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ORIGINAL ARTICLE

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Systolic ejection click versus split first heart sound: Are our ears deceiving us?

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Abstract

Objective: Bicuspid aortic valve (BAV) disease is associated with potential lifetime complications, but auscultation of a BAV click is commonly missed or mistaken for a benign split first heart sound. Our objective was to determine whether pediatric cardiologists could reliably distinguish between BAV clicks and benign split first heart sounds.

Design: Quality evaluation project using de-identified recordings from an outpatient pediatric cardiology clinic.

Outcome Measures: Twenty-one cardiologists listened to five de-identified recordings of pediatric heart sounds (three with BAV clicks, two with mitral components of benign split first heart sounds) and indicated whether they believed each recording was a BAV or split first heart sound. The accuracy of diagnoses was determined using percent agreement and calculated kappa coefficients for the cohort and subgroups based on those with less than 10 years of experience versus those with ≥10 years. To assess precision, a kappa extension was used for multiple raters to assess interrater agreement.

Results: Among participants, diagnostic accuracy of BAV click was 38%, while accuracy of split first heart sound was 41%. No participant correctly diagnosed all sounds. No difference in agreement was observed when stratifying by experience. Kappa was −0.11 (CI 95% −0.31 to 0.08) for all raters, −0.03 (CI 95% −0.39 to 0.33) for those with less than 10 years' experience, and −0.15 (CI 95% −0.38 to 0.08) for those with ≥10 years' experience. The kappa statistic among the 21 raters was 0.01 (95% CI −0.03 to 0.04), indicating poor precision among the raters.

Conclusions: In this sample of pediatric cardiologists, the diagnostic accuracy of BAV clicks versus split first heart sounds was worse than chance. There was no association between years of experience and diagnostic accuracy. While further study is needed, these data suggest that an echocardiogram may be valuable when either a systolic ejection click or split first heart sound is heard.

KEYWORDS

auscultation, bicuspid aortic valve, echocardiography, quality improvement

1 | INTRODUCTION

Biscuspid aortic valve (BAV) disease in children is an often subtle pathology associated with potential lifetime complications. The heterogeneous presentation of BAV makes clinical diagnosis difficult, since at first presentation the patient may be asymptomatic.[1] Of the 1–2% of the population in the United States born with BAV,[2] over a third will develop serious complications including aortic valvular stenosis, aortic regurgitation, bacterial endocarditis, aortic aneurysm, and aortic dissection.[3–5] Some of those complications may occur during

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TABLE 1 Overall diagnostic accuracy and Cohen's kappa for detecting bicuspid aortic valve and split S1

	Diagnostic accuracy % (CI)			Kappa (CI)
	All	BAV	S1	
<10 years (n = 6)	43 (16-71)	44 (36-53)	42 (27-56)	−0.11 (−0.31 to 0.08)
≥10 years (n = 15)	37 (27-47)	36 (21-50)	40 (24-56)	−0.03 (−0.39 to 0.33)
Overall (n = 21)	39 (29-49)	38 (28-48)	41 (26-55)	−0.15 (−0.38 to 0.08)

adolescence,[6] but many of them may not occur until adulthood.[7] Prophylactic surgery may prevent these complications, yet many BAV go undiscovered due to failure to diagnose.[8,9]

The gold standard for diagnosis is echocardiography, but astute auscultation may detect the click from the delayed opening of the stiff BAV shortly following the closure sound of the mitral and tricuspid valves. When BAV disease disrupts valve function, there may be an accompanying systolic ejection murmur, but this is only found if the patient also has aortic valve stenosis. The click of the BAV alone often goes unheard or may be mistaken for the asynchronous closure of the mitral and tricuspid valves.[10] This asynchronous closure causes a split first heart sound (S1),[11] and can be physiologic in children.

The purpose of the study was to examine a sample of pediatric cardiologists and test if they could differentiate between BAV click and split S1. We hypothesized that the physicians with more years of experience would outperform physicians with fewer, but that the overall cohort would be able to distinguish the lesion with greater than 50% accuracy.

