

## Screening for Rheumatic Heart Disease Evaluation of a Focused Cardiac Ultrasound Approach

Mariana Mirabel, MD; Raoul Bacquelin, MD; Muriel Tafflet, PhD; Corinne Robillard, RN;  
Bertrand Huon, MD; Philippe Corsenac, MPH; Isabelle de Frémicourt, MD;  
Kumar Narayanan, MD; Jean-Michel Meunier, MD; Baptiste Noël, MD;  
Albert Alain Hagège, MD, PhD; Bernard Rouchon, MD; Xavier Jouven, MD, PhD;  
Eloi Marijon, MD, PhD

**Background**—Rheumatic heart disease (RHD) remains a major public health problem worldwide. Although early diagnosis by echocardiography may potentially play a key role in developing active surveillance, systematic evaluation of simple approaches in resource poor settings are needed.

**Methods and Results**—We prospectively compared focused cardiac ultrasound (FCU) to a reference approach for RHD screening in a school children population. FCU included (1) the use of a pocket-sized echocardiography machine, (2) nonexpert staff (2 nurses with specific training), and (3) a simplified set of echocardiographic criteria. The reference approach used standardized echocardiographic examination, reviewed by an expert cardiologist, according to 2012 World Heart Federation criteria. Among the 6 different echocardiographic criteria, first tested in a preliminary phase, mitral regurgitation jet length  $\geq 2$  cm or any aortic regurgitation was considered best suited to be FCU criteria. Of the 1217 subjects enrolled (mean,  $9.6 \pm 1$  years; 49.6% male), 49 (4%) were diagnosed with RHD by the reference approach. The sensitivity of FCU for the detection of RHD was 83.7% (95% confidence interval, 73.3–94.0) for nurse A and 77.6% (95% confidence interval, 65.9–89.2) for nurse B. FCU yielded a specificity of 90.9% (95% confidence interval, 89.3–92.6) and 92.0% (95% confidence interval, 90.4–93.5) according to users. Percentage of agreement among nurses was 91.4%.

**Conclusions**—FCU by nonexperts using pocket devices seems feasible and yields acceptable sensitivity and specificity for RHD detection when compared with the state-of-the-art approach, thereby opening new perspectives for mass screening for RHD in low-resource settings. (*Circ Cardiovasc Imaging*. 2015;8:e002324. DOI: 10.1161/CIRCIMAGING.114.002324.)

**Key Words:** acute rheumatic fever ■ developing countries ■ epidemiology ■ heart valve diseases  
■ rheumatic heart disease ■ ultrasound

Rheumatic heart disease (RHD) has been eradicated in many areas, but remains a major public health problem in the developing world with >345 000 related deaths each year.<sup>1–4</sup> RHD is the consequence of valvular damage caused by an exaggerated immune response to group A streptococcal infections, usually during infancy and childhood. Disease control is based on the administration of penicillin for primary prevention (ie, the treatment of group A streptococcal sore throat) and for secondary prevention (ie, at regular intervals to avoid further exposure to group A streptococcal infections that trigger the autoimmune response).

### See Clinical Perspective

Because penicillin prevents RHD progression when initiated in a timely fashion (ie, secondary prevention), early detection has been emphasized to be of particular interest.<sup>1</sup>

The World Health Organization had recommended active surveillance in the past. There are, however, no guidelines as how screening should be undertaken. A 2-step approach involving clinical examination followed by echocardiography has proven to be of low sensitivity and specificity when compared with echocardiography alone.<sup>5</sup> Indeed, echocardiography detects 3 to 25 times more cases than auscultation alone in endemic regions.<sup>6–10</sup> The World Heart Federation (WHF) has, therefore, provided guidelines to optimize echocardiographic RHD diagnosis.<sup>11,12</sup> There are certain issues that may prevent implementation of active surveillance by echocardiography in regions where RHD prevalence is highest.<sup>13</sup> Cost-effectiveness and ethical issues arise when considering echocardiography-based screening as a public health policy in deprived regions. Concerns also include the cost of comprehensive portable

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From the Paris Cardiovascular Research Center, INSERM U970, Paris, France (M.M., R.B., M.T., K.N., X.J., E.M.); Université Paris Descartes, Sorbonne Paris Cité, Paris, France (M.M., A.A.H., X.J., E.M.); Cardiology Department, European Georges Pompidou Hospital, Paris, France (M.M., A.A.H., X.J., E.M.); Cardiology and Development, Paris, France (M.M., X.J., E.M.); Agence Sanitaire et Sociale de Nouvelle Calédonie, Nouméa, New Caledonia (C.R., B.H., P.C., J.-M.M., B.R.); Département de l'Action Sanitaire de Sociale des Iles Loyauté, Wé, Lifou, New Caledonia (I.d.F.); Cedars-Sinai Medical Center, Heart Institute, Los Angeles, CA (K.N.); and Centre Hospitalier Territorial de Nouvelle Calédonie, Nouméa, New Caledonia (B.N.).

