

Application of pediatric Appropriate Use Criteria for initial outpatient evaluation of asymptomatic patients with abnormal electrocardiograms

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Abstract

Introduction: In the pediatric Appropriate Use Criteria (AUC), abnormal electrocardiogram (ECG) in an asymptomatic patient has been rated as an "Appropriate" indication for transthoracic echocardiogram (TTE). We hypothesized that the yield of abnormal findings on TTE for this indication will be low.

Methods: All asymptomatic patients (≤ 18 years) from January 1, 2015 to December 31, 2017 who underwent initial outpatient evaluation at our center and had a TTE ordered for an abnormal ECG, were included. Clinic records were reviewed to obtain ECG and TTE findings.

Results: Of the 199 study patients, 13 (6.5%) had abnormal findings. Incomplete right bundle branch block (IRBBB) had the highest yield of abnormal TTE findings (7/28), with secundum atrial septal defect being the most common (5/7); (Odds ratio (OR) compared to other ECG findings 9.2, 95% CI (2.8-29.9), $P < .001$). OR further increased to 14.6, 95% CI (3.1-68.0), $P < .001$ when either IRBBB, right axis deviation, or right ventricular hypertrophy were present. Left ventricular hypertrophy on ECG had only one incidental abnormality on TTE, while ST segment changes, left axis deviation, right/left atrial enlargement, premature atrial/ventricular contractions, ectopic atrial rhythm, sinus bradycardia/pause, preexcitation, low-grade atrioventricular block, and junctional rhythm did not yield abnormal TTEs.

Conclusions: The yield of abnormal findings on TTE when performed for the AUC indication for an abnormal ECG in asymptomatic pediatric patients is low except when performed for ECG abnormalities suggestive of right heart disease such as IRBBB, right axis deviation, or right ventricular hypertrophy. Future revisions of the AUC document could consider further stratification of this indication and corresponding appropriateness ratings based on ECG findings rather than combining into one broad category.

KEYWORDS

appropriate, criteria, asymptomatic, electrocardiogram

1 | INTRODUCTION

Transthoracic echocardiography (TTE) has emerged as the primary imaging diagnostic modality in outpatient settings in pediatric cardiology given its easy accessibility and noninvasive nature. Due to excessive use and spending on cardiac imaging relative to other health care costs, there has been heightened awareness to use these resources judiciously.^{1,2} The first pediatric Appropriate Use Criteria (AUC) was published in 2014 to help guide clinicians with the initial outpatient evaluation of patients using TTE.³ This document listed 113 indications that were rated for appropriateness for performing a TTE using a modified Delphi method.^{4,5} An abnormal ECG in an asymptomatic patient (indication # 52) was rated as an "Appropriate" indication for a TTE. An abnormal ECG was defined as follows:

Electrocardiographic findings regarded as probably or definitely abnormal according to age as well as clinical significance, and including but not limited to ventricular hypertrophy, atrial enlargement, complete bundle branch block, atrioventricular block, prolonged QTc, abnormal T waves or ST-T wave segments, Wolff-Parkinson-White syndrome, premature atrial contractions (PACs), premature ventricular contractions (PVCs), supraventricular tachycardia, ventricular tachycardia, and Brugada syndrome.

Based on the current recommendations for the standardization and interpretation of the electrocardiogram,⁶⁻⁹ the document has listed certain abnormal ECG findings in those with symptoms of palpitations (PACs in the prenatal period, PACs after the neonatal period, supraventricular tachycardia, PVCs in the prenatal or neonatal period, PVCs after the neonatal period, ventricular tachycardia, sinus bradycardia, and sinus arrhythmia) for which separate appropriate ratings have been assigned. However, the indication for obtaining a TTE for an abnormal ECG in asymptomatic patients (indication # 52) has not been further stratified by the type of ECG abnormality. A prior large multicenter study has suggested the need for clarification of indication # 52 by the type of ECG abnormality as this was the most common "Appropriate" indication for which a TTE was not performed.¹⁰ Though this indication has been rated as "Appropriate," it is our anecdotal observation that a TTE ordered for this indication is mostly normal as several subtle isolated ECG findings may not truly be a marker of cardiac pathology in an otherwise asymptomatic patient. We hypothesized that the yield of abnormal findings on TTE performed for this indication will be low. The purpose of this study was to determine the yield of abnormal findings on TTEs ordered for this indication during the initial outpatient evaluation and the type of ECG abnormalities associated with these findings.

