Utility of auscultatory screening for detecting rheumatic heart disease in high-risk children in Australia's Northern Territory

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Abstract

Objectives: To evaluate the utility of auscultatory screening for detecting echocardiographically confirmed rheumatic heart disease (RHD) in high-risk children in the Northern Territory, Australia.

Design: Cross-sectional screening survey.

Setting: Twelve rural and remote communities in the NT between September 2008 and June 2010.

Participants: 1015 predominantly Indigenous schoolchildren aged 5–15 years.

Intervention: All children underwent transthoracic echocardiography, using a portable cardiovascular ultrasound machine, and cardiac auscultation by a doctor and a nurse. Sonographers and auscultators were blinded to each others' findings and the clinical history of the children. Echocardiograms were reported offsite, using a standardised protocol, by cardiologists who were also blinded to the clinical findings.

Main outcome measures: Presence of a cardiac murmur as identified by nurses (any murmur) and doctors (any murmur, and "suspicious" or "pathological" murmurs), compared with echocardiogram findings. RHD was defined according to the 2012 World Heart Federation criteria for echocardiographic diagnosis of RHD.

Results: Of the 1015 children screened, 34 (3.3%) had abnormalities identified on their echocardiogram; 24 met echocardiographic criteria for definite or borderline RHD, and 10 had isolated congenital anomalies. Detection of any murmur by a nurse had a sensitivity of 47.1%, specificity of 74.8% and positive predictive value (PPV) of 6.1%. Doctor identification of any murmur had 38.2% sensitivity, 75.1% specificity and 5.1% PPV, and the corresponding values for doctor detection of suspicious or pathological murmurs were 20.6%, 92.2% and 8.3%. For all auscultation approaches, negative predictive value was more than 97%, but the majority of participants with cardiac abnormalities were not identified. The results were no different when only definite RHD and congenital abnormalities were considered as true cases.

Conclusions: Sensitivity and positive predictive value of cardiac auscultation compared with echocardiography is poor, regardless of the expertise of the auscultator. Although negative predictive value is high, most cases of heart disease were missed by auscultation, suggesting that cardiac auscultation should no longer be used to screen for RHD in high-risk schoolchildren in Australia.

Rheumatic heart disease (RHD), the long-term sequel of acute rheumatic fever, is a leading cause of heart disease in children in low- and middle-income countries.[1] Poverty and overcrowding are known risk factors for RHD,[2] and with improvements in socioeconomic conditions, the disease has essentially disappeared from industrialised countries, with the exceptions of the Indigenous populations of Australia and New Zealand.[3] Indigenous Australians continue to experience among the highest rates in the world, with an acute rheumatic fever incidence of up to 380 per 100 000 children aged 5–14 years, and an estimated RHD prevalence of 8.5 per 1000 children in this age group.[4] A recent government report shows that young Indigenous Australians (< 35 years) in the Northern Territory have a 122-fold greater prevalence of RHD than non-Indigenous Australians.[5]

In populations with high prevalence, RHD satisfies many of the criteria for a disease to be deemed suitable for screening,[6] and RHD has long been a target of public health screening internationally. Cardiac auscultation was the traditional approach,[7] but with the evolution of portable echocardiography there has been increasing interest in echocardiographic screening for RHD.[8–15] In the echocardiographic era, a new category of RHD has been recognised: "subclinical RHD", defined as structural or functional changes consistent with RHD evident on an echocardiogram in the absence of a pathological cardiac murmur.[6] By definition, it is not possible to identify children who have subclinical RHD using auscultatory screening alone, and published data consistently show that auscultation is considerably less sensitive than echocardiography, missing up to 90% of cases of RHD in some studies.[8] Also of concern is the high false-positive rate associated with auscultation, resulting in many children undergoing further unnecessary diagnostic evaluation.[9,16]

Auscultatory screening for RHD commenced in the NT in 1997 and is still used today. Cardiac auscultation is performed by primary care doctors on schoolchildren aged 10 and 15 years who live in remote Indigenous communities; those with a cardiac murmur are referred for echocardiography.[17] The NT is the only jurisdiction in Australia with a formal RHD screening program.

As part of a large echocardiographic screening study undertaken in northern Australia, we performed cardiac auscultation on a subset of schoolchildren in remote Indigenous communities in the NT and compared clinical findings with echocardiographic findings. We aimed to establish whether cardiac auscultation is an appropriate tool for RHD screening to identify children who should be referred for echocardiography.