2 | METHODS

We performed a quality evaluation project to determine the accuracy of BAV auscultation among cardiology fellows and faculty at Children's Healthcare of Atlanta and Emory University in 2012. A Littman recording stethoscope was used to record heart sounds of pediatric patients with image confirmed bicuspid aortic valves. For control, we recorded the heart sounds of pediatric patients with a split first heart sound whose echocardiogram showed a structurally normal heart without any abnormalities of the mitral or aortic valves. All recordings were performed at the location where the sound was best heard, either the lower left sternal border or the apex. From these patients, we recorded a total of five sound files: three clicks from bicuspid aortic valves, and two split first heart sounds. All recordings were de-identified. Each physician listened to the five sound files and was asked by the interviewer if the sound was a bicuspid aortic valve click or asynchronous closure of the mitral and tricuspid valves. Participants were allowed to decline to guess if they were uncertain. No participants or answers were excluded.

We determined the overall accuracy of diagnosis of pathological clicks versus physiological heart sounds for the overall cohort and subgroups based on those with less than 10 years of experience against those with 10 or more years of experience. Each subgroup was roughly equal in size. A Wilcoxon rank-sum test was used to compare the individual physician accuracy percentages in each of the two experience groups. To examine overall agreement between the physicians and the gold-standard echo, we calculated Cohen's kappa coefficient for both the overall physician cohort and subgroups stratified by experience. In this case, each physician's diagnoses of the five sounds were treated as independent observations, resulting in a total of 94 physician-echo scoring pairs. Cohen's kappa is a statistic measures agreement between two raters and is based on the difference between the observed agreement and the expected agreement based on chance alone. In this case, the physician was considered a single rater and the gold-standard echo was considered the other rater. A kappa coefficient less than 0 indicates worse than chance agreement, a kappa of 0.2 indicates slight agreement, while a kappa of 0.8 indicates substantial agreement. To assess precision in ratings among physicians across the five sounds, we used an extension to kappa to allow for the calculation of the agreement statistic when there are more than two raters.[12] The generalized kappa for more than two raters was calculated using the *MAGREE* macro in SAS.[13] Statistical analyses were performed using SAS 9.4 (Cary, NC).

3 | RESULTS

The study population consisted of 21 pediatric cardiologists, divided into subgroups by years of experience. Among the entire cohort, diagnostic accuracy of the BAV click was 38% (95% CI 28-48), and accuracy of identifying the split S1 was 41% (95% CI 26-55). Both subgroups performed poorly, with diagnostic accuracies between 37 and 44% for all sounds (Table 1). The average years of experience for those with <>= 10 years was 3 years, and the average for those with 10 was 28 years.

No participants correctly identified all sounds (Figure 1). Only 2 of 21 physicians accurately diagnosed 4 of the 5 sounds. Kappa, or percent agreement by chance, was −0.11 (CI 95% −0.31 to 0.08), with no difference observed when stratifying by experience. Participants with

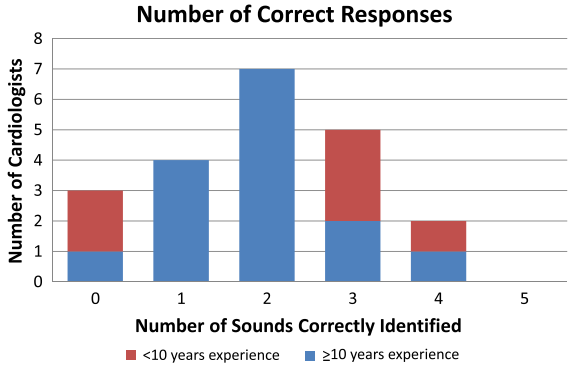

FIGURE 1 Correct responses by the participants

less than 10 years of experience had kappa of −0.03 (CI 95% −0.39 to 0.33), and those with ≥10 years had kappa of −0.15 (CI 95% −0.38 to 0.08). There were no patterns observed among the raters, and no sound file had a consistently higher rate of accuracy. In addition to poor accuracy, the overall agreement among physicians, regardless of the gold standard, showed poor precision. The generalized kappa comparing the 21 raters was 0.01 (95% CI −0.03 to 0.04).

