Handheld Echocardiography Versus Auscultation for Detection of Rheumatic Heart Disease

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abstract

BACKGROUND: Rheumatic heart disease (RHD) remains a major public health concern in developing countries, and routine screening has the potential to improve outcomes. Standard portable echocardiography (STAND) is far more sensitive than auscultation for the detection of RHD but remains cost-prohibitive in resource-limited settings. Handheld echocardiography (HAND) is a lower-cost alternative. The purpose of this study was to assess the incremental value of HAND over auscultation to identify RHD.

METHODS: RHD screening was completed for schoolchildren in Gulu, Uganda, by using STAND performed by experienced echocardiographers. Any child with mitral or aortic regurgitation or stenosis plus a randomly selected group of children with normal STAND findings underwent HAND and auscultation. STAND and HAND studies were interpreted by 6 experienced cardiologists using the 2012 World Heart Federation criteria. Sensitivity and specificity of HAND and auscultation for the detection of RHD and pathologic mitral or aortic regurgitation were calculated by using STAND as the gold standard.

RESULTS: Of 4773 children who underwent screening with STAND, a subgroup of 1317 children underwent HAND and auscultation. Auscultation had uniformly poor sensitivity for the detection of RHD or valve disease. Sensitivity was significantly improved by using HAND compared with auscultation for the detection of definite RHD (97.8% vs 22.2%), borderline or definite RHD (78.4% vs 16.4%), and pathologic aortic insufficiency (81.8% vs 13.6%).

CONCLUSIONS: Auscultation alone is a poor screening test for RHD. HAND significantly improves detection of RHD and may be a cost-effective screening strategy for RHD in resource-limited settings.

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WHAT'S KNOWN ON THIS SUBJECT: Handheld echocardiography is a more portable and lower-cost alternative to standard echocardiography for rheumatic heart disease screening. Direct comparison of handheld echocardiography and auscultation for the detection of rheumatic heart disease has not been done previously.

WHAT THIS STUDY ADDS: Handheld echocardiography significantly improves detection of rheumatic heart disease compared with auscultation alone and may be a cost-effective screening strategy in developing countries.

Rheumatic heart disease (RHD) remains a major public health concern in the developing world, despite its near eradication in industrialized countries.[1–5] It results in significant morbidity and mortality, particularly in adolescents and young adults.[1,3,5,6] RHD is endemic in sub-Saharan Africa, and it is estimated that >1 million children are affected.[2] The prevalence of RHD in this region varies between 6.5 to 30 per 1000[7,8]; however, given the challenges associated with large-scale screening and varying methods used for the diagnosis of RHD, the true prevalence remains unknown. Early identification of RHD is of paramount importance because secondary prevention with monthly penicillin injections has been shown to be an effective method of preventing disease progression.[2,9]

Historically, auscultation has been the mainstay for the diagnosis of RHD in developing countries[10,11]; however, recent echocardiography-based screening programs have shown a high prevalence of subclinical RHD that remains undetected by clinical examination alone.[2,12–14] This has prompted the development of echocardiographic diagnostic criteria to standardize the diagnosis of subclinical RHD.[15] These criteria are meant for use in endemic populations for individuals without a history of rheumatic fever.

Standard portable echocardiography (STAND) is a highly sensitive method for RHD screening[2,11,13,14,16]; however, it remains cost-prohibitive in resource-limited settings, which has prevented the implementation of widespread RHD screening with echocardiography in endemic areas. Handheld echocardiography (HAND) is a highly portable and less costly alternative to STAND that has the potential to expand access to echocardiography-based RHD screening in developing countries.[17] The aim of this study was to determine the incremental value of HAND over auscultation to identify RHD.

METHODS

Study Population

This observational cross-sectional study included children between the ages of 5 and 17 years who attended 5 different schools in Gulu, Uganda. The prevalence of RHD in this region of Africa is unknown. No children included in the study had a history of rheumatic fever or known RHD before screening. There were no exclusion criteria. Each headmaster and/or school counsel consented to school participation. Parents of minors provided informed consent along with informed assent for individuals >8 years old. Adolescents >15 years old provided written informed consent, as is customary in Uganda. This study was approved by the institutional review boards at the University of Michigan, Children's National Medical Center, and Makerere University.