2 | METHODS

2.1 | Study design and data collection

This single center retrospective study was approved by the institutional review board of the Children's Healthcare of Atlanta. The study included all patients who underwent initial outpatient evaluation at our center and had a TTE ordered by the outpatient cardiologist for AUC indication # 52 over a 3-year period between January 1, 2015 and December 31, 2017. Only patients seen by pediatric cardiologists in our clinics were included because we had access to details of the clinical scenarios, allowing application of the pediatric AUC document. The patients referred to our system from other providers for an abnormal ECG for a TTE alone without a clinic visit were excluded since no further clinical details were available for such patients to determine the presence of any symptoms. The common reasons for obtaining the ECG in an asymptomatic patient included family history of heart disease, prior to initiation of certain medications or sports clearance. Clinic records were reviewed to obtain ECG findings and TTE results. The ECG findings were based on the interpretation of the outpatient cardiologist at the time of the clinic visit. The ECGs were not reinterpreted by the investigators since the AUC is applied at the time of ordering the TTE and the decision to perform the TTE is based on the clinic physician's interpretation of the ECG.

2.2 | Classification of TTE findings

The TTE findings noted included the specific abnormality, its severity and whether it was related to the indication of ordering the TTE. The TTE findings were graded as normal, incidental, or abnormal.¹¹ The incidental TTE findings included patent foramen ovale, peripheral pulmonary stenosis, patent ductus arteriosus, left superior vena cava, retroaortic innominate vein, left arch with aberrant subclavian, common brachiocephalic trunk, and tiny coronary fistula.¹¹ When the TTE findings were compatible with the ECG, it was classified as "related to indication" (eg, IRBBB in those with TTE finding of an atrial septal defect (ASD) and right ventricular enlargement), otherwise it was classified as "unrelated to indication" (eg, IRBBB in a patient with a normally functioning bicuspid aortic valve). The severity of TTE findings (mild, moderate, or severe) were classified based on a previously published AUC implementation study.¹¹

2.3 | Study outcomes

The primary outcome measure was the yield of abnormal findings on TTEs ordered for AUC indication # 52. Secondary outcome measure was the type of ECG abnormality associated with abnormal TTE findings and the severity of the TTE finding.

2.4 | Statistics

Statistical analyses were performed using SAS 9.4 (SAS Institute, N. Cary, North Carolina). Statistical significance was assessed at the .05 level. Descriptive statistics were calculated for all variables of interest and included medians with interquartile range (IQR) for continuous variables and counts with percentages for categorical variables. Patient age was compared between patients with normal vs abnormal TTE using a Wilcoxon rank-sum test. Comparisons made between categorical variables were performed using the chi-square test. Odds ratios (OR) and 95% confidence intervals (CI) were used to compare the proportion of abnormal findings on TTE between different patient subgroups based on the specific ECG abnormality.

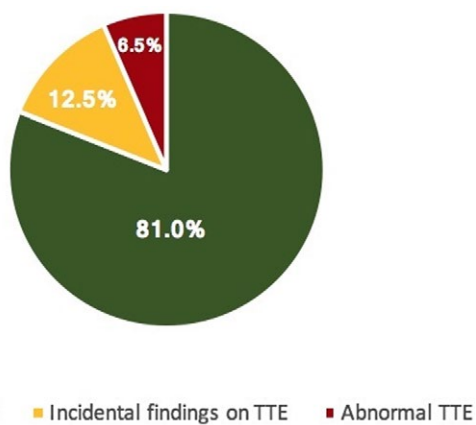


FIGURE 1 Classification of transthoracic echocardiogram findings when ordered for abnormal electrocardiogram in asymptomatic patients (Appropriate Use Criteria indication # 52)

3 | RESULTS

The study population included 199 patients (median age (IQR): 9.9 (3.1-14.8) years). Of these, 186 patients (93.5%) had normal or incidental findings on TTE. One hundred sixty-one patients (81.0%) had normal findings and 25 patients (12.5%) had an incidental finding (patent foramen ovale in 20 and peripheral pulmonary artery stenosis in 5 patients) (Figure 1). Thirteen patients (6.5%) had abnormal findings on TTE, of which 9 were related to the indication for ordering the TTE (Table 1). Three patients had a moderate secundum ASD and underwent surgical or transcatheter closure. Patients with normal or incidental findings on TTE were older than patients with an abnormal TTE (10.5 years vs 2.1 years, $P = .004$).

