


Yield of Echocardiogram and Predictors of Positive Yield in Pediatric Patients: A Study in an Urban, Community-Based Outpatient Pediatric Cardiology Clinic

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Ramya Deepthi Billa, MBBS, FAAP¹, Susan Szpunar, PhD²,
Lida Zeinali, MD³, and Premchand Anne, MD, FACC²

Abstract

The yield of outpatient echocardiograms varies based on the indication for the echocardiogram and the age of the patient. The purpose of this study was to determine the cumulative yield of outpatient echocardiograms by age group and reason for the test. A secondary aim was to determine the predictors of a positive echocardiogram in an outpatient cardiology clinic at a large community teaching hospital. We retrospectively reviewed the charts of 891 patients who had a first-time echocardiogram between 2011 and 2015. Positive yield was defined as echocardiographic findings that explained the reason for the echocardiogram. The overall positive yield was 8.2%. Children between birth and 3 months of age had the highest yield (34.2%), and children between 12 and 18 years of age had the lowest yield (1%). Patients with murmurs (18.1%) had the highest yield compared with patients with other signs or symptoms. By age group and reason, the highest yields were as follows: 0 to 3 months of age, murmur (39.2%); 4 to 11 months of age, >1 symptom (50%); and 1 to 5 years of age, shortness of breath (66.7%). Based on our study, the overall yield of echocardiograms in the outpatient pediatric setting is low. Age and symptoms should be considered before ordering an echocardiogram.

Keywords

pediatric outpatient echocardiogram, diagnostic yield

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Introduction

The original description of M-mode echocardiography by Inge Edler and Hellmuth Hertz in 1953 marked the beginning of a new diagnostic noninvasive technique.^{1,2} An echocardiogram (echo) provides extensive anatomic and hemodynamic information noninvasively.³ Advances in echocardiography, including the introduction of Doppler and color flow mapping, have provided prompt, detailed, and noninvasive assessment of cardiac disorders.⁴

The most common reasons for ordering an echo in an outpatient pediatric cardiology clinic are heart murmurs, chest pain/tightness, shortness of breath, palpitations, syncope, and family history of cardiac abnormalities/rhythm abnormalities.⁵⁻⁷ In the Pediatric Cardiology Clinic at St. John Providence Children's Hospital, Detroit, Michigan, echocardiograms are requested as "test-only" from pediatricians and family practitioners

or at the request of a cardiologist after a cardiology consultation for evaluation of the above symptoms.

Previous studies investigated the yield of echocardiography for individual signs and symptoms.⁸⁻¹² Many of them studied the utility of echo in heart murmurs in different age groups. Kwiatkowski et al⁸ studied the utility of echo in patients (1 month to 4 years of age) with asymptomatic heart murmurs in an outpatient clinic. Moderate pathology was seen among 8% of patients and

¹Children's Hospital of Michigan, Detroit, MI, USA

²St. John Hospital and Medical Center, Detroit, MI, USA

³UBMD Women & Children's Hospital of Buffalo, Buffalo, NY, USA

Corresponding Author:

Premchand Anne, Division of Pediatric Cardiology, Department of Pediatrics, St. John Hospital and Medical Center, 22201 Moross, PB II, Suite 275, Detroit, MI 48236, USA.

Email: premchand.anne@ascension.org



severe pathology was seen in 1%. The yield of studies decreased as the age increased, with an overall yield of 34.1% on echo. The incidence of abnormal pathology was higher among tests ordered by cardiologists, across all severity levels.⁸ Geva et al⁹ evaluated the utility of echo in patients (1 month to 16 years of age) with heart murmurs. The echo confirmed the clinical diagnosis of innocent murmurs in 96% of the patients and the clinical diagnosis of definite heart disease in 95% of the patients. It was concluded that physical examination by expert pediatric cardiologists can be relied on for diagnosis. Danford et al¹⁰ evaluated the incidence and nature of heart disease in children (<21 years) with innocent murmurs of uncertain cause. In this study, the patients of younger age (<6 weeks) had a higher incidence of heart disease (6/22; 27%), and the patients of older age (>6 weeks) had lower incidence of heart disease (10/165; 6%). Moreover, the patients with positive clinical/laboratory findings were more likely to have heart disease in both age groups.¹⁰