All subjects underwent a focused STAND examination. A random subset (10%) was preselected by a unique identification number to undergo HAND and auscultation. In addition, any subject with detectable mitral or aortic stenosis or regurgitation was referred for HAND and auscultation. The current study focuses on this subset who underwent both HAND and auscultation.

Echocardiograms

STAND (Vivid Q or I [General Electric, Milwaukee, WI] or CX50 [Philips, Amsterdam, Netherlands]) was performed by experienced imagers (attending pediatric cardiologists, senior cardiology fellows, or sonographers). In this cohort, all subjects underwent a focused echocardiogram (Table 1) to evaluate the aortic and mitral valves.

HAND was performed with a VScan (General Electric, Milwaukee, WI) by using the same echocardiogram protocol, with the omission of continuous-wave Doppler of the mitral and aortic valves, because HAND lacks spectral Doppler capabilities.

TABLE 1 Echocardiogram Protocol

Parasternal long axis
2D of AV and MV
Color Doppler of AV and MV
Parasternal short axis
2D of AV
Color Doppler of AV
2D of MV
Color Doppler of MV
Apical 4-chamber
2D of MV
Color Doppler of MV
CW Doppler of MR[a]
Apical 5-chamber
2D of AV
Color Doppler of AV
CW Doppler of AR[a]

AR, aortic regurgitation; AV, aortic valve; CW, continuous wave; MR, mitral regurgitation; MV, mitral valve; 2D, two-dimensional imaging.
[a] Spectral Doppler is not available on HAND.

All STAND studies in children who underwent HAND and auscultation were blindly reviewed by experienced cardiologists using the 2012 World Heart Federation (WHF) criteria.[15,17] These criteria define borderline and definite RHD on the basis of aortic and mitral valve morphology as well as the presence of regurgitation or stenosis (Tables 2 and 3). A second reader confirmed any study with borderline or definite RHD, with any disagreements adjudicated by a third reader. HAND studies were interpreted by the same cardiologists using modified 2012 WHF criteria (Fig 1). Because HAND lacks spectral Doppler capability, pathologic valve regurgitation was defined on the basis of the regurgitation jet length, its presence in 2 views, and presence in consecutive frames (as a surrogate for pan-systolic or pan-diastolic regurgitation) (Table 3). All physicians performing or interpreting HAND were blinded to STAND findings.

Auscultation

Auscultation was performed under typical screening conditions by

TABLE 2 2012 WHF Guidelines for Echocardiographic Diagnosis of RHD in Patients Aged <20 Years

Definite RHD
- A. Pathologic MR and at least 2 morphologic features[a] of RHD of the MV
- B. MS mean gradient >4 mm Hg[b]
- C. Pathologic AR and at least 2 morphologic features[a] of RHD of the AV[c]
- D. Borderline disease of both the AV and MV

Borderline RHD
- A. At least 2 morphologic features of RHD of the MV without pathologic MR or MS
- B. Pathologic MR
- C. Pathologic AR

AR, aortic regurgitation; AV, aortic valve; MR, mitral regurgitation; MS, mitral stenosis; MV, mitral valve.
[a] Morphologic features include MV: anterior leaflet thickening, chordal thickening, restricted leaflet motion, excessive leaflet tip motion during systole; and AV: irregular or focal thickening, coaptation defect, restricted leaflet motion, prolapse.
[b] Congenital MV anomalies must be excluded.
[c] Bicuspid AV and dilated aortic root must be excluded.

2 experienced local physicians (G.M., R.S.) who were blinded to STAND and HAND findings. Children were designated as "normal" if no murmur was appreciated or if a murmur was felt to be physiologic in nature. If a nonphysiologic murmur was present, the auscultator designated it as mitral or aortic regurgitation, mitral or aortic stenosis, or "other."

