Original Article

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Echocardiographic Screening for Diagnosis of Rheumatic Heart Disease by Nurses: A Diagnostic Accuracy Study in Nepal

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Abstract

Background and Aims: Growing evidence suggests that training nurses in echocardiographic screening for latent rheumatic heart disease (RHD) detection could be a promising strategy, especially in settings where cardiologists are often inaccessible. This diagnostic accuracy study evaluated the feasibility and accuracy of nurse-led RHD focused echocardiographic screening in Nepal.

Methods: The prospective diagnostic accuracy study consisted of three phases: training, screening and testing. Four nurses were trained in RHD-focused echocardiography for six weeks using a structured training module. Nurses were tested on an enriched, conveniently selected sample of 100 children aged 6–16 years (36 with RHD, 64 without) to ensure adequate statistical power for sensitivity estimates. Findings were compared with standard echocardiographic assessments performed by an expert pediatric cardiologist. Diagnostic accuracy was assessed using sensitivity, specificity, area under the ROC curve (AUC) and Cohen's kappa

Results: Among all nurses, mean sensitivity and specificity for any RHD were 87.5% (95% CI: 84.3–90.7%) and 95.3% (95% CI: 93.2–97.4%), respectively, with almost perfect inter-rater agreement ($\kappa = 0.84$, $p<0.001$). AUC ranged from 0.90 to 0.95. Sensitivity for borderline RHD was markedly lower at 47.9%. The mean time difference between nurses and the cardiologist was modest but statistically significant (00:32 min:sec for RHD-negative, 01:31 for RHD-positive cases; $p<0.05$).

Conclusions: Nurse-performed echocardiographic screening following brief structured training demonstrated acceptable diagnostic accuracy for RHD in school-age children. Within a two-step model (nurse screener followed by cardiologist confirmation), task-shifting represents a scalable and equitable strategy for early RHD detection in resource-limited settings such as Nepal.

Keywords: Cardiology, Diagnosis, Echocardiographic screening, Rheumatic heart disease, Nepal, Nurses

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Introduction

Rheumatic heart disease (RHD) remains one of the most preventable causes of heart disease in children and young adults worldwide, and is the most common cardiovascular disease in individuals under 25 years of age.[1] RHD is the long-term sequela of acute rheumatic fever (ARF) arising from an autoimmune response to Group A Streptococcus pharyngitis.[2-4]

Rheumatic carditis frequently occurs at a subclinical level, making primary prophylaxis alone insufficient for population-level disease control.[5] Echocardiography is the gold standard for RHD diagnosis; accurate classification is critical because false positives expose patients to unnecessary long-term penicillin prophylaxis and psychological labelling, while false negatives forfeit secondary prevention.[6]

In Nepal, RHD prevalence ranges from 1 to 10 per 1,000 schoolchildren.[7-12] With approximately 150 cardiologists serving 29 million people, most of whom are concentrated in urban centres, Therefore, comprehensive echocardiographic screening at population level is not feasible by specialists alone. Task-shifting to trained nurses using portable devices is an emerging solution in comparable settings.[13-18] This study evaluated whether nurses, following a brief structured RHD-focused echocardiography training programme with supervised field experience, could perform screening with acceptable diagnostic accuracy. This represents one of the first formal diagnostic accuracy validations of a nurse-led RHD screening model in South Asia.

Methods

Study Setting

This prospective RHD diagnostic accuracy study was conducted in Kathmandu, Nepal between August 2022 to August 2023 in three phases: (1) training, (2) supervised field experience, (3) competency testing. Nepal Heart Foundation (NHF) developed the training programme and led implementation. The six-week training phase (1 May to 15 June 2023) comprised one week of theory, one week of supervised practical training and four weeks of hands-on field experience. In the third phase, diagnostic competency was assessed on a pre-selected group of 100 children with established diagnoses (Figure 1).

Ethical clearance was obtained from the National Health Research Council (Protocol No. 275/2022). Written informed consent was obtained from guardians, and assent was obtained from children aged 7 years and older (verbal assent for those aged 7 to <12 years and written assent for those aged 12 to 16 years), in accordance with the National Ethical Guidelines for Health Research in Nepal 2022. All procedures were conducted in accordance with the Declaration of Helsinki.

Sample size

Sample size was calculated using a published formulae for diagnostic accuracy studies.[19] To determine the minimum number of participants required, we utilized the standard formula for diagnostic accuracy.