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Correspondence to Mariana Mirabel, MD, Paris Cardiovascular Research Center, Inserm U970, Hôpital Européen Georges Pompidou, 56 rue Leblanc, 75737 Paris Cedex 15, France. E-mail [mariana.mirabel@inserm.fr](mailto:mariana.mirabel@inserm.fr)

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equipment, the complexity of echocardiographic criteria, and the need for highly trained health workers in countries where access to specialist care remains limited. All these factors represent significant barriers to mass screening in low-income countries.<sup>14</sup> Echocardiography may, however, emerge as the method of choice for active surveillance in highly endemic regions in this rapidly moving field.<sup>15</sup>

We, therefore, prospectively assessed a new approach for RHD screening based on focused cardiac ultrasound (FCU) combining the use of a pocket-sized echo system, performed by nurses after a standardized training program, and using a simplified diagnostic algorithm.

## Methods

### Settings, Study Populations, and Screening

#### Methodology

New Caledonia is a special collectivity of France located in the southwest Pacific Ocean. The prevalence of RHD in this region remains high, especially among indigenous populations.<sup>16</sup> The country's social security, however, provide access to secondary prophylaxis, specialist care, and cardiac interventions overseas free of charge.

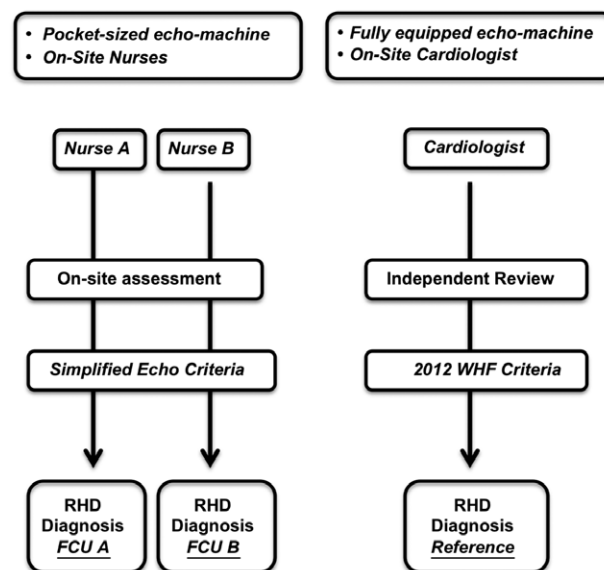
The study comprises 2 parts. We first tested the most appropriate simplified set of echocardiographic criteria for RHD to be used for FCU among 189 selected children with and without RHD in March 2013 (part 1 of the study). These children had previously participated in the yearly echo-screening campaigns conducted in New Caledonia since 2008 (then aged 9–10 years). Participants in part 1 included children with subclinical RHD and children with previously normal echocardiograms.<sup>16</sup> We then prospectively evaluated the feasibility and performance of an FCU approach among a population of school children (fourth graders aged 9–10 years in Nouméa, the capital city, and its suburbs) from April to August 2013 (part 2).

Participants were enrolled after parental written consent. Ethical clearance was granted from the Committee for the Protection of Persons of Overseas Territories and from the French Institute of Medical Research and Health (IRB00003888-FWA00005831).

The FCU approach used (1) a pocket-sized echo machine (V-scan; General Electric, Milwaukee, WI), (2) nonexpert staff (2 nurses after a standardized 60-hour training program) for performance and interpretation, and (3) a simplified set of echocardiographic criteria. The FCU approach was compared with the reference state-of-the-art approach. Each participant underwent 3 echocardiograms the same day in a randomly allocated order, blinded to the child's diagnosis and to the other sonographer's findings: 2 independent examinations by nurses using FCU and 1 examination by a cardiologist on-site (Figure 1). Each participant was assigned a unique research identification number, which could be used to link the imaging studies to the research participant. All studies were systematically reviewed in part 1 of the study, including the on-site cardiologist (reference echocardiogram) and nurses' (FCU) recordings. The time for each scan was also systematically recorded in part 1.

The different echocardiographic criteria tested in part 1 were (1) any mitral regurgitation (MR); (2) MR jet length  $\geq 1.5$  cm; (3) MR jet length  $\geq 2.0$  cm; (4) morphological changes of the mitral valve defined as any irregular/focal thickening of the mitral leaflet, chordal thickening, restricted leaflet motion, excessive leaflet motion, or flail; (5) any aortic regurgitation; and (6) MR jet length  $\geq 2.0$  cm or any aortic regurgitation.

After determination of the optimal simplified set of echocardiographic criteria for FCU, we applied the FCU to a broader population of children (part 2 of the study) from April to August 2013 in local primary schools. All children attending these schools in fourth grade (aged 9–10 years) were offered to take part in the study. During this second part of the study, all suspected abnormal reference echocardiograms, identified either by the nurses or the on-site cardiologist, were independently reviewed.



**Figure 1.** Methodology of the focused cardiac ultrasound (FCU) and of the reference approach. RHD indicates rheumatic heart disease; and WHF, World Heart Federation.

### Focused Cardiac Ultrasound Approach

The FCU approach was defined by the evaluation of on-site screening using a pocket echocardiography device, performed by 2 nurses trained specifically for the purpose of the study, according to simplified echocardiographic criteria. The ability to detect RHD was evaluated in comparing the on-site diagnosis made by the nurses by FCU to the reference approach.

The pocket-echo machine used was the V-scan (GE Medical Systems, version 1.2), with a 1.7- to 3.4-MHz transducer. The V-scan offers regular grayscale imaging and color blood flow mode with a 75° imaging sector. Grayscale and color Doppler parasternal long axis and parasternal short axis, apical 4-, 2-, and 3-chamber views were acquired, saved on the device's microSD card and transferred to a computer. Distance measurements were performed during the examination using a caliper.