Statistical Analysis

Sensitivity and specificity were calculated for auscultation and HAND with the use of STAND as the gold standard for the detection of definite RHD, borderline or definite RHD, and pathologic valve regurgitation. Sensitivities were compared between auscultation and HAND by using McNemar's test. P values <.05 were considered statistically significant. The number needed to screen to detect 1 additional case with HAND compared with auscultation was calculated (1/[prevalence × difference in sensitivity between auscultation and HAND]) for each disease state by using the prevalence in the total population screened. Positive likelihood ratios were calculated for each diagnostic modality to determine the likelihood of disease in the setting of a positive screen.

RESULTS

A total of 4773 children underwent screening with STAND. Definite RHD was present in 52 children (1.1%), borderline in 140 children (2.9%), and 37 children (0.8%) had other findings on STAND (congenital heart disease, cardiomyopathy, or arrhythmia).

A subgroup of 1317 children (46% boys, 10.8 ± 2.6 years) underwent both HAND and auscultation. In this subgroup, 45 (3.4%) children met criteria for definite RHD, 126 (9.6%) had borderline RHD, and 1146 (87%) had normal findings on STAND (Table 4). Because of a busy screening environment, 21 children with borderline (n = 14) or definite (n = 7) RHD by STAND failed to undergo either HAND or auscultation and were excluded from analysis. Children with a STAND diagnosis of "other" were also excluded.

Detection of RHD

Auscultation had poor sensitivity for RHD (whether borderline or definite), whereas HAND had markedly higher sensitivity (Table 5). Specificity for RHD was similar between auscultation and HAND. Based on the prevalence of RHD (1.1% definite, 4.0% borderline or definite) in the overall, nonselected cohort, 123 children would require HAND screening to diagnose 1 additional case of definite RHD and 41 children would require screening to detect 1 additional case of borderline or definite RHD by using HAND compared with auscultation.

Detection of Mitral or Aortic Regurgitation

With the use of STAND, 126 (9.6%) children had pathologic mitral and 22 (1.7%) children had pathologic aortic regurgitation. Auscultation had poor sensitivity for both pathologic mitral and aortic regurgitation (Table 5). HAND had higher sensitivity than auscultation for both pathologic aortic and mitral regurgitation, but sensitivity remained suboptimal for the detection of pathologic mitral regurgitation. Specificity for pathologic mitral or aortic regurgitation was similar between auscultation and HAND.

Detection of Mitral or Aortic Stenosis

Mitral stenosis was present in 5 children. Auscultation failed to identify any cases of mitral stenosis; however, HAND correctly identified 3 of 5 cases (sensitivity of 60%). There were no cases of aortic stenosis. Auscultation incorrectly documented aortic stenosis in 2 children, both of whom had normal STAND examinations. No cases of aortic stenosis were identified by HAND.

Impact of Disease Prevalence

A sensitivity analysis was performed to determine the impact of disease prevalence on the positive predictive value (PPV) of both auscultation and HAND to diagnose definite RHD.

TABLE 3 2012 WHF Guidelines for Diagnosis of Pathologic Regurgitation

	Pathologic MR	Pathologic AR
2012 WHF criteria		
	Seen in 2 views	Seen in 2 views
	In at least 1 view, jet length >2 cm	In at least 1 view, jet length >1 cm
	Velocity >3 m/second for 1 complete envelope	Velocity >3 m/second in early diastole
	Pan-systolic jet in at least 1 envelope	Pan-diastolic jet in at least 1 envelope
Modified criteria[a]		
	Seen in 2 views	Seen in 2 views
	In at least 1 view, jet length >2 cm	In at least 1 view, jet length >1 cm
	Pan-systolic jet (by color Doppler)	Pan-diastolic jet (by color Doppler)

Data from refs 15 and 17. AR, aortic regurgitation; MR, mitral regurgitation.
[a] Criteria modified to exclude the use of spectral Doppler for HAND.

