# Handheld echocardiography for rural cardiac triage in primary care: A feasibility and diagnostic agreement study of a task-shifting model with remote cardiologist validation

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## ABSTRACT

**Introduction: Access to formal echocardiography is often delayed in geographically remote settings. This study evaluated the feasibility, image quality and diagnostic agreement of focused handheld echocardiography performed by a trained Family Medicine Specialist (FMS) in a rural Malaysian clinic with asynchronous cardiologist validation.**

**Materials and Methods: We conducted a retrospective observational study of 41 adult patients who underwent focused handheld echocardiography for dyspnoea or suspected cardiac symptoms at a rural primary care clinic in Sarawak, Malaysia, between 24 August 2025 and 5 February 2026. A trained FMS performed focused examinations during routine care. Stored images were reviewed asynchronously by a consultant cardiologist blinded to the FMS interpretation. We evaluated workflow feasibility, cardiologist-rated image quality and agreement for classification of left ventricular (LV) systolic function as normal or reduced.**

**Results: Forty-one patients were included (mean age 60.4±17.5 years; 51% male). Median scan duration was 8 minutes (range 3–14), and technical difficulties were reported in 19 examinations (46.3%). Nevertheless, all 41 stored studies contained sufficient images for cardiologist classification of LV systolic function. Endocardial border definition was rated good or fair in 87.8% of studies, whereas colour Doppler was frequently non-diagnostic. The FMS identified reduced LV systolic function in 13 patients (32%), compared with 10 patients (24%) by cardiologist review. Overall agreement was 82.9%, with Cohen's kappa 0.58. Sensitivity was 80.0%, specificity 83.9%, positive predictive value 61.5%, negative predictive value 92.9% and overall accuracy 82.9%.**

**Conclusion: In this rural primary care setting, focused handheld echocardiography performed by a trained FMS was feasible and showed moderate agreement with remote cardiologist interpretation for identifying reduced left ventricular systolic function. These findings support a hypothesis-generating service-delivery model in which handheld ultrasound may assist rural cardiac triage and referral prioritization, but larger multi-site studies are needed before practice-changing implementation can be recommended.**

**KEYWORDS:**
*Handheld echocardiography, Rural healthcare, Task shifting, Health service delivery, Cardiac triage*

## INTRODUCTION

Cardiovascular disease remains a major cause of morbidity and mortality, and timely access to cardiac imaging is central to the evaluation of symptoms such as dyspnoea, suspected heart failure, and structural heart disease.[1] Echocardiography is particularly valuable because it is non-invasive, portable relative to other imaging modalities, and capable of providing real-time assessment of cardiac structure and function.[2-3]

Despite its clinical importance, access to formal transthoracic echocardiography remains uneven. In rural and geographically isolated settings, echocardiography services are commonly concentrated in tertiary centres, creating delays in diagnosis and referral for patients who must travel long distances for specialist assessment. This access gap is especially relevant in Sarawak, where dispersed populations, difficult terrain, and long travel times can limit timely evaluation of patients presenting to primary care clinics with cardiopulmonary symptoms.[3-4]

Handheld cardiac ultrasound offers a potential service-delivery response to this problem. When used as focused cardiac ultrasound rather than comprehensive echocardiography, handheld devices may allow frontline clinicians to answer targeted clinical questions at the point of care, including whether left ventricular systolic function appears reduced or whether urgent escalation is needed. Prior studies have shown that handheld ultrasound can improve bedside cardiovascular assessment and that non-cardiologist clinicians, after focused training, may identify clinically important abnormalities with variable but sometimes acceptable accuracy.[5-12]

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Task-shifting models are particularly relevant in rural health systems, where workforce constraints and limited specialist availability require new approaches to diagnostic access. In low-resource settings, handheld echocardiography performed by non-cardiologists has been studied in screening and service-delivery roles, including rheumatic heart disease programmes and focused cardiac assessment pathways.[13-16] However, evidence from remote primary care settings remains limited, especially in Southeast Asia, and many published studies have been conducted in hospital-based or urban environments.[5-12]

Within our current practice context, rural patients with suspected cardiac disease are often assessed clinically and then referred onward for formal echocardiography if concern persists. This pathway can delay risk stratification, prolong uncertainty, and contribute to inefficient referral prioritization. We therefore implemented a focused handheld echocardiography workflow in a rural primary care clinic, supported by asynchronous cardiologist review of stored images. This approach was designed not to replace standard echocardiography, but to strengthen frontline triage in a setting where access is constrained.