Incomplete right bundle branch block (IRBBB) had the highest yield of abnormal TTE findings (7/28, 25.0%) with a secundum ASD being the most common abnormal finding (5/7, 71.4%). The odds of an abnormal finding with IRBBB on ECG were significantly higher compared to other findings (OR = 9.2, 95% CI (2.8-29.9), $P < .001$). When ECGs with findings of either IRBBB, right axis deviation, or right ventricular hypertrophy were combined, the odds of TTE abnormalities were further increased (OR = 14.6, 95% CI (3.1-68.0), $P < .001$). Left ventricular hypertrophy (LVH) without any other ECG abnormality was the most common abnormality for which a TTE was performed but only had one incidental abnormality (tiny inaudible patent ductus arteriosus). Findings of left axis deviation, nonspecific ST segment changes, biventricular hypertrophy, right atrial enlargement, PVCs, preexcitation, and low-grade atrioventricular block did not yield any abnormal findings on TTEs. Two patients had a right bundle branch block on their ECG with QRS duration of 130 and 147 ms. The TTE was normal for both these patients. Abnormal ECGs labeled as "other" (PACs, ectopic atrial rhythm, left atrial enlargement, sinus pause, sinus bradycardia, and junctional rhythm) did not yield any abnormal TTEs either (Table 2).

TABLE 1 Electrocardiogram abnormalities and their associated transthoracic echocardiogram findings when ordered for Appropriate Use Criteria indication # 52

Specific ECG abnormality	Number (%)	Number of TTE abnormalities	Specific TTE abnormality	TTE abnormality related to indication
IRBBB	28 (14.1)	7	Small secundum ASD (3)	Yes
			Moderate secundum ASD (2)	Yes
			Bicuspid aortic valve without stenosis (2)	No
Right ventricular hypertrophy	20 (10.1)	2	Small secundum ASD	Yes
			Tiny muscular ventricular septal defect	No
Right axis deviation	14 (7.0)	2	Small secundum ASD	Yes
			Moderate secundum ASD	Yes
Left ventricular hypertrophy	44 (22.1)	1	Tiny inaudible patent ductus arteriosus	No
Ectopic atrial rhythm	6 (3.1)	1	Small secundum ASD	Yes

Abbreviations: ASD, atrial septal defect; IRBBB, incomplete right bundle branch block.

TABLE 2 The electrocardiogram abnormalities not associated with transthoracic echocardiogram abnormalities when ordered for Appropriate Use Criteria indication # 52

Specific ECG abnormality	Number (%)
Other	15 (7.5)
Left axis deviation	14 (7.0)
Nonspecific ST segment changes	11 (5.5)
Biventricular hypertrophy	11 (5.5)
Right atrial enlargement	11 (5.5)
Premature ventricular contraction	9 (4.5)
Preexcitation	8 (4.0)
First-degree atrioventricular block	6 (3.1)
Right bundle branch block	2 (1.0)

4 | DISCUSSION

This single-center study focusing on the applicability of the pediatric AUC for the initial evaluation of an asymptomatic patient with an abnormal ECG shows that in the majority of patients, TTEs ordered for this indication were normal. None of our patients had findings on TTE that would warrant urgent hospitalization or intervention. Only a small proportion of patients (3 patients, 1.5%) had an abnormality on TTE that required intervention later. There were certain other abnormalities noted on TTE such as bicuspid aortic valve, tiny ventricular septal defect, and an inaudible patent ductus arteriosus that were clearly unrelated to the ECG abnormality for which the TTE was obtained. While the finding of a bicuspid aortic valve merits lifelong cardiology follow-up, this finding was purely incidental in our patients as the TTE was performed for IRBBB on ECG. Bicuspid aortic valve has an estimated prevalence of 0.5%-2% in the general population, and it is not uncommon to discover it incidentally on TTE ordered for other reasons.¹² Common abnormalities on ECG such as LVH, biventricular hypertrophy, left/right atrial enlargement, and nonspecific ST segment changes did not yield abnormalities on TTE that altered patient management.

A large multicenter study looking at TTE utilization before the release of the AUC document demonstrated abnormalities in 9% of TTEs when ordered for an abnormal ECG in an asymptomatic patient and only one finding of moderate severity (non-compaction cardiomyopathy).¹⁰ The authors had suggested that the AUC document may require further clarification regarding the specific definition of an abnormal ECG finding, especially in asymptomatic patients. In addition, in this study the most common "Appropriate" AUC indication for which a TTE was not ordered was an abnormal ECG in an asymptomatic patient (indication # 52).¹⁰ This was speculated to be secondary to physician experience with the knowledge that the likelihood of an abnormal TTE is low with certain subtle ECG abnormalities in this group of patients. However, the study did not list the specific ECG findings for which a TTE was not ordered. These results demonstrated the importance of determining

specific ECG findings associated with an increased likelihood of TTE abnormalities in asymptomatic patients and subsequent education of outpatient cardiologists. It also suggested the possible need for revisiting the original recommendations for the standardization, interpretation and classification of an ECG finding as abnormal based on TTE findings.