Methods

Setting and participants

Our study was conducted in 12 rural and remote communities in Central Australia and the Top End of the NT between September 2008 and June 2010. Children aged 5–15 years, identified by school enrolment records, were eligible to participate. These children were a subset of a larger

1 Comparison of auscultation findings with echocardiographic findings for 1015 children from rural and remote parts of the Northern Territory, 2008–2010

Auscultation approach	No. of children with abnormalities* (*n* = 34)	No. of children without abnormalities (*n* = 981)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	AUC† (95% CI)
One stage, by nurse							
Any murmur	16	247	47.1% (29.8%–64.9%)	74.8% (72.0%–77.5%)	6.1% (3.5%–9.7%)	97.6% (96.2%–98.6%)	0.61 (0.52–0.70)
No murmur	18	734					
One stage, by doctor							
Any murmur	13‡	244	38.2% (22.2%–56.4%)	75.1% (72.3%–77.8%)	5.1% (2.7%–8.5%)	97.2% (95.8%–98.3%)	0.57 (0.48–0.65)
No murmur	21§	737					
One stage, by doctor							
Significant murmur¶	7	77	20.6% (8.7%–37.9%)	92.2% (90.3%–93.8%)	8.3% (3.4%–16.4%)	97.1% (95.8%–98.1%)	0.56 (0.49–0.63)
No significant murmur	27	904					
Two stage**							
Significant murmur	6	51	17.6% (6.8%–34.5%)	94.8% (93.2%–96.1%)	10.5% (4.0%–21.5%)	97.1% (95.8%–98.1%)	0.56 (0.50–0.63)
No significant murmur	28	930					

PPV = positive predictive value. NPV = negative predictive value. AUC = area under the receiver operating characteristic curve. * Definite or borderline rheumatic heart disease and congenital abnormalities detected on echocardiogram; there was no difference in the findings when only definite rheumatic heart disease and congenital abnormalities were considered true cases (data not shown). † AUC is a measure of overall test accuracy; 0.5 indicates zero discrimination, and values approaching 1.0 indicate high sensitivity and specificity. ‡ Includes 8 children with rheumatic heart disease (5 definite, 3 borderline) and 5 with congenital heart disease. § Includes 16 children with rheumatic heart disease (10 definite, 6 borderline) and 5 with congenital heart disease. ¶ Includes 20 pathological and 64 suspicious cardiac murmurs. ** By a nurse to identify any murmur, then by a doctor to identify significant murmur. ◆

group of children, from 17 communities in Northern Australia, who had echocardiography performed for a larger study. Nurse and doctor auscultators were present during visits to the 12 communities, and all the children in these communities who were participating in the larger study were eligible to participate in the auscultation component.

Written informed consent was obtained from parents and guardians, and written assent was obtained from children aged ⩾ 13 years before they took part. Ethics approval was obtained from the Human Research Ethics Committee of the Northern Territory Department of Health and Community Services, and the Central Australian Human Research Ethics Committee.

Echocardiography

All children had a screening echocardiogram performed by an experienced cardiac sonographer using a Vivid *e* (GE Healthcare) portable cardiovascular ultrasound machine. Sonographers were blinded to the auscultators' findings and to the clinical history of the children. Screening echocardiograms were performed according to an abbreviated protocol, previously used in Tonga and Fiji,[9,16] that focused on the mitral and aortic valves, but would also enable detection of significant congenital lesions. If a potential abnormality was detected, a complete echocardiogram was performed.

Echocardiograms were recorded to DVD and reported offsite by a pool of 14 cardiologists who were blinded to the clinical findings. Detailed data about the mitral and aortic valves were entered into an electronic database.

Children were classified as having definite or borderline RHD according to the 2012 World Heart Federation (WHF) criteria for the echocardiographic diagnosis of RHD.[18] This was done by extracting each individual echocardiographic feature, as objectively measured and recorded by reporting cardiologists, and combining features to determine whether WHF definitions were met. Children were also classified as having pathological mitral regurgitation or pathological aortic regurgitation according to these criteria.

Cardiac auscultation

Children underwent auscultation performed by a nurse and a doctor who were blinded to the sonographers' findings, each others' findings and to the clinical history of the children. Auscultation was performed by nurses with varying levels of experience and doctors of different specialties (including general practitioners, paediatricians and cardiologists). It was completed with children supine and sitting, in a quiet room where possible. The diaphragm and bell of the stethoscope were used at the apex and axilla, lower left sternal edge, upper left sternal edge and upper right sternal edge. The nurses and doctors who performed auscultation were asked to comment on the presence or absence of a murmur. The doctors were further asked to specify whether a murmur was "innocent", "suspicious" or "pathological". Suspicious and pathological murmurs were classified as "significant" murmurs. This enabled assessment of three screening approaches: one-stage auscultation by a nurse to detect any murmur; one-stage auscultation by a doctor to detect any significant murmur; and two-stage auscultation, with the first stage to detect any murmur by a nurse and the second stage to detect which of these was significant by a doctor.