For RHD Cases (Sensitivity):

$$n\_cases = (Z2 \text{ X } Se(1-Se))/d2$$
$$= (1.96)2 \text{ X } 0.90(1\text{-}0.90)/(0.10)2$$
$$= 35$$

For Controls (Specificity):

$$n\_controls = (Z2 \text{ X } Sp(1-Sp))/d2$$
$$= (1.96)2 \text{ X } 0.92(1\text{-}0.92)/(0.10)2$$
$$=28$$

where *Se* = sensitivity, *Sp* = specificity, *d* = absolute precision, and *Z* = 1.96 (95% confidence). Using *Se* = 0.90, *Sp* = 0.92, and *d* = 0.10, the minimum sample comprised 35 RHD cases and 28 controls (total n = 63). The sample was increased to 100 (36 RHD, 64 non-RHD) to improve precision and support inter-rater reliability analysis across four nurses (400 total observations). Participants aged 6–16 years were selected by convenience sampling from a cohort with previously established diagnoses.

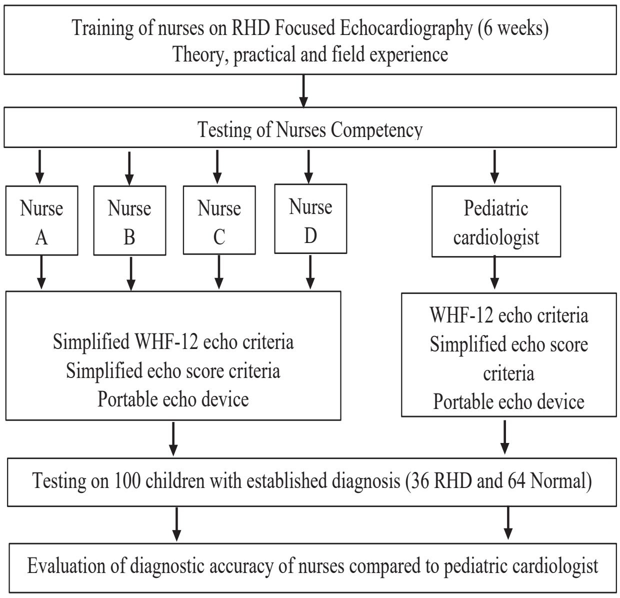

Figure 1: *Flow Diagram of the Study*

Nurse Selection, Training and Field Experience

Four bachelor's-level nurses with no prior ultrasound experience were selected by structured interview. A six-week programme comprised one week of theory, one week of practical instruction, and four weeks of supervised echocardiographic field experience (minimum 20 screenings per day). Nurses were trained on the M-Turbo Ultrasound System (SonoSite, USA) using simplified echocardiographic criteria derived from the 2012 WHF guidelines [20] and an echo-based risk stratification score.[21] Competency was recorded daily on a 10-point, 30-item Likert instrument.

Competency Testing

Following training, nurses independently assessed 100 pre-selected children (36 RHD, 64 normal echocardiographic findings) at a Heart Centre in Lalitpur. Four identical portable devices were used simultaneously in four blinded rooms. Each child was independently examined by all four nurses and by the expert pediatric cardiologist on the same day; all operators were blinded to each other's findings and to prior diagnoses.

Reference Standard and Statistical Analysis

A single expert pediatric cardiologist (>15 years of RHD imaging experience) applied unmodified 2012 WHF criteria[20] as the reference standard, blinded to all prior data. Sensitivity, specificity, PPV, and

NPV were estimated with Clopper-Pearson exact binomial 95% CI. Mixed-effects logistic regression with random intercepts for participant ID accounted for within-subject clustering across four assessments per child. ROC curves and AUC were derived from an ordinal 0–10 diagnostic score. Cohen's kappa (κ) was interpreted using Landis and Koch benchmarks.[22] Predictive values were adjusted to a real-world prevalence of ~1%. Analysis used SPSS v29 and STATA v18.

Procedures

Nurses were trained in basic RHD echocardiography, focusing on left heart views (PLAX, PSAX, Apical 4 and 5 chamber), valve morphology, and regurgitation jet measurement using Color Doppler. Screening followed a 9 step algorithm. Each child completed a questionnaire, was coded, and examined sequentially by all four nurses and the cardiologist, with findings and test duration recorded. Ten children were screened daily, and all raters were blinded.