Ritter et al¹¹ evaluated the yield of echocardiography in pediatric patients (1.5-18 years of age) with syncope in an outpatient setting; the yield of echo was 1.3%. The sensitivity of echo was very low (18%) compared with history, physical examination, and electrocardiography (96%) in detecting cardiac causes of syncope. Wiesen et al¹² evaluated echocardiographic yield in pediatric patients (mean age = 13.3 ± 4.4 years) with mild to moderate hypertension. In this study, yield of echo was 17% in detecting cardiac abnormalities including left ventricular hypertrophy (LVH; 11%) and other significant cardiac abnormalities (6%).¹² Venugopalan et al¹³ in Oman studied patients aged 1 day to 12.9 years with various signs and symptoms in an outpatient setting; the yield of echo was 41.4%. Higher yield was obtained when reasons for referral were other than heart murmurs (>60%). When the reason for referral was murmurs, the yield of echo was 34.4%.

There is a lack of knowledge pertaining to the yield of echo performed for each indication and cumulatively for all signs and symptoms. All previous studies that were done in the United States investigated the yield of echo in individual symptom groups. Limited data exist on the predictors/determinants of a positive echo in the evaluation of symptoms. We examined the cumulative yield of outpatient echocardiograms by age and individual signs and symptoms in an urban, community setting. We also determined the predictors of a positive echocardiogram for various symptoms.

Methods

This was a retrospective chart review of all echocardiograms performed at St. John Providence Children's

Hospital pediatric cardiology office from January 2011 to December 2015. Inclusion criteria were as follows: patients from age birth to 18 years, who had their first echo in our cardiology office, and who had no previous diagnosis of cardiac disease. Exclusion criteria were as follows: patients with a prior echo, a previous diagnosis of congenital or acquired heart disease, a prenatal diagnosis of heart disease, dysmorphic features and congenital noncardiac defects, diseases/syndromes that can affect the cardiovascular system, or those receiving or having received chemotherapy. This study was approved by the St. John Hospital and Medical Center Institutional Review Board.

Demographic and clinical data were collected: age, gender, body mass index (BMI), BMI%, body surface area, reason(s) for echo, number of reasons, and ordering physician type. Reasons for echo were the following: murmur, chest pain, syncope/near syncope, palpitations/arrhythmia, short of breath/respiratory distress, hypertension, family history of heart disease, cyanosis, >1 symptom, and other reasons (failure to thrive, feeding difficulty, fatigue, and diaphoresis with feeds). "Yield" was defined for this study as "the finding that explains the symptom(s) and not a normal variant for the age, as judged by the clinician."^{8,11}

Descriptive statistics were calculated using the mean with standard deviation and frequency distributions. Univariate analysis was done using the χ^2 test and Student's *t* test. Multivariable analysis was done using logistic regression. All data were analyzed using SPSS v. 24.0, and a *p*-value of .05 or less was considered to indicate statistical significance.

Results

We reviewed 1052 patient charts; 891 were included in the analysis (Figure 1). The major reason for the exclusion (123/161) was previous diagnosis of cardiac disease. Demographic characteristics of the patients are noted in Table 1. The mean age was 109 ± 78.3 months (age range = 2 days to 216 months). Females and males were in equal proportion. Nearly half of the patients were in the age group of 12 to 18 years (*n* = 405, 45.5%). The fewest subjects were in the 4 to 11 months age group (*n* = 58, 6.5%).

The overall positive yield of echo was 8.2%. The overall yield in females (10.5%) was greater than the yield in males (6.3%; *p* = .022). The most common findings on echo were ventricular septal defect (*n* = 34, 46%), atrial septal defect (*n* = 14, 19%), and pulmonary stenosis (*n* = 11, 15%). Positive yield findings are shown in Table 2. The yields of echocardiograms by age group is: 0 to 3 months, 34.2%; 4 to 11 months, 17.2%; 1 to 5 years, 5.7%; 6 to 11 years, 1.3%; 12 to 18 years, 1% (χ^2 test for trend, *p* < .0001; Figure 2).

