# Using Point-of-Care Ultrasound in Heart Failure Diagnosis and Management in Rural and Resource-Limited Settings

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## INTRODUCTION

Point-of-care ultrasound (POCUS) is a portable and low-cost diagnostic tool well suited for use in resource-limited settings where comprehensive echocardiography is not available. Rheumatic heart disease (RHD) continues to be endemic in sub-Saharan Africa, causing a large burden of heart failure,[1] but physical examination is notoriously poor in diagnosing nonsevere mitral valve dysfunction[2] and mitral stenosis.[3] Beginning in 2006, the Rwandan Ministry of Health, supported by Inshuti Mu Buzima (Partners in Health Rwanda), began to decentralize heart failure diagnosis and management in select districts, which included POCUS training for noncardiologist health care providers. We describe two common cases often seen in our rural hospital setting in Rwanda.

## CASE 1 PRESENTATION

A 71-year-old man presented to the outpatient clinic of a rural district hospital in Rwanda. Presenting symptoms were progressive abdominal swelling, fatigue, and a mild cough. He had worked as a farmer for all his adult life and was registered under Ubudehe category 1 (the poorest category of socioeconomic status in Rwanda). He had no history of smoking but consumed a fair amount of local traditionally brewed banana beer.

The physical examination performed by the general physician was concerning for general muscle wasting, abdominal distention, and presence of shifting dullness. Recorded vital signs were: blood pressure of 100/64 mm Hg, pulse of 86 beats/min (noted to be irregular), respiratory rate of 16 breaths/min, and oxygen saturation of 97% on room air. The lungs were recorded to be clear on auscultation bilaterally, but bilateral pitting edema was noted. There was no report of a cardiac examination in the electronic medical record.

A bedside abdominal ultrasound examination performed by the general physician showed features of cirrhosis and presence of moderate ascites. A diagnosis of decompensated cirrhosis was made, and treatment was started with oral furosemide 40 mg daily and spironolactone 100 mg daily. The patient was sent home to continue medical management.

The patient returned 2 weeks later to the emergency department because of worsening cough, orthopnea, and progressive fatigue on usual activity. The abdominal distension had not improved, nor had the peripheral edema. The patient was hypoxic, with the majority of oxygen saturation readings between 84% and 86% on room air at rest. He was immediately placed on supplemental oxygen. At this point, the hospital's internist was asked to reassess the patient.

A diagnosis of clinical heart failure was suspected on the basis of the clinical presentation. In addition, a systolic murmur was noted on physical examination. A five-view POCUS study (Lumify; Philips) without color or spectral Doppler was performed by the internist, which demonstrated restricted diastolic excursion of the mitral valve with commissural fusion, calcification, and thickening of the leaflet margins and appearance consistent with rheumatic mitral stenosis (Figure 1). The right ventricle was severely dilated, with leftward shift of the interventricular septum. Left ventricular systolic function was normal, and there was a small pericardial effusion (Videos 1-3, Figure 2).

From the POCUS study, a diagnosis of heart failure due to mitral stenosis caused by RHD was made. Management was started with intravenous furosemide, and oral spironolactone was continued. After the patient had undergone some diuresis, atenolol was introduced. The patient's clinic status improved. He was no longer hypoxic and was able to ambulate around the medical ward with no respiratory limitation (New York Heart Association functional class II). The peripheral edema and cough had resolved at the time of hospital discharge. Because of financial limitations, transfer to the capital city for comprehensive echocardiography was not possible, and the patient was referred to the hospital's noncommunicable disease clinic for ongoing follow-up, where repeat POCUS studies could be performed by trained nurses.

## CASE 2 PRESENTATION

A 15-year-old boy presented to an emergency department in rural Rwanda, reporting progressively increasing cough over 1 month that was worse when lying flat. He had stopped attending school at 11 years of age because of a feeling of weakness when walking. He was unable to keep up with his peers in play. His medical history was not documented, and his history of pharyngitis was unknown.

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## VIDEO HIGHLIGHTS

**Video 1:** Parasternal long-axis view by two-dimensional transthoracic echocardiography showing restriction of the anterior and posterior mitral leaflets and leaflet margin thickening and calcification. The left atrium is significantly dilated. The right ventricular outflow tract visually appears dilated. There is flattening of the interventricular septum and a small pericardial effusion. Cardiac rhythm is irregular.

**Video 2:** Parasternal short-axis view by two-dimensional transthoracic echocardiography at the level of the mitral valve showing mitral leaflet thickening and commissural fusion. The right ventricle is not well visualized but appears dilated compared with the left ventricle, and there is flattening of the interventricular septum suggestive of raised right heart pressures. There is a small pericardial effusion. Cardiac rhythm is irregular.