Data Management and Analysis

The study proforma data were verified, double entered, and analyzed in SPSS and STATA. Diagnostic accuracy was assessed with sensitivity, specificity, and ROC AUC, accounting for clustered observations via mixed effects logistic regression. Inter rater reliability was measured with percent agreement and Cohen's Kappa. Efficiency was evaluated by comparing diagnostic times between nurses and the cardiologist, stratified by case category. Statistical significance was set at $p<0.05$.

Results

Of 100 children, 41 (41%) were males and 59 (59%) females. The 36 RHD cases comprised 24 definite and 12 borderline diagnoses; by risk category: 7 low-risk, 7 intermediate-risk, and 22 high-risk (Table 1).

For any RHD, mean sensitivity and specificity were 87.5% (95% CI: 84.3–90.7%) and 95.3% (95% CI: 93.2–97.4%), with almost perfect agreement (mean κ = 0.84, $p<0.001$). For definite RHD, sensitivity was 89.6% (κ = 0.84). For borderline RHD, sensitivity was markedly lower at 47.9% (95% CI: 43.0–52.8%) with specificity 95.7% and moderate agreement (κ = 0.48). Individual nurse metrics are presented in Table 2. Risk category stratification accuracy is in Table 3, sensitivity was 50.0% (low-risk), 46.4% (intermediate-risk), and 84.1% (high-risk).

AUC ranged from 0.90 to 0.95 across nurses (Figure 2). ROC curve equality between operators was not significant (p=0.27), confirming consistent discriminative performance. At adjusted real-world prevalence (~1%), NPV was 99.8% and PPV was 15.8%, demonstrating that the tool is highly effective for ruling out disease; low PPV in low-prevalence settings mandates expert confirmation of positive findings.

Mean diagnostic time was longer for nurses than the cardiologist in all categories (Table 4); differences were 01:31 min:sec for RHD-positive and 00:32 min:sec for RHD-negative cases (both $p<0.05$). Absolute differences were modest and operationally acceptable.

Table 1. Demographic Characteristics and Diagnosis of the Test Sample (n=100)

Characteristic	All n(%)	Def RHD	BL RHD	Any RHD	Low Risk	Int Risk	High Risk
Male	41(41.0)	9(37.5)	3(25.0)	12(33.3)	1(14.3)	2(28.6)	9(40.9)
Female	59(59.0)	15(62.5)	9(75.0)	24(66.7)	6(85.7)	5(71.4)	13(59.1)
Age 6–10	26(26.0)	2(8.3)	2(16.7)	4(11.1)	2(28.6)	0(0.0)	2(9.1)
Age 11–13	41(41.0)	6(25.0)	6(50.0)	12(33.3)	3(42.9)	3(42.9)	6(27.3)
Age 14–16	33(33.0)	16(66.7)	4(33.3)	20(55.6)	2(28.6)	4(57.1)	14(63.6)

BL = Borderline; Def = Definite; Int = Intermediate. Values are n (%).

Table 2. Diagnostic Accuracy of Nurses for RHD Detection (vs Pediatric Cardiologist Reference Standard)

Operator	n	Sens % (95%CI)	Spec % (95%CI)	PPV%	NPV%	κ
Any RHD						
Nurse A	32	83.3 (76.0–90.6)	96.9 (93.5–100.0)	93.8	91.2	0.82***
Nurse B	34	86.1 (79.3–92.9)	95.3 (91.2–99.5)	91.2	92.4	0.82***
Nurse C	35	86.1 (79.3–92.9)	93.8 (89.0–98.5)	88.6	92.3	0.80***
Nurse D	37	94.4 (90.0–98.9)	95.3 (91.2–99.5)	91.9	96.8	0.89***
Mean	—	87.5 (84.3–90.7)	95.3 (93.2–97.4)	91.3	93.1	0.84***

Operator	n	Sens % (95%CI)	Spec % (95%CI)	PPV%	NPV%	κ
Borderline RHD						
Nurse A	7	41.7 (32.0–51.3)	97.7 (94.8–100.0)	71.4	92.5	0.48***
Nurse B	9	41.7 (32.0–51.3)	95.5 (91.4–99.5)	55.6	92.3	0.42***
Nurse C	10	50.0 (40.2–59.8)	95.5 (91.4–99.5)	60.0	93.3	0.49***
Nurse D	12	58.3 (48.7–68.0)	94.3 (89.8–98.9)	58.3	94.3	0.53***
Mean	—	47.9 (43.0–52.8)	95.7 (93.8–97.7)	60.5	93.1	0.48***
Definite RHD						
Nurse A	25	91.7 (86.3–97.1)	96.1 (92.2–99.9)	88.0	97.3	0.87***
Nurse B	25	91.7 (86.3–97.1)	96.1 (92.2–99.9)	88.0	97.3	0.87***
Nurse C	25	91.7 (86.3–97.1)	96.1 (92.2–99.9)	88.0	97.3	0.87***
Nurse D	25	83.3 (76.0–90.6)	93.4 (88.6–98.3)	80.0	94.7	0.76***
Mean	—	89.6 (86.6–92.6)	95.4 (93.3–97.5)	86.0	96.7	0.84***