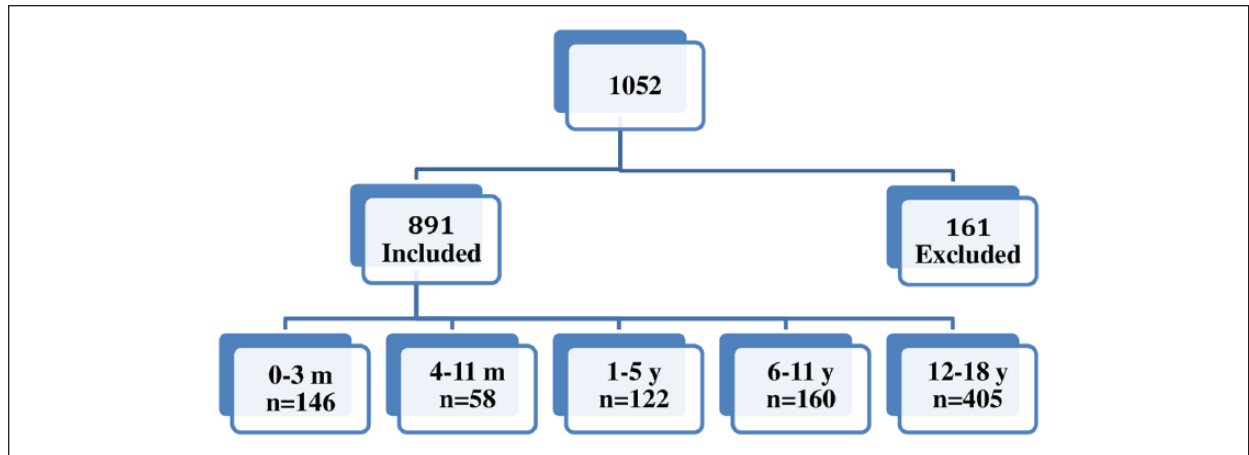


Figure 1. A total of 1052 patient charts were collected. Age groups were divided based on the Centers for Disease Control and Prevention charts and previous studies.

Table 1. Demographic Characteristics of the Patients.

Mean age	109 ± 78.3 months
Age, n (%)	
0-3 months	146 (16.4%)
4-11 months	58 (6.5%)
1-5 years	122 (13.7%)
6-11 years	160 (18%)
12-18 years	405 (45.5%)
Sex, n (%)	
Male	480 (53.9%)
Female	411 (46.1%)
Mean BMI	20.8 ± 5.7
Mean BMI%	62% ± 29.6%
Mean BSA	1.14 ± 0.64
Mean number of reasons	1.43 ± 0.69
Physician type ordering echocardiogram	n (%)
Noncardiologist	299 (33.6%)
Cardiologist	592 (66.4%)

Abbreviations: BMI, body mass index; BSA, body surface area.

The yield of echo in patients with each symptom was compared with the yield in patients without that specific symptom (having other symptoms). Among all the symptoms, patients presenting with a murmur had the highest yield (18.1%) compared with patients presenting with other signs or symptoms ($p < .001$; Table 3). The predictors of a positive yield differed by age group (Table 4). In the 0 to 3 months age group, murmur had the highest positive yield (39.2%, $p = 0.002$); in 4 to 11 months, >1 symptom (50%, $p = .008$); and in 1 to 5 years, shortness of breath (66.7%, $p < .0001$) had significant positive yields.

In the 6 to 11 years and 12 to 18 years age groups, children with positive yield had a higher mean BMI percentile than those with negative yield ($83.5 \pm 0.7\%$ vs

Table 2. Positive Yield Findings in Individual Symptom Groups.