This study aimed to evaluate the feasibility, image quality, and diagnostic agreement of this task-shifting model in rural Sarawak. We conceptualised the project as a hypothesis-generating implementation study: if focused handheld echocardiography can be integrated into rural primary care with acceptable performance, it may inform larger-scale research on equitable diagnostic access, rural referral systems, and service redesign.

## MATERIALS AND METHODS

### Study Design and Setting

This was a retrospective observational service-evaluation study of a task-shifting echocardiography workflow implemented at Klinik Kesihatan Sungai Asap, a rural primary care clinic in Sarawak, Malaysia, located approximately three hours from the nearest tertiary cardiac centre. All adult patients recorded as having undergone handheld echocardiography between 24 August 2025 and 5 February 2026 as part of routine care were included.

### Training Programme

Prior to implementation of handheld echocardiography services at the clinic, a Family Medicine Specialist (FMS) underwent a structured two-week supervised echocardiography training programme at Sarawak Heart Centre, focusing on acquisition of standard parasternal and apical views, qualitative assessment of left ventricular (LV) systolic function, and recognition of major valvular abnormalities. The training programme was designed to provide competency-based acquisition of standard echocardiographic views and qualitative assessment of left ventricular systolic function, in line with recommendations for focused cardiac ultrasound training.[17]

### Patient Recruitment

Adult patients presenting with dyspnoea or suspected cardiac symptoms who underwent handheld echocardiography as part of routine clinical care were included. All 41 recorded examinations during the study period were analysed, and no scanned patient was excluded. The total number of clinic attendees with these symptoms who were not selected for scanning was not captured; therefore, the proportion of all symptomatic attendees who underwent scanning could not be determined.

### Echocardiography Protocol

Focused cardiac ultrasound examinations were performed using a wireless phased-array handheld ultrasound probe (VaveHealth, San Jose, CA, USA). Standard views included parasternal long-axis, parasternal short-axis, and apical four-chamber views. LV systolic function was assessed qualitatively (eyeballing method) and categorised as normal or reduced based on overall myocardial contractility across the standard views. The examinations were performed as focused cardiac ultrasound, with the primary objective of assessing LV systolic function rather than providing a comprehensive echocardiographic evaluation, in accordance with ASE recommendations.[17] Stored images were reviewed asynchronously by a single consultant cardiologist at a tertiary cardiac centre. The cardiologist was blinded to the FMS interpretation.

### Image Quality Assessment

Image quality was evaluated asynchronously by a consultant cardiologist using three predefined domains: endocardial border definition, valve visualization, and colour Doppler quality. Endocardial border definition was graded as good (>95% of endocardial borders visualized), fair (70–95% visualized), poor (<70% visualized), or non-diagnostic. Valve visualization was classified as good, fair, poor, or non-diagnostic, based on the clarity and completeness of valve structure assessment. Colour Doppler quality was categorized as good, fair, poor, or non-diagnostic, depending on the ability to reliably assess flow signals. The FMS did not independently grade image quality; therefore, interobserver agreement for image-quality ratings was not assessed.

### Outcome Measures

The primary outcome was the level of agreement between FMS and cardiologist in the classification of LV systolic function, categorized as normal or reduced. Secondary outcomes included scan feasibility, scan duration, technical difficulties encountered during image acquisition, and overall image quality assessment.

### Statistical Analysis

Continuous variables were expressed as mean ± standard deviation or median with range. Categorical variables were presented as frequencies and percentages. Agreement between FMS and cardiologist assessment of LV systolic function was analysed using Cohen's kappa coefficient. Diagnostic performance including sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy were calculated using cardiologist interpretation as the reference standard.

### Ethical Approval

Ethical approval for this study was obtained from the Medical Research and Ethics Committee, Ministry of Health Malaysia (NMRR ID-25-04126-YJM). This study was conducted in accordance with the Declaration of Helsinki.