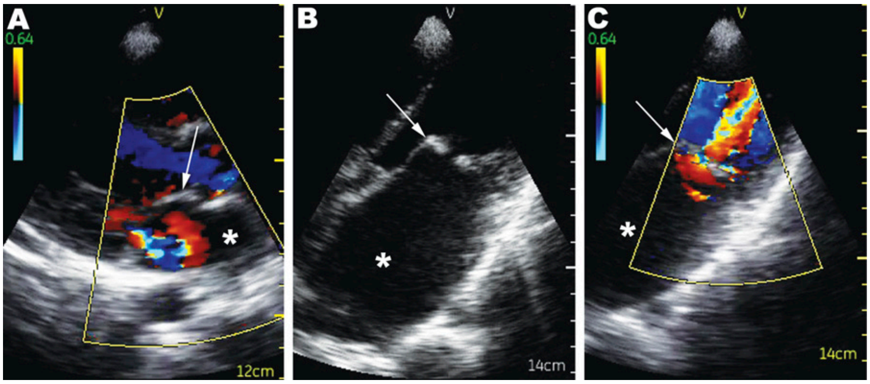

FIGURE 1
Pathologic findings consistent with RHD detected by HAND. A, Parasternal long-axis view: mitral regurgitation by color Doppler. B, Apical 4-chamber view: mitral stenosis by two-dimensional imaging. C, Apical 4-chamber view: mitral stenosis by color Doppler. The left atrium is denoted by an asterisk; the mitral valve is shown by an arrow.

HAND demonstrates superior PPV compared with auscultation, with improved PPV in high-prevalence environments. With a 1% prevalence of definite RHD, HAND yields a PPV of 7.2%, whereas the PPV for auscultation is 2.5%. At a prevalence of 2%, the PPV of HAND is 13.6% and for auscultation is 4.9%. The negative predictive value of HAND for definite RHD was excellent (>99%) regardless of disease prevalence.

DISCUSSION

Auscultation alone has poor sensitivity for the detection of RHD. HAND significantly improves sensitivity, approaching that of standard echocardiography. To our knowledge, this is the first study to directly compare HAND with auscultation in the setting of large-scale RHD screening.

The poor sensitivity of auscultation in the current study is similar to previous large-scale RHD screening studies. A study performed in Tonga found that 54% of children with pathologic findings (definite RHD, borderline RHD, or congenital heart disease) on echocardiography were not classified as having a pathologic murmur on physical examination.[16] Similarly, a study in Cambodia and Mozambique including >5000 children found that auscultation failed to detect >90% of RHD that was detected by echocardiography.[14] Screening programs relying on auscultation alone will miss a significant number of affected individuals, limiting opportunities for intervention and possible prevention of disease progression. This study reinforces the World Health Organization recommendations that support the use of echocardiography for detection of RHD in endemic areas.[1,17]

Unfortunately, access to echocardiography-based screening is limited in the developing world, particularly in resource-poor settings, which often have the highest prevalence of RHD. HAND is highly portable, is a fraction of the cost of STAND, and was shown in the current study to significantly improve detection of RHD over auscultation alone. These findings are comparable to previous studies, which have shown that HAND used in conjunction with physical examination improves the detection of cardiovascular pathology.[18–20] This remains true even when auscultation is performed by experienced cardiologists.[18,20] The ability of auscultation to detect pathology is likely to be even worse when performed by noncardiologists in a busy screening environment. Thus, HAND appears to be a reasonable approach to RHD screening in endemic populations, with distinct advantages over auscultation. However, the specificity of HAND in this study was less than ideal, with the potential for false-positive results. To limit the erroneous identification and inappropriate treatment of RHD, positive screening should be confirmed with a full evaluation, including a more detailed echocardiogram. However, one must also consider the potential that false-positive screenings could impose an additional stress on a health system with already limited resources.

In addition to the detection of definite RHD, HAND markedly increased the detection of borderline RHD compared with auscultation. Although the significance of detecting borderline disease is unclear, a previous study with a 2-year follow-up in Ugandan schoolchildren demonstrated that ~10% of these cases progress to definite RHD.[21] The implications of early RHD identification and the possible utility of penicillin prophylaxis on disease progression remain to be explored.