Two nurses with no previous experience in echocardiography underwent focused training for the recognition of left-sided valve abnormalities. The aim and stepwise methodology used for training the nurses are reported in the Data Supplement (Supplemental Methods). Briefly, the training included first theoretical lectures for 3 days, followed by 30 hours of hands-on sessions (with normal volunteers followed by sessions with RHD patients at the echocardiography laboratory, Centre Hospitalier Territorial de Nouvelle Calédonie, Nouméa, New Caledonia) in February 2013. Additional tailored tutorship was undertaken between parts 1 and 2 of the study, including a review of the nurses' scans and hands-on sessions addressing pitfalls in their practice.

### Reference Approach

An experienced cardiologist performed standard echocardiograms with a portable machine (Vivid I, GE) on site after a predefined acquisition protocol with a 1.5- to 3.6-MHz probe. Frame rates ranged from 25 to 35 Hz for black-and-white imaging and from 12 to 18 Hz for color Doppler. Parasternal long axis and parasternal short axis, apical 4-, 2-, and 3-chamber views were acquired and settings optimized: grayscale without harmonics were recorded in the parasternal long-axis view for subsequent measurements of the anterior mitral leaflet, color Doppler was used in all views, continuous wave Doppler was applied to systematically measure the mean transmitral gradient and if a mitral or aortic regurgitant jet was seen on color Doppler. An experienced reader (M.M.) reviewed all studies using WHF criteria.

## Statistical Analysis

Participant characteristics were described as mean (SD) or proportions, as appropriate. Categorical variables were compared using  $\chi^2$  test. Sensitivity and specificity were calculated for the detection of any RHD (including borderline and definite RHD), with 95% confidence intervals (CIs). CIs for sensitivity and specificity were computed using the log-odds scale. Additional sensitivity analysis was performed for definite RHD cases. A predefined analysis was performed for part 1 of the study, including (1) sample size calculations based on the hypothesis that the FCU approach would yield a sensitivity of 80% with 95% CI of 70% to 90% if 61 definite RHD and 61 controls were included in the study; (2) the sensitivity and specificity to detect RHD for both nurses, with predefined cutoff values of 70%, to implement a simplified algorithm in part 2 prospectively. To evaluate agreement between investigators, we used  $\kappa$  coefficient with 95% CIs or percentage of agreement, as appropriate. Perceived differences in image quality (qualified as poor, moderate, and good) according to users were compared between the 2 users using Bowker test of symmetry. All data were analyzed at the Cardiovascular Epidemiology Unit of the Paris Cardiovascular Research Center, INSERM 970, Paris, France, with the use of Statistical Analysis System software (version 9.3).

## Results

### Evaluation of the Optimal Simplified Set of Echocardiographic Criteria for FCU Approach: Part 1

One hundred eighty-nine children were enrolled in this preliminary study. Mean age was 12.2 years (SD, 2.0) and 84 (44.4%) were male. One hundred six (56.1%) children had findings of RHD (63 definite and 43 borderline RHD), whereas 83 (43.9%) had normal echocardiograms.

Sensitivity and specificity of the 6 criteria interpreted by the nurses, when compared with the reference approach, are reported in Table 1 and Figure 2. Overall, there was an important heterogeneity with sensitivity varying from 26.4 (95% CI, 18.9–35.6) to 97.2 (95% CI, 91.7–99.1), specificity from 13.5 (95% CI, 7.6–22.7) to 91.6 (95% CI, 83.4–95.6), with also a wide range for interobserver agreement ( $\kappa$  varying from 0.09 to 0.57). The breakdown of echocardiographic findings according to WHF criteria is presented in the Data Supplement (Table).

Among the 6 criteria tested, the combined criteria of MR jet length  $\geq 2.0$  cm or any aortic regurgitation (regardless the length) seemed to achieve the best combination of sensitivity and specificity. Compared with the reference approach, sensitivity of the combined criteria to detect any RHD was 76.4% (95% CI, 67.4–83.5) and 70.7% (95% CI, 61.4–78.6)

for nurses A and B, respectively. The specificity to detect any RHD was of 73.5% (95% CI, 63.0–81.9) and 69.9% (95% CI, 59.2–78.8) according to nurses A and B, respectively. The agreement between nurses was moderate for the detection of all RHD cases when using the combined criteria ( $\kappa=0.48$ ; 95% CI, 0.35–0.60; Figure 3).

### Assessment of Image Quality and On-Site Diagnosis: Part 1

Image quality of the FCU recordings was evaluated as good in 68 (36.8%) and 79 (42.7%), fair in 109 (58.9%) and 104 (56.2%), and poor in 8 (4.3%) and 2 (1.1%) cases, for nurses A and B, respectively (missing data in 4 cases), without significant difference between the 2 nurses ( $P=0.07$ ).

When an experienced cardiologist reviewed FCU recorded by nurses in the field, the sensitivity and specificity of the diagnoses made by the nurses were not statistically significantly different from the corresponding values obtained from the experienced cardiologist (Figure 4). Mean scanning time per FCU scan was 5.9 minutes (1.7) for nurse A and 7.0 minutes (1.9) for nurse B.

### Focused Cardiac Ultrasound in the Population (School-Based Screening): Part 2

Among the 1217 children included at school (mean age,  $9.6 \pm 0.5$  years; 603 male; 49.6%), 49 (4.0%) were diagnosed with findings of RHD according to the reference approach, including 15 definite and 34 borderline RHD cases (Figure 5).