Symptoms/Reasons for Echocardiogram	Findings
Murmurs	VSD, ASD, PS, PDA, bicuspid aortic valve with AS, and multiple defects
Hypertension	LVH
SOB/respiratory distress	ASD and PDA (both with chamber dilatation)
Abnormal ECG	LVH
Family history of heart disease	ASD, PS, VSD, PDA, and bicuspid aortic valve
Palpitations	ASD with chamber dilatation

Abbreviations: VSD, ventricular septal defect; ASD, atrial septal defect; PS, pulmonary valve stenosis; PDA, patent ductus arteriosus; AS, aortic stenosis; LVH, left ventricular hypertrophy; SOB, shortness of breath; ECG, electrocardiogram.

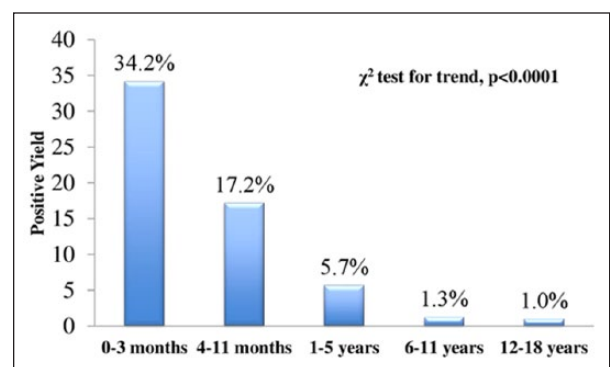


Figure 2. Yield of echocardiogram by age groups.

$60.4 \pm 30.9\%$, $p < .0001$, and $91.8 \pm 6.4\%$ vs $65.8 \pm 27.2\%$, $p = .001$, respectively). The patients in the 6 to

Table 3. Yield of Echocardiogram by Symptoms.

Symptom	Yield	<i>p</i>
Murmurs	18.1% (69/381)	<.0001
Syncope	1.5% (2/134)	.002
Palpitations/arrhythmias	0.7% (1/134)	.001
>1 Symptom	6.2% (18/292)	.123
Family history of heart disease	6.9% (8/116)	.585
Abnormal ECG	5.4% (6/111)	.252
Others	8.2% (8/98)	.991
SOB/respiratory distress	3.4% (2/59)	.164
Hypertension	3.8% (1/26)	.412
Chest pain	0% (0/193)	—
Cyanosis	0% (0/8)	—

Abbreviations: ECG, electrocardiography; SOB, shortness of breath.

Table 4. Predictive Factors for Positive Yield in Different Age Groups.

Symptom by Age Group	Yield	<i>p</i>
0-3 months		
Heart murmurs	39.2% (49/125)	.002
4-11 months		
>1 Symptom	50% (4/8)	.008
1-5 years		
Respiratory distress/SOB	66.7% (2/3)	<.0001

Abbreviation: SOB, shortness of breath.

11 years age group had left ventricular outflow tract (LVOT) obstruction with LVH, patent ductus arteriosus (PDA). In the 12 to 18 years age group, patients had LVH, LVOT obstruction, and PDA with moderate left atrial/left ventricular dilatation. Multivariable logistic regression was done for the age groups where there was more than one factor associated with yield. In the birth to 3 months group, 2 variables that remained associated on logistic regression were murmur (odds ratio [OR] = 13.5, 95% confidence interval [CI] = 1.7-106.1, $p = .01$) and age at examination (OR = 0.53, 95% CI = 0.37-0.77, $p = .001$). Finally, echocardiograms ordered by a cardiologist were more likely to have a positive yield than those ordered by a primary care physician, although this did not reach statistical significance (9.3% vs 6.0%, respectively, $p = .09$).

Discussion

To our knowledge, this is the first study evaluating the cumulative yield of echocardiograms in patients from birth to 18 years of age and presenting with a variety of reasons to an outpatient pediatric clinic in an urban, community setting. The overall yield of echo was low in the outpatient cardiology setting. The results for

murmurs and syncope in our study are consistent with the previous studies evaluating individual signs and symptoms.^{8,11}

The yield of echo in a study by Ritter et al¹¹ at University of Utah was 1.3% in patients with syncope, which was similar to yield of 1.5% in our study. In this study, 4 patients had cardiac abnormalities that caused syncope (2 with cardiomyopathy and 2 with valve abnormalities and long QT). Overall, the sensitivity of echocardiography for detecting a cardiac cause of syncope was 18%. Exercise-induced syncope, positive family history, abnormal physical examination, and abnormal electrocardiogram all had a sensitivity of 96% (21/22) in detecting cardiac causes of syncope, when used in combination. In our study, the echocardiograms with positive yield in syncope showed LVOT obstruction and aortic stenosis with bicuspid aortic valve. Our study was a retrospective chart review; we did not evaluate the sensitivity of clinical findings or electrocardiogram to diagnose heart diseases.