4 | DISCUSSION

In this study, we found that our sample of pediatric cardiologists was unable to reliably distinguish the physiologic sounds of the mitral and tricuspid valves closing from the ejection click of a bicuspid aortic valve. They performed worse than random guessing, with accuracy consistently below 50% for all subgroups for both heart sounds.

Our study has important ramifications for clinical practice. In the most recent guidelines from the American College of Cardiology/American Heart Association regarding appropriate use of echocardiography, there was no mention of the appropriateness of echocardiography utilization for a click or split S1.[14] However, in a 2015 pediatric multicenter trial on appropriate use of echocardiography, 5% of all transthoracic ultrasounds ordered were for auscultation of a click, and 2 of the 25 were discovered to have a bicuspid aortic valve.[15] It is likely that the patient population with clicks is underreported due to the inability of physicians to detect this physical exam finding, as demonstrated in our study. Given the results of this study in which physicians poorly differentiate between a BAV click or a benign split S1, it would be reasonable for physicians to order an echocardiogram when they hear what they perceive to be either of these findings.

It was surprising in our study that cardiologists with more experience did not perform better than those with less experience. This finding is in contrast to a study by Vukanovic-Criley et al. which showed that expertise with cardiac examination skills improved with time since completion of training.[16] However, that study included heart sounds from adults, and results specifically for a BAV click versus split S1 were not reported. While the detection of murmurs, rubs, or other sounds may indeed improve with experience, it may be the case that the human ear simply cannot discern between a BAV click and a split S1. Further investigation of the causes of such differences may be warranted.

Nevertheless, the overall poor performance warrants efforts to improve clinician performance. Electronic stethoscopes, such as the one used to record sounds for this study, have been marketed as improving performance, but physician use of these devices has not been shown to meet those claims.[17] However, a recent study by Lai et al. suggests that computer-aided interpretation of the phonocardiograms recorded by such electronic stethoscopes may indeed improve performance, with a sensitivity of 87% and specificity of 100% compared with echocardiogram for the evaluation of murmurs in children.[18] Although this study did not evaluate the performance of distinguishing a BAV click versus benign split S1, its findings hold the promise of potentially needing fewer echocardiograms in such instances.

This study does have some limitations, most notably that this was a simulation exercise and does not reflect real world experience. First, physicians had to rely solely on auscultation and did not have the benefit of having further history, physical exam, or electrocardiographic findings. Such information can be useful in determining the presence of disease. Second, the prevalence of BAV in our study was 60%, which is much higher than that of the general population. In real world experience, the vast majority of abnormal S1 sounds will be benign as evidenced in a recent study,[15] but the consequences of missing a BAV can be severe.

With a current absence of a system in place to evaluate a physician's auscultation abilities, particularly for subtle findings, it is likely that auscultation skills vary widely between physicians. Our study suggests that, in general, depending on even a specialist's auscultation may be unreliable for identifying bicuspid aortic valve disease. Given the importance of this disease and the results of this study, the authors encourage physicians to strongly consider an echocardiogram for an abnormal S1.

CONFLICT OF INTEREST

None.

FINANCIAL DISCLOSURES

There are no financial relationships to disclose.

AUTHOR CONTRIBUTIONS

Concept/design: McConnell
Data analysis and Interpretation: Hoeting, McCracken
Drafting article: Hoeting
Critical revision of article: Hoeting, Oster, McConnell, Sallee, Iannucci
Statistics: Hoeting, McCracken
Approval of article: Oster, McConnell, McCracken, Sallee, Iannucci

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