The sensitivity, specificity, and interobserver agreement between the 2 nurses are shown in Tables 2 and 3. The sensitivity of FCU to detect any RHD cases was 83.7% (95% CI, 70.7–91.6) for nurse A and 77.6% (95% CI, 63.9–87.1) for nurse B. FCU yielded a specificity of 90.9% (95% CI, 89.1–92.4) and 92.0% (95% CI, 90.3–93.4) according to nurses A and B, respectively. The percentage of agreement between nurses was 91.4%.

When restricted to definite RHD, the performance of the FCU approach was better. FCU yielded a sensitivity of 93.3% (95% CI, 64.7–99.1) and 86.7% (95% CI, 59.5–96.7) according to nurses A and B, respectively. The percentage of agreement between nurses was 91.8%. All RHD valve lesions detected in schools were graded as mild with no case of mitral stenosis.

## Discussion

We report here, to the best of our knowledge, the first evaluation of an FCU approach for RHD screening by nonexperts

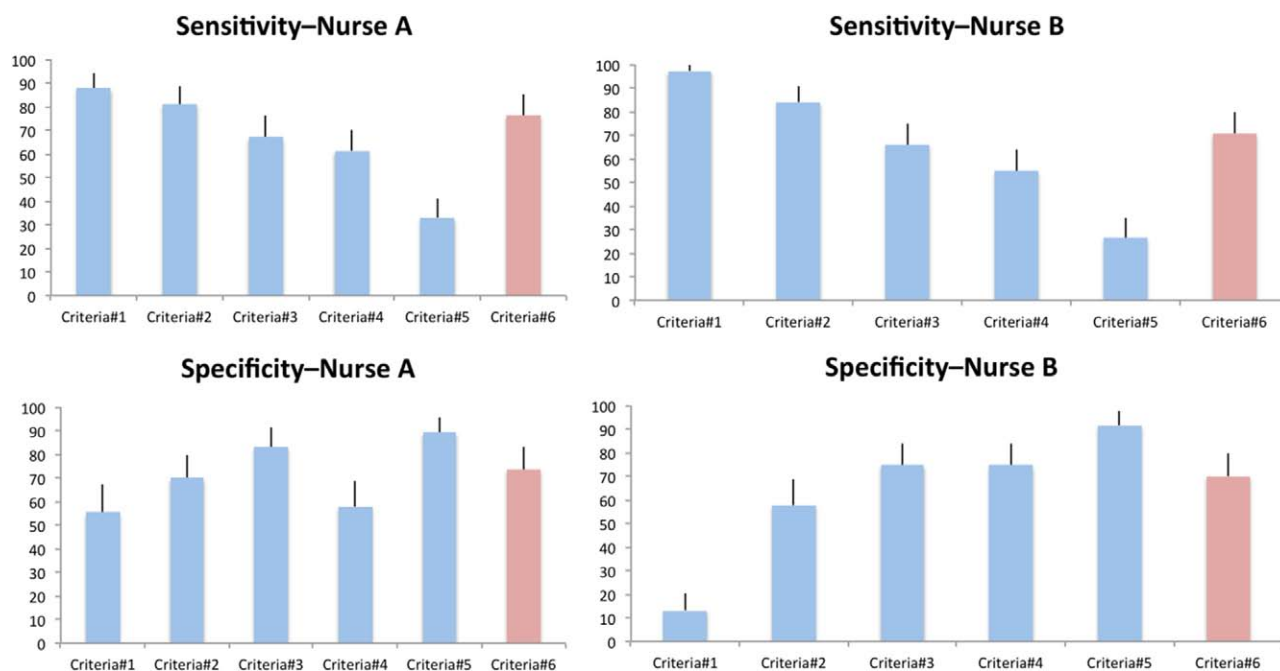
**Table 1. Sensitivity, Specificity, and Interobserver Variability of the Simplified Approach Per Criterion in Part 1 Including 189 Selected Children**

Criteria Tested	Sensitivity Nurse A	Sensitivity Nurse B	Specificity Nurse A	Specificity Nurse B	$\kappa$
MR	87.7 (80 to 92.7)	97.2 (91.7 to 99.1)	55.4 (44.6 to 65.7)	13.5 (7.6 to 22.7)	0.27 (0.14 to 0.40)
MR $\geq 15$ mm	81.1 (72.5 to 87.5)	84 (75.8 to 89.8)	69.9 (59.2 to 78.8)	57.8 (47 to 67.9)	0.47 (0.35 to 0.60)
MR $\geq 20$ mm	67 (57.5 to 75.3)	66 (56.5 to 74.4)	83.1 (73.5 to 89.7)	74.7 (64.3 to 82.9)	0.51 (0.39 to 0.63)
Morphological changes of the MV*	61.3 (51.7 to 70.1)	54.7 (45.2 to 63.9)	57.8 (47 to 67.9)	74.7 (64.3 to 82.9)	0.09 (−0.05 to 0.23)
AR	33 (24.7 to 42.5)	26.4 (18.9 to 35.6)	89.2 (80.5 to 94.3)	91.6 (83.4 to 95.9)	0.57 (0.43 to 0.71)
MR $\geq 20$ mm or AR	76.4 (67.4 to 83.5)	70.7 (61.4 to 78.6)	73.5 (63 to 81.9)	69.9 (59.2 to 78.8)	0.48 (0.35 to 0.60)

AR indicates aortic regurgitation; MR, mitral regurgitation; and MV, mitral valve.