Analysis

Statistical analysis was performed using Stata statistical package version 12.1 (StataCorp). Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated for each screening approach.

Results

A total of 1986 NT children had a screening echocardiogram as part of the larger study, of whom 1015 had auscultation performed by a doctor

2 Comparison of one-stage doctor auscultation findings with echocardiographic findings, by specialty of doctors who performed auscultation, for children from rural and remote parts of the Northern Territory, 2008–2010

	No. of children who underwent auscultation	No. of children with abnormalities*	No. (%) of children with any murmur	No. (%) of children with significant murmur	Sensitivity†	Specificity†
General practitioner	157	8	33 (21.0%)	14 (8.9%)	12.5%	91.3%
Paediatrician	637	17	159 (25.0%)	48 (7.5%)	17.7%	92.7%
Cardiologist	106	4	37 (34.9%)	2 (1.9%)	0	98.0%
Physician	45	2	14 (31.1%)	7 (15.6%)	100.0%	88.4%
Resident medical officer	70	3	14 (20.0%)	13 (18.6%)	33.3%	82.1%
Any doctor	1015	34	257 (25.3%)	84 (8.3%)	20.6%	92.2%

* Definite or borderline rheumatic heart disease and congenital abnormalities detected on echocardiogram. † Comparison of doctor identification of significant cardiac murmur with any abnormality detected on echocardiogram. ◆

3 Comparison of auscultation findings with echocardiographic findings in three large rheumatic heart disease screening studies

	Country (auscultator)			
	Mozambique (physician)[8]	Tonga (medical student)[9]	Tonga (paediatrician)[9]	Fiji (paediatrician)[16]
No. of children who underwent auscultation	2170	980	980	3462
No. of children who underwent echocardiography	2170	980	980	331
No. of children with abnormalities detected on echocardiogram	71	140	140	41
No. (%) of children with any murmur	456 (21%)	964 (98%)	779 (79%)	889 (26%)
No. (%) of children with significant murmur	91 (4%)	NA	358 (37%)	359 (10%)
Sensitivity*	14%	96%	46%	NA
Specificity*	96%	1%	65%	NA
Positive predictive value*	11%	14%	18%	14%
Negative predictive value*	97%	69%	88%	NA

NA = not applicable. * Comparison of significant murmurs (where reported) with any abnormality (rheumatic heart disease and congenital heart disease) detected on echocardiogram; echocardiographic definitions of rheumatic heart disease varied slightly between studies. ◆

and a nurse; 960 (94.6%) were Indigenous and 498 were girls (49.1%). The mean age was 9.3 years (SD, 2.5 years), and the median body mass index was 15.6 kg/m^2 (interquartile range, 14.4–17.8 kg/m^2). Children who had an echocardiogram but did not undergo auscultation were slightly older (mean age, 9.7 years), but were otherwise comparable based on sex and body mass index.

Echocardiographic findings

Thirty-four children (3.3%) had abnormalities identified on their echocardiogram. Fifteen (1.5%) of them had definite RHD, 9 (0.9%) had borderline RHD (including two who also had small atrial septal defects), and 10 (1.0%) had isolated congenital anomalies: ventricular septal defect (two), atrial septal defect (one), mitral valve prolapse (two), patent ductus arteriosus (two), dilated aortic root (two) and complex congenital heart disease (one). Of the 24 children with RHD, 14 had pathological mitral regurgitation, six had pathological aortic regurgitation, and one child had both.

Clinical findings

One-stage auscultation

A cardiac murmur (significant or not) was heard by nurses in 263 children (25.9%), by doctors in 257 children (25.3%), and by a doctor and a nurse in 137 children (13.5%). Compared with echocardiogram, one-stage auscultation to detect any murmur by a doctor or a nurse had a sensitivity of less than 50%, a specificity of about 75%, and a positive predictive value (PPV) of less than 10% (Box 1). Asking doctors to decide which murmurs were pathological or suspicious increased the specificity from 75.1% to 92.2%, but further dropped the sensitivity to 20.6%. The breakdown of medical specialists and their auscultation findings are presented in Box 2.

