiratory or GI issues (i.e., asthma) were less likely to have abnormal ECG findings ($P < 0.005$) [Table 3].

Table 3: Univariate likelihood of abnormal electrocardiograms

Factor	Abnormal ECG (%)	*P*
Normal RR	108/665 (16.2)	0.08
Tachypnea	45/215 (20)	
No tachycardia	110/712 (15.4)	0.002
Tachycardia	43/168 (25.6)	
No bradycardia	120/784 (15.3)	0.025
Bradycardia	23/96 (24)	
No diagnosis of chest pain	131/716 (18.3)	0.08
Diagnosis of chest pain	22/164 (13.4)	
GI or respiratory medical history	31/255 (12.2)	0.005
No GI or respiratory medical history	122/625 (19.5)	

All vital signs are age-adjusted and defined as > or <95% for age.
GI: Gastrointestinal, ECG: Electrocardiograms, RR: Respiratory rate

Table 4: Logistic regression analysis for predictors of abnormal electrocardiograms

Risk of abnormal ECG	OR	CI (95%)
Tachypnea	1.74	1.42-2.62
Tachycardia	1.85	1.10-3.09
Bradycardia	3.69	1.47-9.28
Diagnosis of chest pain	0.383	0.18-0.80
GI or Respiratory past medical history	0.484	0.29-0.79

All vitals signs are age-adjusted and defined as >or<95% for age. OR: Odds ratio, ECG: Electrocardiograms, CI: Confidence interval, GI: Gastrointestinal

The logistic regression model adjusted for demographic differences (age, gender, race, and insurance type) shows a significant increased likelihood of an abnormal ECG read with abnormal age-adjusted vitals sign abnormalities including tachycardia (odds ratio [OR] 1.85, 95% confidence interval [CI]: 1.10–3.09), bradycardia (OR 3.69, 95% CI: 1.47–3.09), and tachypnea (OR 1.74, 95% CI: 1.42–2.62) [Table 4]. In the regression model, a significant medical history for respiratory of GI issues (i.e., asthma) was associated with lower odds of an abnormal ECG (OR 0.49, 95% CI: 0.29–0.79). In addition, a chief complaint of chest pain on history was associated with lower odds of an abnormal ECG (OR 0.38, 95% CI: 0.18–0.80) [Table 4].

A recursive partitioning model was developed and is shown in Figure 1. Our recursive partitioning model identified patients with a higher likelihood of having an abnormal ECG (Rsq 0.17 [K-fold value of 0.24]). The model shows that those patients with a medical history of a cardiac condition had the highest risk of an abnormal ECG read. In addition, patients with age-adjusted clinical findings of tachycardia and tachypnea were at higher risk for having an abnormal ECG.

DISCUSSION

A robust decision support tool may help guide ED clinicians to order ECGs only in those cases where the results will change management. While ECGs are not an invasive test, there is an associated monetary cost to the test and the formal cardiology read. Previous studies have shown the majority of ECGs performed in the PED are unnecessary and can often be avoided with a thorough history

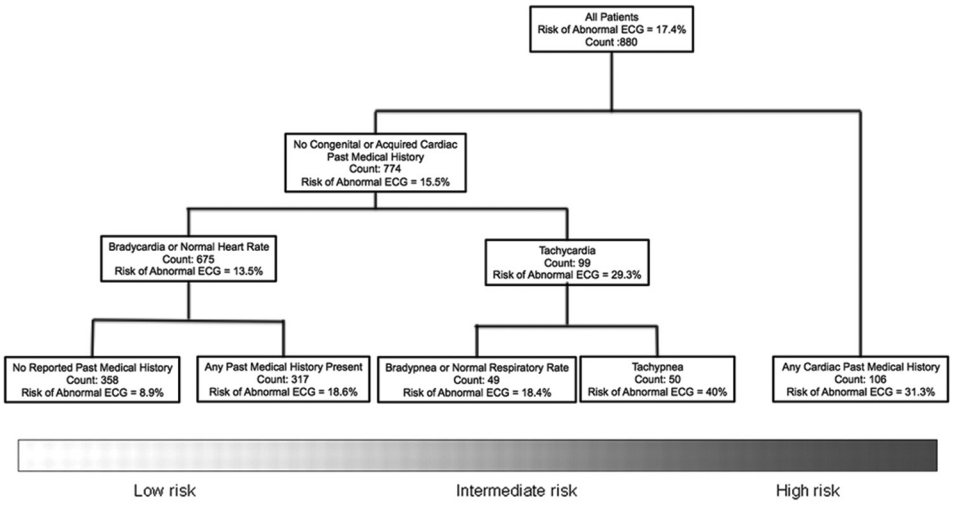

Figure 1: Recursive partitioning model stratifying the risk of abnormal electrocardiogram. Patients with any cardiac medical history were at high risk. Those with age-adjusted tachycardia and/or tachypnea were are intermediate risk

and physical examination. Our study reinforces that a majority of ECGs done in the PED do not change clinical management; however, in patients with a significant cardiac medical history or objective abnormal age-adjusted vital signs, ECGs are more likely to be abnormal.

In this study cohort of PED patients, the majority of chief complaints resulting in an ECG were for syncope or chest pain, two very common ED complaints. Avoiding unnecessary ECGs in this population would yield significant cost savings, reduce time in the ED, and potentially reduce distress to families who may have false-positive reads. Children without significant cardiac history and with normal age-adjusted vital signs in this cohort are less likely to have abnormal ECGs. Carefully guiding the decision to obtain an ECG by asking directed questions about personal and family history and flagging abnormal age-adjusted vital signs may prevent a significant portion of unnecessary testing in this cohort.

This study highlights some specific elements to be gathered in the clinical and medical history that may guide clinicians about when to order an ECG. Based on our study cohort, clinicians should consider ordering ECGs in patients with known cardiac history and those who present with palpitations or syncope who have abnormal age-adjusted vital signs. In those patients who present with chest pain or know respiratory problems (like asthma) and normal vital signs the routine performance of ECGs is less likely to change clinical management. However, to formulate a more thorough, robust, evidence-based decision rule, a multicenter study would be needed. Furthermore, additional studies should be done to test the implementation of such a decision rule.

Some of the abnormal findings identified in our cohort, including prolonged QTc, may precipitate potentially fatal cardiac conditions and require close follow-up. ECG findings did change management in a small percentage of patients, either resulting in cardiology consultation in the emergency room (ER) or as an outpatient and further testing in the ER (echocardiograms, blood work, X-rays).

This study has several limitations. Our cohort is composed of patients who had an ECG done in the ED, which may bias the sample in favor of patients with higher likelihood of abnormal testing. A small percentage of patient data was not interpretable as data elements were missing from the medical record although this represented only 4% of all data. Finally, this is a single institution, and although this is a large, diverse cohort of patients, it may not be representative of other institutions.

CONCLUSION

In this study population, the greatest llikelihood of an abnormal ECG is in children with known cardiac medical history and those with abnormal age-adjusted HR or RR. PED patients with a variety of chief complaints without significant cardiac history and normal age-adjusted HR and RR rarely have abnormal ECGs. In the cohort of patients with a chief complaint of chest pain, normal age-adjusted vital signs in the ED reduce the likelihood of an abnormal ECG. Prospectively developed decision rules in a larger cohort may help further refine these associations.

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Conflicts of interest

There are no conflicts of interest.

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