\*Defined by  $\geq 2$  morphological changes of the MV, as per World Heart Federation criteria.<sup>11</sup>





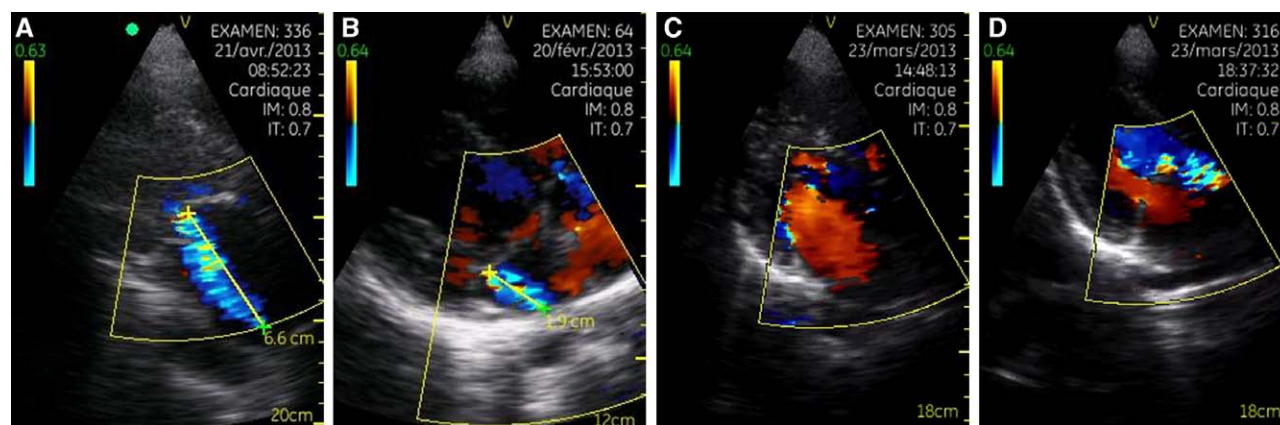
**Figure 2.** Sensitivity and specificity (with upper 95% confidence interval) of the simplified approach for all 6 criteria tested in 189 selected children with high prevalence of rheumatic heart disease (RHD) to diagnose overall RHD for nurses A and B (part 1 of the study). Criteria 1, any mitral regurgitation; criteria 2, mitral regurgitation jet length  $\geq 1.5$  cm; criteria 3, mitral regurgitation jet length  $\geq 2.0$  cm; criteria 4, any morphological changes of the mitral valve defined as coaptation defect, restricted leaflet motion, prolapse, anterior mitral leaflet thickening  $\geq 3$  mm, restricted leaflet motion, chordal thickening, excessive leaflet motion or flail for mitral valve; criteria 5, any aortic regurgitation; and criteria 6 (in red), mitral regurgitation jet length  $\geq 2.0$  cm or any aortic regurgitation (combined criteria).

with pocket devices using simple echocardiographic criteria. Such an approach may be potentially applicable in many poorly resourced settings. We first established an optimal simplified diagnostic algorithm for nonexperts, and then tested it in the field. Our findings suggest that this approach, although imperfect, yields acceptable sensitivity and specificity ( $\approx 80\%$  and  $\approx 90\%$ ) to detect RHD within minutes with no further readings when compared with the state-of-the-art approach.<sup>11</sup> These findings open new possibilities for the implementation of active surveillance of RHD in developing countries.

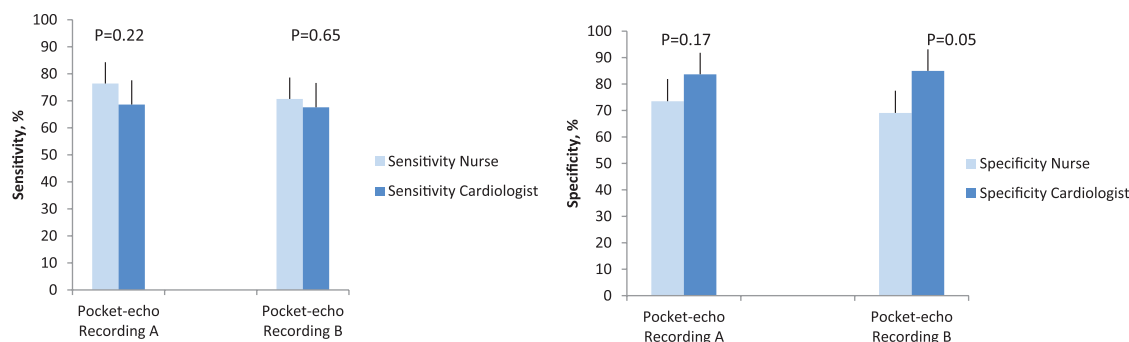
Overall, our study tested a combination of 3 factors, such as (1) the adequacy of the pocket-echo machine in detecting

RHD, (2) the proficiency of the nurses after brief training, and (3) the performance of simplified criteria combining MR jet  $\geq 2.0$  cm or any aortic regurgitation (regardless of jet length). This global strategy incorporates affordable equipment by nonexperienced users with the aim to be translated into public health policies with widespread applicability.