PPV = Positive Predictive Value; NPV = Negative Predictive Value; CI = Clopper–Pearson exact; κ = Cohen's kappa. ***p<0.001. Shaded rows = mean across four nurses.

Table 3. Risk Category Stratification Accuracy — Mean Across Four Nurses (n=36 RHD cases)

Category	Sens% (95%CI)	Spec% (95%CI)	PPV%	NPV%	Mean κ
Low Risk RHD	50.0 (41.8–58.2)	93.1 (89.0–97.2)	63.6	88.5	0.47***
Intermediate Risk	46.4 (38.3–54.6)	83.6 (77.6–89.7)	40.6	86.6	0.29**
High Risk RHD	84.1 (78.1–90.1)	71.4 (64.1–78.8)	82.2	74.1	0.56***

**p<0.01; ***p<0.001.

Table 4. Time-to-Diagnosis: Nurses vs Expert Cardiologist

Case Category	Cardiologist mean (mm:ss)	Nurses mean (mm:ss)	Difference (95%CI)	p
RHD-Positive (n=36)	04:20	05:51	01:31 (01:06–01:55)	<0.05
Borderline (n=12)	03:41	05:12	01:31 (00:51–02:11)	<0.05
Definite (n=24)	04:40	06:11	01:30 (00:59–02:02)	<0.05
RHD-Negative (n=64)	02:59	03:32	00:32 (00:17–00:47)	<0.05

Wilcoxon signed-rank test. Absolute time differences were modest and operationally acceptable in screening settings.

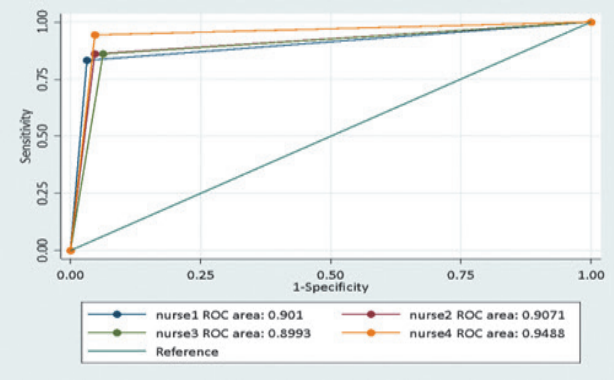

Figure 2. *Receiver Operating Characteristic (ROC) Curves for Each Nurse for Detection of Any RHD (AUC range 0.90–0.95; inter-operator equality p=0.27)*

Discussion

This study is among the first to evaluate a structured and validated nurse-led RHD echocardiography training model within the South Asian context. Prior task-shifting studies from sub-Saharan Africa and the Pacific [13-15] established broad feasibility but did not address three critical gaps that this study fills:[1] a training curriculum adapted for the South Asian context;[2] risk stratification across all three WHF categories rather than binary RHD detection alone; and[3] an explicitly defined role for nurses as first-line screeners within a two-step model (nurse followed by cardiologist confirmation) rather than as autonomous diagnosticians. These distinctions sharpen both the scientific contribution and the implementation pathway.

We designed a six-week training programme comprising one week each of theory and practical instruction and four weeks of supervised field experience. This duration was sufficient for nurses with no prior ultrasound experience to achieve competency. By the end of the second week, nurses were able to acquire the PLAX view with colour Doppler imaging, which proved to be the most accessible view. High-quality images of the mitral and aortic valves in all four required views (PLAX, PSAX, apical four-chamber, and apical five-chamber) were consistently achieved by the end of week four. The fifth and sixth weeks were used to refine regurgitation jet measurements and build diagnostic confidence. The successful use of portable devices in this setting further supports future integration of ultra-portable handheld devices to extend screening reach into rural areas without cardiologist access.