A study by Wiesen et al¹² at Children's Hospital of North Shore-LIJ Health System showed that yield of echo in patients with hypertension was 17%. This study included patients from birth to 21 years of age, which was slightly different from our study age group of birth to 18 years; yield of echo in patients with hypertension in our study was 3.8%. The findings on echo in Wiesen et al's study were LVH (11%) and other significant abnormalities (6%), including 4 cases of aortic coarctation, 2 with a dilated aortic root, and 1 case of Takayasu arteritis, dilated left ventricle, hyperdynamic left ventricle, and hypertrophic cardiomyopathy, in contrast to only LVH in our study.

Our findings of a higher yield in patients with murmurs were consistent with that shown in previous studies that were conducted in patients with heart murmurs.^{8,10} Murmur had the highest yield (18%) in our study. This was different from the study by Venugopalan et al,¹³ which showed a higher yield if the reason for echo was not a heart murmur (>60%), and the yield of echo for murmur was 34.4%. There was higher frequency of abnormalities detected in patients with cardiac symptoms with an overall yield of 41.4% yield on echocardiogram; however, the study included patients with acquired heart diseases such as rheumatic heart disease and infective endocarditis. These conditions were the common heart diseases in children in developing countries at the time of the study.

Predictors of positive yield differed by age groups. More than one symptom in the 4 to 11 months age group and shortness of breath or respiratory distress in the 1 to 5 years age group had significantly high yields; these 2 predictors were not addressed in the previous studies. We had patients with higher BMIs in age groups 6 to 11

years and 12 to 18 years, who had positive yield on echo. The positive yield findings of LVH and LVOT obstruction in these patients might directly be associated to higher BMI percentile.¹⁴

Finally, previous studies showed that physical examination by pediatric cardiologists was reliable, and echo confirmed their clinical diagnosis in majority of the patients.⁹ In this community setting, one third of echocardiograms were ordered by noncardiologists (pediatricians and family practitioners). The echo may have been ordered to “rule out” pathology rather than to evaluate for pathology, which might have resulted in nonsignificant difference in the yield between cardiologists and noncardiologists who ordered echocardiograms. In October 2014, the American College of Cardiology, the Society of Pediatric Echocardiography, and the American Society of Echocardiography participated in publishing appropriate use criteria (AUC) for rational use of first-time echocardiography in children for different indications in an out-patient setting.¹⁵ Using AUC may help improve the yield in the older age groups and also help improve the yield of outpatient echocardiograms ordered by pediatric cardiologists.

Primary strengths of this study include a large sample size at a single facility. The study is limited by its retrospective nature. In addition, the symptom subgroups had smaller sample sizes for each individual symptom and age group compared with other studies, which might have contributed to different results on the yield from other studies.

Conclusion

The overall yield of echocardiography was low. Age and symptoms should be considered before ordering an echo. Other methods of evaluation should be considered while evaluating the older pediatric population. The findings in our study should be available and useful to general pediatricians and family practitioners, who often refer patients for an echo after the initial visit. The primary care physician’s “echo only” orders contribute to a significant portion of echocardiograms done in the cardiology office.

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Author Contributions

RDB: Contributed to conception and design; contributed to analysis; drafted the manuscript; critically revised the

manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

LZ: Contributed to analysis; drafted the manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

SMS: Contributed to conception and design; contributed to analysis; drafted the manuscript; critically revised the manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

PA: Contributed to conception and design; contributed to analysis; drafted the manuscript; critically revised the manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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