In our study, the image quality of the pocket-echocardiograms was good or fair in the majority ( $\approx 90\%$ ) of cases by 2 operators, as in other settings including adults with larger body habitus.<sup>17,18</sup> Beaton et al<sup>19</sup> have recently shown that pocket-echo (V-scan; GE) was highly sensitive and specific ( $>90\%$ ) to diagnose RHD in a set of previously screened schoolchildren when operated by an experienced cardiologist



**Figure 3.** Examples of images acquired with a pocket-sized echocardiographic device (V-scan; GE) during the study. **A**, Maximum mitral regurgitant jet length measurement  $\geq 2.0$  cm by one of the nurses on a still frame of an apical 2-chamber view. **B**, Maximum mitral regurgitant jet length measurement  $<2.0$  cm by one of the nurses on a still frame of a parasternal long-axis view. **C**, Physiological aortic regurgitation. **D**, Pathological aortic regurgitation.



**Figure 4.** Ability to diagnose any rheumatic heart disease (RHD; ie, definite and borderline RHD), using the focused cardiac ultrasound approach, according to the reader's experience. Light blue, nurse's on-site interpretation; dark blue, cardiologist's interpretation after review of the nurses' recordings (nurse A, pocket-sized echo recording A and nurse B, pocket-sized echo recording B).

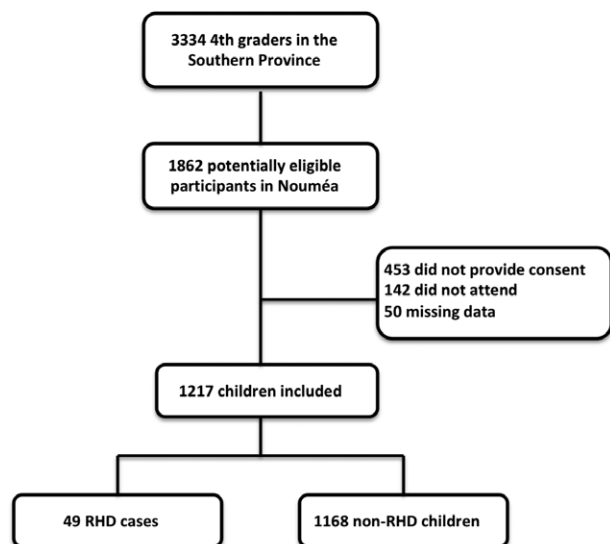
with off-line interpretation by another experienced cardiologist on a dedicated software. Their findings are of the outmost importance because they demonstrate the technical capabilities of pocket-echo for RHD screening. However, the extent to which their methods could be translated into public health policies, in the light of a scarcity of specialized health workers in many low-income countries, remains questionable.<sup>14</sup> Not surprisingly, the performance of pocket-echo in our study was slightly lower, even when an experienced reader interpreted the nurses' echocardiograms, suggesting that operators' skills in acquiring the images may affect the performance of an FCU strategy.

We deliberately chose to test nonexperienced users because it would be the most probable scenario in low-income countries. Sensitivity and specificity of the FCU approach were higher in part 2 than in part 1. Proficiency may have improved after additional tailored training between the 2 parts of the study, which would suggest the effect of longer training schemes on the accuracy of an FCU approach by nonexperts. Several studies have tested FCU by nonexperts with variable results. This may be because of high expectancies of FCU and to different training schemes.<sup>20,21</sup> Echocardiography requires skilled users in image acquisition and during interpretation.

Galderisi et al<sup>22</sup> showed that trainees yield lower performance when compared with experienced cardiologists, in spite of 15 hours of lectures and  $\approx 150$  supervised echocardiograms for the purpose of FCU with a V-scan. We based our training scheme on a previous experience in neighboring Fiji with a total of  $\approx 60$  hours of training (combining lectures and supervised hands-on sessions).<sup>23</sup> Consistently, our results are similar to this pilot study that assessed the feasibility of echo screening by nurses using standard nonportable equipment.<sup>23</sup> As outlined by the American Society of Echocardiography and the European Society of Cardiology, standardization of training programs and proficiency are of outmost need before the widespread use of pocket-echo for FCU, especially for screening purposes by nonexperts.<sup>24,25</sup> In the absence of such standardization, varying results may be obtained according to the skills and motivation of different health workers. There may be room for improvement in the proficiency of RHD screening by nonexperts, possibly through the experience acquired in the field.

Finally, we used simplified echocardiographic criteria for the diagnosis of RHD on site. Diagnostic criteria directly affect the case-detection rates, which may partly explain the performance of our strategy in the detection of RHD.<sup>7</sup> The increasing interest in exploring echocardiographic detection of silent or subclinical RHD has led to the publication of standardized echocardiographic criteria.<sup>6,8,9,11,13</sup> In the lack of a gold standard for RHD diagnosis, the WHF criteria are of the outmost importance as a surrogate marker of the disease. Although based on the best level of evidence, the WHF criteria require experienced operators and readers because it includes the use of continuous Doppler and the analysis of morphological changes of the mitral and aortic valves.<sup>11</sup> Morphological criteria seem to be of additional value in experienced hands with high-end equipment.<sup>7</sup> However, preliminary data suggest that more simple criteria may carry acceptable sensitivity and specificity when it comes to RHD detection.<sup>26</sup> Our prospective evaluation demonstrates that complex diagnostic criteria is not applicable to pocket-echo, such as the analysis of morphological changes of the mitral valve, in line with a previous report.<sup>19</sup>