**Table I: Baseline characteristics of patients**

| Variable | Overall (n=41) |
|---|---|
| Age, years | 60.4 ± 17.5 |
| Male sex | 21 (51%) |
| Systolic BP, mmHg | 135 ± 27 |
| Diastolic BP, mmHg | 79 ± 16 |
| Heart rate, bpm | 88 ± 20 |
| Respiratory rate, breaths/min | 24 ± 4 |
| Oxygen saturation (%) | 93.9 (66-100) |
| Hypertension | 24 (58%) |
| Diabetes mellitus | 5 (12%) |
| Chronic kidney disease | 7 (17%) |
| Atrial fibrillation | 3 (7%) |
| Heart disease | 6 (14%) |
| Chronic lung disease | 10 (24%) |

**Table II: Scan feasibility and workflow**

| Parameter | Result |
|---|---|
| Scan duration, minutes | 8 (3-14) |
| Any technical difficulty encountered | 19 (46.3%) |
| Thick chest wall/breast tissue | 8 (42.1%) |
| Pulmonary interference | 3 (15.8%) |
| Technical limitation | 3 (15.8%) |
| Tachypnoea/patient unable to cooperate | 2 (10.5%) |
| Cause not specified by the operator | 3 (15.8%) |

Note: Percentages for individual technical difficulties use the 19 difficult examinations as the denominator.

**Table III: Image quality assessment**

| Image quality parameter | Good | Fair | Poor | Non-diagnostic |
|---|---|---|---|---|
| Endocardial Border Definition | 13(32%) | 23(56%) | 5(12%) | 0(0%) |
| Valve visualization | 14(34%) | 13(32%) | 11(27%) | 3(7%) |
| Colour Doppler quality (n=37)a | 2(5%) | 0(0%) | 5(13.5%) | 30(81.3%) |

[a] Colour Doppler assessment was performed in 37 of 41 examinations; in 4 examinations, colour Doppler was not performed.

**Table IV: Diagnostic findings by FMS and Cardiologist**

| Findings | FMS | Cardiologist |
|---|---|---|
| LV systolic dysfunction | 13(32%) | 10 (24%) |
| Pericardial effusion | 0(0%) | 0(0%) |

**Table V: Agreement analysis**

| | Cardiologist:Normal | Cardiologist:Reduced | Total |
|---|---|---|---|
| FMS:Normal | 26 | 2 | 28 |
| FMS:Reduced | 5 | 8 | 13 |
| Total | 31 | 10 | 41 |
| Overall agreement: 82.9% | | | |
| Cohen's kappa coefficient: 0.58 | | | |

## RESULTS

### Baseline Characteristics

A total of 41 patients were included in the study. Mean age was 60.4 ± 17.5 years and 51% were male. Common comorbidities included: Hypertension: 58%, Chronic lung disease: 24%, Chronic kidney disease: 17%, Diabetes mellitus: 12%. Vital signs demonstrated a mean heart rate of 88 ± 20 bpm and mean systolic blood pressure of 135 ± 27 mmHg. The baseline characteristics are summarised in Table I.

### Scan Feasibility

The median scan duration was 8 minutes (range: 3–14 minutes). Technical challenges were encountered in 19 scans; however, the specific cause was only documented for 16 of these examinations. The most common factors contributing to these difficulties were increased chest wall thickness or breast tissue (42.1%), pulmonary interference (15.8%), technical limitation (15.8%), and tachypnoea or reduced patient cooperation (10.5%). All 41 examinations, including those with technical difficulties, contained sufficient stored images for cardiologist classification of LV systolic function.

Details of scan duration and technical challenges are provided in Table II.

**Image Quality**
As shown in Table III, the endocardial border definition was rated as good or fair in 87.8% of examinations. Valve visualisation quality varied, with a minority of studies classified as non-diagnostic. Colour Doppler assessment was frequently limited due to device constraints, non-diagnostic quality was 30/37 (81.1%); among the entire cohort it was 30/41 (73.2%), with four not performed.

**Diagnostic Findings**
The FMS identified LV systolic dysfunction in 13 patients (32%), while cardiologist interpretation identified LV systolic dysfunction in 10 patients (24%). FMS slightly overestimated LV dysfunction compared to cardiologist interpretation. No cases of pericardial effusion were detected by either observer. The observed diagnostic findings for both assessors are outlined in Table IV.

**Diagnostic Agreement**
Overall agreement between FMS and cardiologist in the classification of LV systolic function was 82.9%. Interobserver agreement was moderate, with a Cohen's kappa coefficient of 0.58.

The diagnostic performance of FMS for detecting LV systolic dysfunction was as follows: sensitivity 80%, specificity 83.9%, positive predictive value 61.5%, negative predictive value 92.9%, and overall accuracy 82.9%. Table V provides the cross-tabulation and agreement analysis for LV systolic function assessment.