These findings suggest that a regurgitation-focused simplified protocol rather than the complete WHF morphological feature set may be more appropriate for non-expert screeners, and warrants prospective validation. The lower sensitivity for borderline RHD (47.9%) relative to definite RHD (89.6%) reflects the inherent diagnostic difficulty of early or equivocal valve changes. Borderline RHD, by definition, occupies a diagnostic grey zone and requires more nuanced echocardiographic assessment. This limitation should be considered when designing future nurse-led screening algorithms. Borderline RHD is precisely the group in which screening has the greatest potential impact for secondary prevention: studies demonstrate that borderline RHD prevalence is at least double that of definite RHD and may more than triple the number eligible for prophylaxis.[23] However, the consequences of false positives in this group must be explicitly acknowledged. Labelling a healthy child with RHD carries substantial psychological burden and may lead to years of unnecessary, painful long-term benzathine penicillin injections.[5] This risk reinforces a fundamental principle of this model: nurses function strictly as screeners, and every suspicious finding requires formal cardiologist confirmation before any treatment is initiated. Future nurse-led screening algorithms should embed this two-step safeguard as a mandatory clinical governance requirement.

These results align with evidence from Fiji,[13] Uganda,[16] and Australia,[14] where non-expert health workers following targeted training achieved comparable accuracy for definite RHD. Our work extends this evidence base to Nepal and addresses an important equity dimension: in Nepal, nearly all of the approximately 150 cardiologists practice in urban centres, while the rural population where the RHD burden is highest has virtually no access to early diagnosis. Task-shifting to trained nurses directly bridges this rural-urban divide and provides a concrete pathway for equitable national health system integration.

The diagnostic time difference between nurses and the cardiologist, while statistically significant, was modest in absolute terms (approximately 90 seconds for RHD-positive and 32 seconds for RHD-negative cases).

This gap is operationally acceptable in high-volume school-based screening and will likely narrow further with accumulated experience.

Several limitations of this study warrant acknowledgement. First, the sample of four nurses drawn from similar academic and professional backgrounds limits generalizability to a broader range of non-expert operators. Second, the convenience sampling approach for case selection may have introduced selection bias. Third, the enriched 36% RHD prevalence inflates PPV relative to the real-world ~1% population prevalence; this is addressed through AUC analysis and prevalence-adjusted metrics. Fourth and critically this study lacks long-term follow-up data on the progression or regression of identified borderline cases, a gap that persists across the broader RHD literature. Longitudinal studies in South Asian populations are needed to define the natural history of borderline RHD and to validate these screening findings in field conditions.

Implications for National RHD Programs

The findings offer a scalable framework for integrating RHD screening into the national health architecture of resource-limited settings like Nepal. We propose a two-step model: trained nurses use simplified echocardiographic criteria and portable or handheld devices to identify suspicious cases during mass school-based screenings (Step 1); all flagged cases are referred to a cardiologist for WHF-12 adjudication before any management decision (Step 2). This structure safeguards against false-positive harm while enabling broad population coverage.

Regarding throughput and cost-effectiveness: nurses demonstrated a minimum capacity of 20 screenings per day during the field phase. Although a formal cost-effectiveness analysis was beyond this study's scope, task-shifting substantially reduces dependence on specialist time. With a cardiologist-to-population ratio of approximately 1:200,000 in Nepal, universal specialist screening is not feasible; the lower cost per nurse trained compared with physician training, combined with integration into existing national school health programmes, could substantially lower the cost per child screened and enable systematic coverage of the 5–14 year age group at peak RHD incidence risk.

Conclusions

Nurses, following a brief structured echocardiographic training programme, demonstrated acceptable diagnostic accuracy for RHD in school-age children. Functioning as first-line screeners within a two-step model with mandatory cardiologist confirmation prior to treatment initiation, they can meaningfully expand early case detection while protecting against false-positive harm. This approach addresses both the specialist workforce shortage and the rural-urban equity gap in Nepal, and represents a viable, scalable strategy for health policy in RHD-endemic settings.

Contributors

Prakash Raj Regmi (concept, protocol, overall supervision, paper writing); Urmila Shakya (nurses training, testing, paper writing); Raja Ram Dhungana (data management, data analysis, paper writing), Durga Sapkota (nurses training); Shyam Thapa (protocol development, report writing, editing). All authors contributed to the writing of the manuscript and read and approved the final version.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Declaration Of Competing Interests

The authors declare no known competing financial interests or personal relationships that could have influenced the conduct or reporting of this work.

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