To date, studies have systematically used a 2-step diagnostic approach using high-quality nonportable equipment and qualified cardiologists.<sup>6,8-10,13,27,28</sup> Although imperfect, our methods explore ways of providing a diagnosis on site with no need for further testing or readings. Remoteness is a major barrier to healthcare delivery, especially in rural areas



**Figure 5.** Flow chart of the school-based study (part 2). RHD indicates rheumatic heart disease.

**Table 2. Sensitivity and Specificity According to Users for the Focused Cardiac Ultrasound Using the Combined Criteria (Mitral Regurgitation Jet  $\geq 2.0$  cm or Any Aortic Regurgitation) in 1217 School Children to Diagnose Either Any RHD or Definite RHD**

Combined Criteria	Nurse A	Nurse B
Sensitivity of any RHD (definite and borderline), n=49	83.7 (70.7–91.6)	77.6 (63.9–87.1)
Sensitivity of definite RHD only, n=15	93.3 (64.7–99.1)	86.7 (59.5–96.7)
Specificity n=1168	90.9 (89.1–92.4)	92.0 (90.3–93.4)

RHD indicates rheumatic heart disease.

in developing countries. Therefore, a rapid diagnosis in school or in the community (without the need for further testing in hospital) seems most appropriate in the planning of active surveillance for RHD.

In addition, the performance of this FCU approach improves in the detection of definite RHD, with a sensitivity of  $\approx 90\%$ . Definite RHD requires secondary prophylaxis by penicillin for  $\geq 10$  years, whereas borderline RHD should be offered regular follow-up.<sup>12</sup> Indeed, some authors question the pathogenicity of borderline RHD although significantly more prevalent among children at risk of RHD.<sup>27</sup> High sensitivity for the detection of definite RHD is, therefore, crucial for the management of screened populations, whereas the interest of screening borderline RHD remains unclear.<sup>29</sup>

### Strengths and Limitations

In considering all issues together, this is the first pragmatic global approach to RHD echocardiography-based screening. We carried out a preliminary step to assess the feasibility of FCU with pocket-echo by nurses in a selected population, and then translated it into the real conditions of school-based screening. Although the performance of the test is imperfect, it yields acceptable sensitivity and specificity, especially in the case of definite RHD.

However, we acknowledge some limitations. First of all, echocardiography-based screening for RHD cannot be recommended at this stage.<sup>30</sup> Active surveillance should be advocated only in places where secondary prophylaxis can be effectively administered, ideally within the frame of a disease control program including a register. Although there are some data that support the cost-effectiveness of echocardiography-based screening, this needs to be more thoroughly addressed.<sup>31</sup> There are still significant unanswered questions about the significance of borderline cases. In addition, a simplified approach does not discriminate

**Table 3. Inter-observer Variability and Percentage of Agreement Among Users for the Focused Cardiac Ultrasound Approach Using the Combined Criteria (Mitral Regurgitation Jet  $\geq 2.0$  cm or Any Aortic Regurgitation) in 1217 Schoolchildren to Diagnose Either Any RHD or Definite RHD.**

Combined Criteria	$\kappa$	Concordance, %
Any RHD (definite and borderline), n=1217	0.57 (0.50–0.65)	91.4
Definite RHD only, n=1183	0.53 (0.44–0.61)	91.8

RHD indicates rheumatic heart disease.

definite from borderline RHD leading to potentially unnecessary treatment in some children. This, however, needs to be appreciated in the context of poor-resourced settings where a more complex approach would be prohibitive. We tested FCU using echocardiographic criteria based on the results of a preliminary study that included older selected children (part 1). The age difference may have an effect on our results.

We assessed in this study a combination of factors that affect the accuracy of our methods and render interpretations challenging. FCUs using pocket-echo by nonexperienced users are still the subject of research and need further evaluation before being recommended in daily practice.<sup>24,25</sup> Longer training schemes may improve users' skills in both the image acquisition and interpretation. Our population-based study may have lacked power, especially to address improvement of the performance overtime. We screened relatively young children aged 9 to 10 years. This may explain why all lesions were mild. Although we cannot generalize our results to other settings, RHD lesions usually become more severe later in adolescence, thereby more probably be detected by FCU.<sup>32</sup>

Further studies are needed to validate this strategy before being translated into public health policies. Cost-effectiveness analysis should, however, consider simplified strategies for active surveillance as the one described in this work.

### Conclusions

FCU with pocket-sized devices, operated by nonexperts, through simple echocardiographic criteria, seems feasible and yields acceptable sensitivity and specificity for RHD detection when compared with the state-of-art approach. FCU has the potential to provide a diagnosis on site within minutes. However, echocardiography-based screening cannot be advocated for at this stage, and further evaluation is needed before implementation in countries where RHD remains endemic.

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### Disclosures

None.