## DISCUSSION

This study suggests that focused handheld echocardiography can be integrated into rural primary care workflow and may support frontline cardiac triage when performed by a trained FMS with remote cardiologist validation. In our setting, scans were completed in a median of 8 minutes, diagnostically usable left ventricular images were obtained in all 41 cases, and agreement with cardiologist interpretation for reduced left ventricular systolic function was moderate. Taken together, these findings support the operational feasibility of a task-shifting model in a geographically remote clinic where formal echocardiography is not readily accessible.

The moderate agreement observed in this study is broadly compatible with prior work. In the primary-care study by Nilsson et al. used a training programme comprising 20 supervised examinations and reported poor agreement for identifying reduced LVEF, with Cohen's kappa of 0.22.[12] Acheampong et al. trained two internal-medicine residents to perform 50 examinations and interpret 20 studies; final agreement for left ventricular function was 80% with kappa 0.65. Our agreement of 82.9% with kappa 0.58 after a two-week supervised programme was broadly comparable, although differences in operator background, training exposure, case mix, and reference standards limit direct comparison.[5]

The study also highlights the boundaries of handheld echocardiography in this context. Colour Doppler was frequently non-diagnostic, limiting more detailed valvular assessment and reinforcing that this focused assessment should not substitute for comprehensive echocardiography.

A normal qualitative LV systolic assessment does not exclude heart failure with preserved ejection fraction. The binary normal-versus-reduced assessment used here should therefore be considered a triage finding only and should not replace clinical assessment or comprehensive echocardiography. Formal assessment of LV ejection fraction can subsequently guide evidence-based heart failure therapy according to ejection-fraction phenotype.[18]

From a health-services perspective, the key contribution of this study is not that handheld ultrasound replaces conventional echocardiography, but that it may improve the way rural patients are triaged within existing referral systems. In current practice, patients in remote clinics are often referred on the basis of symptoms, examination findings, and clinical uncertainty alone. A focused handheld scan, even if limited in scope, may provide additional information at the first point of contact and help distinguish patients who may require expedited referral from those who can be managed locally while awaiting further assessment. This is particularly relevant in Sarawak, where distance, transport logistics, and specialist concentration in tertiary centres can create substantial barriers to timely diagnosis.

The observed negative predictive value was 92.9%; however, because this estimate was derived from a small selected cohort using cardiologist interpretation of handheld images as the reference standard, it should not be interpreted as establishing rule-out performance. Larger multi-site studies are needed before the approach can be recommended for wider service redesign, and such studies should evaluate not only diagnostic agreement but also patient-centred and system-level outcomes, including referral efficiency, time to definitive diagnosis, unnecessary transfers avoided, cost implications, and clinical outcomes after implementation.

Although equity and health-system outcomes were not measured, bringing targeted diagnostic support closer to underserved communities is conceptually aligned with Sustainable Development Goal 3 and universal health coverage.[19]

Overall, our study provides an early proof-of-concept that a rural clinic-based handheld echocardiography pathway with remote cardiologist support is feasible in the Malaysian context. The next step is not immediate widespread adoption, but pragmatic larger-scale evaluation of whether such a model can improve rural referral systems and contribute meaningfully to more equitable cardiac care.

## LIMITATIONS

Several limitations should be acknowledged. First, this was a small single-site study involving a single FMS and a single reviewing cardiologist, limiting generalisability and preventing assessment of between-operator variability.

Second, patients were selected for scanning during routine care, and the total number of potentially eligible symptomatic clinic attendees was not captured, creating possible selection bias. Third, the reference standard was cardiologist interpretation of stored handheld images rather than formal standard transthoracic echocardiography. Fourth, image quality was graded only by the cardiologist, so interobserver agreement for quality could not be assessed. Fifth, the handheld platform had limited Doppler capability, restricting assessment of valvular pathology. Sixth, the cohort consisted of symptomatic patients in routine clinical practice, so the findings may not apply to screening populations. Finally, this study did not evaluate downstream service outcomes such as referral prioritization, time to formal diagnosis, patient travel burden, cost, or clinical outcomes.

## CONCLUSION

Focused handheld echocardiography performed by a trained FMS in a rural primary care clinic was feasible and showed moderate agreement with remote cardiologist interpretation for identifying reduced left ventricular systolic function. The findings support a hypothesis-generating task-shifting model for rural cardiac triage in which handheld imaging augments, rather than replaces, standard referral pathways. If validated in larger implementation studies, this approach may offer a scalable model to strengthen diagnostic access in underserved rural settings.

## CONFLICT OF INTEREST

The authors declare no other conflicts of interest.

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