Two-stage auscultation

Only 52% (137/263) of the murmurs heard by nurses were also heard by doctors. Of these, 57 were considered pathological or suspicious. Using two-stage auscultation, 28 children with abnormalities were missed (sensitivity, 17.6%), and six children with abnormalities were correctly identified (PPV, 10.5%). This approach had a specificity of 94.8%.

Discussion

Our study confirms that cardiac auscultation has poor sensitivity, despite moderately high specificity, for detecting RHD and other cardiac abnormalities evident on echocardiograms, regardless of the experience of the examiner. More than 50% of children with abnormal echocardiography results did not have a murmur detected, and more than 90% of murmurs heard were false positives. The observed high NPVs and low PPVs are expected in a low-prevalence disease such as RHD, and are consistent with the results of previous studies (Box 3). Our findings highlight the paramount importance of sensitivity in determining the utility of auscultation as a screening test for RHD.

The current approach to screening for RHD in the NT is one-stage doctor auscultation by a GP, with referral of any child with a murmur for an echocardiogram.[17] Program reports suggest that cardiac murmurs are

heard in about 10% of those screened,[19] but few data regarding follow-up and clinical outcomes for these children are available. In a detailed report on RHD screening in Central Australia during 2009, 67 of 1095 children who were screened (6.1%) had a murmur and were referred for echocardiography. One year later, only 38 of them had had their echocardiogram, of whom four had abnormalities (two RHD, two non-RHD abnormalities).[19] This prevalence of RHD (2 per 1000 children) is considerably lower than expected in the Central Australian population and suggests that some disease went undetected. In addition, the fact that nearly half of referred children had not had their echocardiogram 12 months later also highlights difficulties with the current approach.

According to the current NT screening model (one-stage doctor auscultation), 257 children in our study would have been referred for echocardiogram, with only 13 of them having abnormalities (eight with RHD, five with congenital heart disease). A high false-positive rate has important implications for screening programs, to both the individual and the health system. In the NT, limited paediatric cardiology services exist, and waiting times for echocardiography can be long. Such high false-positive rates would result in a substantial increase in referral of children to tertiary services for further evaluation, and would risk overburdening already-stretched paediatric cardiology services with children who do not have heart disease.

Of greatest concern, however, is that using the current approach to RHD screening, 16 of 24 children with RHD (10 with definite RHD, six with borderline RHD) would have been missed. While there is uncertainty about the significance of the borderline RHD category, the WHF recommends that all children meeting echocardiographic criteria for definite RHD be started on secondary prophylaxis.[18] In our study, the 10 children who met these criteria but did not have murmur detected by one-stage doctor auscultation would not have had further evaluation and would not have commenced secondary antibiotic prophylaxis, leaving them at high risk of acute rheumatic fever recurrences and further valve damage.

The prognosis of RHD is best if secondary prophylaxis with long-acting intramuscular penicillin is commenced when the disease is mild; continuous adherence to treatment with penicillin can result in valve damage being halted or reversed.[20-22] It is therefore imperative that the test used to screen for RHD is highly sensitive, so that children with the earliest stage of disease, who stand to gain the most from the only currently available preventive treatment, are identified.

It is widely accepted that echocardiography is more sensitive than auscultation. While there has been much discussion about echocardiographic definitions of RHD, including concerns about specificity, it is hoped that the publication of the WHF diagnostic criteria will minimise false-positive results. Whether echocardiographic screening for RHD is appropriate, feasible and cost-effective will vary between settings, and remains a topic of vigorous debate.[6,23-25] A cost-effectiveness analysis of our data is underway and will contribute to our ultimate recommendations about the future of echocardiographic screening in Indigenous Australian children who are at high risk of RHD.

A limitation of this study is that auscultation was carried out by several different doctors and nurses, potentially leading to high interobserver variation. Similarly, the screening environment varied between communities, and the conditions under which auscultation was performed (eg, in a quiet room) were not the same for all participants. However, we believe that these limitations reflect the day-to-day reality of health care service provision in the participating communities, allowing valid extrapolation of our results to the current school screening procedure in the NT and many other settings.

We conclude that cardiac auscultation is not an effective method of RHD screening, regardless of the expertise of the auscultator. The risk of missing more than 50% of children with RHD, and the risk of overburdening cardiology services with false positives, preclude recommendation of one-stage or two-stage auscultation as a rational approach to RHD screening. We recommend that cardiac auscultation no longer be used to screen for RHD in high-risk schoolchildren in Australia.

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