The ECG abnormality with the highest yield of abnormal TTE in our study was IRBBB. This finding on ECG suggests right-sided volume overload, most commonly associated with the presence of an ASD.¹³ The odds of an abnormal TTE in an asymptomatic patient with IRBBB were approximately 10 times higher than in someone without IRBBB. It is important to note that interpretation of IRBBB by cardiologists may vary. Presence of right ventricular conduction delay is a benign variant, that may be misinterpreted as IRBBB given the slight widening of QRS interval. The majority of TTE abnormalities were detected when ECGs with findings of IRBBB, right axis deviation, or right ventricular hypertrophy were combined as compared to the other ECG findings. The wide confidence interval in this analysis was secondary to majority of the TTE abnormalities being detected in patients with IRBBB, right axis deviation, or right ventricular hypertrophy (11/13) as compared to patients who did not have these ECG findings. LVH is a common reason for ordering TTEs in the pediatric population to rule out lesions such as hypertrophic cardiomyopathy among others.¹⁴ In our cohort of patients, the finding of LVH on ECG in asymptomatic patients was the most common reason for which a TTE was performed but only 1 patient had an incidental abnormality (tiny inaudible patent ductus arteriosus). It has been suggested that LVH on ECG is more common in the African American population as compared to Caucasians.¹⁵ One limitation of our study was that we did not study the race/ethnicity of our cohort which may have explained the common ECG finding of LVH. While the ECG findings of left axis deviation, right bundle branch block, biventricular hypertrophy, PVCs, and preexcitation did not yield any abnormal findings on TTEs in our study, these findings are known to be associated with underlying pathology in some cases and warrant further investigation with TTE. However, nonspecific ST-T wave changes, rare PACs, isolated right or left atrial enlargement, sinus bradycardia and junctional rhythm (especially in an athlete) are seldom associated with any cardiac pathology and may not warrant a TTE in an asymptomatic patient. The AUC indication # 52 for obtaining a TTE is currently not stratified based on the type of ECG abnormality. Knowing that the yield of abnormal findings on TTE is negligible for many of the isolated ECG findings, we propose that future revisions of the AUC document should consider further stratification of this indication so that they could be rated differently for appropriateness. This study lays the framework for designing such stratification to improve the appropriateness of the outpatient TTEs ordered for the evaluation of an abnormal ECG in an asymptomatic patient.

While there is physician variability in interpreting an ECG as abnormal, especially those with subtle abnormalities, we did not reinterpret the ECG diagnosis of outpatient cardiologists. This was because classification of an ECG as abnormal and ordering a

subsequent TTE for this indication (indication # 52) is at the discretion of the outpatient cardiologist and based on their interpretation of the ECG. Reinterpreting the ECGs retrospectively may affect the validity of the results and would not align with the primary objective of this study. Physician variability with respect to interpretation of ECGs and the original recommendations for labeling an ECG as abnormal for certain subtle abnormalities may need to be evaluated in a future study.

5 | CONCLUSIONS

The yield of abnormal findings on TTE when performed for an abnormal ECG in an asymptomatic patient is low, except for those suggestive of right heart disease including IRBBB, right axis deviation, and right ventricular hypertrophy. IRBBB had the highest yield of abnormal findings, with a secundum ASD being the most common. Identifying specific ECG findings associated with an increased likelihood of TTE abnormalities in asymptomatic patients may improve the yield of abnormal TTEs. Future revisions of the AUC document could consider further stratification of the AUC indication for abnormal ECG in an asymptomatic patient by the type of ECG abnormality. This would allow assignment of a different appropriateness score for the common ECG abnormalities, rather than combining them together into one broad category that is currently rated "Appropriate."

CONFLICT OF INTEREST

The authors declare that they have no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Soham Dasgupta, Shae Anderson, and Ritu Sachdeva contributed equally to the genesis of the research design, analysis, and interpretation of data, initial drafting of the manuscript, and review and approval of the submitted and final version.

Michael Kelleman contributed to the genesis of the research design, analysis, and interpretation of data and review and approval of the submitted and final version.

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