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### CLINICAL PERSPECTIVE

Rheumatic heart disease (RHD), a preventable condition, remains the leading cause of acquired cardiac disease in the young worldwide. Early detection has the potential to prevent progression of the disease. Echocardiography may be of value in the design of active surveillance. Methods used to date, have, however, involved high-end equipment and experienced cardiologists using complex diagnostic criteria. This study explored ways of making echo-based screening for RHD feasible and affordable in low- and middle-income countries. We tested a focused cardiac ultrasound approach compared with the current gold standard for the diagnosis of RHD (including definite and borderline cases). The focused cardiac ultrasound approach used included (1) a pocket-sized echo machine, (2) nonexpert staff (2 nurses after a standardized 60-hour training program) for performance and interpretation, and (3) a simplified set of echocardiographic criteria. We first tested different echocardiographic criteria in a pilot study including selected children with high prevalence of RHD. Our initial findings suggested that a mitral regurgitation jet length  $\geq 2.0$  cm or aortic regurgitation (regardless its jet length) yielded acceptable sensitivity and specificity. We then prospectively used these criteria in a school-based survey including 1217 children. Using this approach, the sensitivity and specificity to detect all RHD were of  $\approx 80\%$  and  $\approx 90\%$ , respectively. Our findings suggest that focused cardiac ultrasound by nonexperts using pocket-echocardiograms may be an attractive solution to implement echo-based active surveillance in resource-constrained regions.



## **SUPPLEMENTAL MATERIAL**

### **Supplemental Methods: Training scheme**

The objectives of the training scheme were to gradually: (i) introduce the basic knowledge in cardiovascular physiology and cardiac anatomy; (ii) recognize the long and short axis parasternal, and all 3 apical transthoracic views, name the four chambers and the four cardiac valves; (iii) acquire the views in grey scale and use Color Doppler; (iv) recognize morphological changes of the mitral valve (thickening of the anterior leaflet and of the chordae, restriction of the posterior and anterior leaflet, prolapse of the tip of the mitral leaflet); (v) detect the presence of mitral and/or aortic regurgitation; (vi) measure the maximum mitral regurgitation length using the caliper function on the device.

Training included theoretical lectures for 3 days, followed by 30 hours 2 to 1 hands-on sessions (with normal volunteers followed by sessions with patients at the echocardiography unit, Centre Hospitalier Territorial de Nouvelle Calédonie, Nouméa, New Caledonia) in February 2013. Further tailored tutorship was undertaken after a preliminary assessment of the nurses' capacities, after completion of part 1. Nurses reviewed a set of 50 of their scans with an experienced reader and undertook 12-hours practical sessions (one to one sessions) addressing the pitfalls of each nurse (acquisition, interpretation). Nurses were not asked to detect lesions of other etiologies, namely congenital heart disease.

**Supplemental Table. Echocardiographic findings - Part 1.**

Reference echocardiographic findings	RHD N=106 (%)	No RHD N=83 (%)	All, N=189 (%)
Definite RHD	63 (59.4)	0	63 (33.3)
Borderline RHD	43 (40.6)	0	43 (22.8)
MR	101 (95.3)	51 (61.4)	152 (80.4)
Physiological MR	21 (19.8)	46 (55.4)	67 (35.4)
MR grade 1	73 (68.9)	5 (6.0)	78 (41.3)
MR grade 2	1 (9.4)	0	1 (0.5)
MR grade $\geq 3$	6 (5.7)	0	6 (3.2)
AR	36 (34.0)	10 (12.0)	46 (24.3)
Physiological AR	13 (12.3)	9 (10.8)	22 (11.6)
AR grade 1	17 (16.0)	1 (1.2)	18 (9.5)
AR grade 2	5 (4.7)	0	5 (2.6)
AR grade $\geq 3$	1 (0.9)	0	1 (0.5)
Mitral stenosis (mean gradient $\geq 4$ mmHg)	6 (5.7)	0	6 (3.2)
MR :			
Seen in 2 views	98 (92.5)	39 (47.0)	137 (72.5)
Jet length $\geq 2$ cm	80 (75.5)	9 (10.8)	89 (47.1)
Vmax $\geq 3$ m/s	86 (92.0)	15 (18.1)	101 (53.4)
Pan-systolic	58 (54.7)	0	58 (30.7)
AR :			
Seen in 2 views	32 (30.2)	9 (10.8)	41 (21.7)
Jet length $\geq 1$ cm	32 (30.2)	8 (9.6)	40 (21.2)
Vmax $\geq 3$ m/s	25 (23.6)	5 (6.0)	30 (15.9)
Pan-diastolic	20 (18.9)	0	20 (10.6)
Morphological changes of the MV			
AML thickening $\geq 3$ mm	45 (42.5)	0	45 (23.8)
Restricted leaflet motion	93 (87.7)	1 (1.2)	94 (49.7)
Chordal thickening	90 (84.9)	0	90 (47.6)
Excessive leaflet motion	1 (0.9)	0	1 (0.5)
Flail	2 (1.9)	0	2 (1.1)
Morphological changes of the AV:			
Coaptation defect	3 (2.8)	0	3 (1.6)
Restricted leaflet motion	2 (1.9)	0	2 (1.1)
Prolapse	4 (3.8)	0	4 (2.1)
Irregular or focal thickening	12 (11.3)	2 (2.4)	14 (7.4)

RHD, Rheumatic Heart Disease. MR, mitral regurgitation. AR, aortic regurgitation. Vmax, maximum peak velocity on continuous wave Doppler. MV, mitral valve. AV, aortic valve. AML, anterior mitral valve.

## Screening for Rheumatic Heart Disease: Evaluation of a Focused Cardiac Ultrasound Approach

Mariana Mirabel, Raoul Bacquelin, Muriel Tafflet, Corinne Robillard, Bertrand Huon, Philippe Corsenac, Isabelle de Frémicourt, Kumar Narayanan, Jean-Michel Meunier, Baptiste Noël, Albert Alain Hagège, Bernard Rouchon, Xavier Jouven and Eloi Marijon

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