This study has several limitations. STAND studies interpreted as normal were not confirmed by a second reader; the use of multiple readers was not feasible due to the number of echocardiograms and would be unlikely to significantly change results because of the low prevalence of disease. The yield of auscultation depends on factors such as expertise and environment

TABLE 4 Cases of Borderline and Definite RHD Accurately Identified by Auscultation and HAND

	Normal	Borderline RHD	Definite RHD
STAND, *n*	1146	126	45
HAND, *n* (%)	1001 (87.3)	90 (71.4)	44 (97.8)
Auscultation, *n* (%)	1045 (91.2)	18 (14.3)	10 (22.2)

TABLE 5 Comparison Between Auscultation and HAND for the Detection of Definite/Borderline RHD, Pathologic MR, and Pathologic AR

	Prevalence,[a] %	Sensitivity, %	Specificity, %	P[b]	NNS[c]	LR+
Definite RHD[d]	1.1					
Auscultation		22.2	91.2	<.0001	123	2.5
HAND		97.8	87.3			7.7
Definite or borderline RHD	4.0					
Auscultation		16.4	91.2	<.0001	41	1.9
HAND		78.4	87.3			6.2
Pathologic MR (jet ≥ 2cm & pansystolic)	3.0					
Auscultation		15.9	91.5	.31	89	1.9
HAND		53.2	96.6			15.8
Pathologic AR (jet ≥ 1 cm & pandiastolic)	0.5					
Auscultation		13.6	99.8	<.0001	283	58.9
HAND		81.8	99.2			96.3

AR, aortic regurgitation; LR+, positive likelihood ratio; MR, mitral regurgitation; NNS, number needed to screen.
[a] Prevalence from entire population screened with STAND (N = 4773).
[b] P values from McNemar's test to compare sensitivities between auscultation and HAND.
[c] NNS calculated as 1/(prevalence × difference in sensitivity between auscultation and handheld).
[d] Borderline cases excluded when analyzing definite RHD.

(eg, ambient noise). Although the environment may have been suboptimal for auscultation, it represents typical screening conditions. Even under ideal conditions or with newer-generation electronic stethoscopes, the majority of latent RHD is likely silent. The use of 2 independent examiners for each child could improve the sensitivity of auscultation, but was not feasible due to limitations in time and resources. The cohort who underwent HAND and auscultation was selected to oversample subjects with mitral and/or aortic regurgitation to evaluate the ability of HAND and auscultation to differentiate physiologic and pathologic regurgitation. Although there may be some variation in sensitivity and specificity in different cohorts, such effects do not explain the marked difference in sensitivity between auscultation and HAND. The WHF criteria used in this study were adapted for use with HAND. The development of criteria specific to HAND could improve the sensitivity and specificity of HAND in the detection of RHD. In addition, HAND was performed and interpreted by expert users, which is unlikely to be the case in future screening efforts and could compromise the reliability of HAND screening. If such an approach is to be used, future studies are necessary to examine the potential impact that nonexperts would have on the sensitivity and specificity of HAND screening.

CONCLUSIONS

HAND offers a significant improvement over auscultation for the diagnosis of RHD and represents a highly portable and more cost-effective alternative to STAND in RHD screening. Auscultation fails to detect many cases of definite or borderline RHD, thereby limiting opportunities for potential intervention. The optimization of HAND screening protocols and criteria has the potential to improve diagnostic capability and may help to expand the reach of echocardiography-based RHD screening in the developing world.

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Drs Mirembe and Sanya performed auscultation; Dr Aliku performed and reviewed echocardiograms, aided in study design and study coordination, and performed data entry; Ms Yu contributed statistical support and aided in data analysis; Dr Lwabi provided critical review and revision of the manuscript; Dr Webb performed handheld echocardiograms, reviewed echocardiograms, assisted in study coordination, and provided critical review and revision of the manuscript; Dr Ensing performed standard portable and handheld echocardiograms, reviewed echocardiograms, assisted in study design and study coordination, performed data entry, and assisted in drafting and critical revision of the manuscript; and all authors approved the final manuscript as submitted.

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