**Video 3:** Apical four-chamber view by two-dimensional transthoracic echocardiography showing mitral leaflet thickening and the appearance of rheumatic mitral stenosis. There is biatrial enlargement, and the right ventricle is significantly dilated. Right ventricular systolic function appears reduced by visual estimation, and there is a small pericardial effusion adjacent to the right atrium. The left ventricular cavity is small. Cardiac rhythm is irregular.

**Video 4:** Parasternal long-axis view by two-dimensional transthoracic echocardiography showing mitral leaflet thickening and a notably restricted posterior mitral leaflet. There is a coaptation gap between the anterior and posterior leaflets, and the left atrium is significantly dilated.

**Video 5:** Apical four-chamber view by two-dimensional transthoracic echocardiography showing thickened mitral leaflets and posterior mitral leaflet restriction. There is a coaptation gap between the anterior and posterior mitral leaflets. There is biatrial dilation, and the right ventricle appears dilated.

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On general observation he was restless, with features of muscle wasting and pedal edema. His respiration rate was 24 breaths/min, oxygen saturation was 86% on room air, pulse was 110 beats/min, blood pressure was 90/54 mm Hg, and temperature was 36°C. A holosystolic murmur was auscultated, and bilateral crackles to the lung bases were present.

Supplemental oxygen was applied, and because of hypoxia, empiric antibiotics were started for suspicion of community-acquired pneumonia. The patient was admitted to the general medical ward, and tuberculosis was excluded by sputum microscopy. On day 3 of hospital admission, the patient was not improving, and a POCUS scan was done at the bedside (Lumify; Philips) because of suspicion for heart failure. A five-view scan was attempted, but limited POCUS images were obtained because of the patient's respiratory distress and inability to lie flat. Images were obtained with the patient sitting upright (Videos 4 and 5). The mitral valve was noted to be thickened, with significant restriction of the posterior mitral leaflet (Figure 3). There was a large coaptation gap between the anterior and posterior leaflets due to posterior leaflet restriction and significant left atrial dilation (Figure 4). Left ventricular systolic function was normal.

A diagnosis of RHD with severe mitral valve disease was made, and intravenous furosemide was initiated. The patient showed some clinical improvement, but because of the severity of his cardiac disease, he was transferred to the nearest referral hospital in the capital city 2 hours away by ambulance to undergo comprehensive echocardiography and to be reviewed by a cardiologist for surgical candidacy. No formal updates were received from the tertiary care hospital following transfer.

## DISCUSSION

We showcase two typical patients seen in rural Rwanda who presented with heart failure and, using focused echocardiography with a POCUS device, were both found to have RHD causing severe mitral valve dysfunction. The cause of each patient's heart failure was diagnosed appropriately without direct input from a cardiologist, and early management was implemented. The majority of cases of RHD in the districts supported by Inshuti Mu Buzima/Partners in Health Rwanda are received late in heart failure stages but can still be identified and treated. Increased use of POCUS by noncardiologist health care providers has improved access to cardiac diagnostics for this population and has increased case finding earlier in their disease.

RHD is one of the most common causes of heart failure in rural Rwanda.[4] The population prevalence of RHD is estimated to be 12.9 per 1,000 people in sub-Saharan Africa, and RHD mainly affects children and young adults,[5] which can lead to dangerous pregnancy complications and a substantial amount of lost economic income.[6] One fifth of adults with advanced RHD have concomitant left ventricular systolic dysfunction,[6] which further worsens prognosis.

According to the World Bank, an estimated 58.7% of the sub-Saharan African population and 83% of Rwandans live in rural areas.[7] Approximately one third of African households, or an estimated 490 million people, live under the poverty line ($1.90 purchasing power parity per day).[8] Many work as subsistence farmers and access medical care at rural district hospitals. However, these rural hospitals typically have very limited capacity to diagnose and manage heart failure. Specialized cardiovascular care is available only at tertiary care facilities in capital cities such as Kigali. The long distances between patients' homes and referral hospitals require public transport, which is unaffordable for most. Decentralizing POCUS by training nurses and physicians who care for patients at noncommunicable disease clinics in rural areas of Rwanda and across sub-Saharan Africa radically extends access to cardiac imaging for heart failure diagnosis to a large rural population.

Considerations for the use of POCUS in these setting are multiple. Given this task shifting to nonexpert providers, views must be limited and easy to obtain to enhance standardization and decrease variability. In our setting, providers are trained to use a five-view study, obtaining a parasternal long-axis view, a parasternal short-axis view at the level of the papillary muscles, an apical four-chamber view, a subcostal view, and an inferior vena cava view. Color and spectral Doppler are not used, because of the level of training of nonexpert providers and a lack of widespread capability on common POCUS devices. Assessment of valvular heart abnormalities without Doppler is limited, and more complete discussions on this topic can be found in the literature.[9] Training of frontline providers such as nurses to use POCUS in addition to a focused heart failure management protocol[10] has previously been shown to lead to timely and accurate diagnoses of heart failure, initiation of appropriate medications, and expedited referral for surgery[11] among rural Rwandan patients. In Uganda, nurses trained

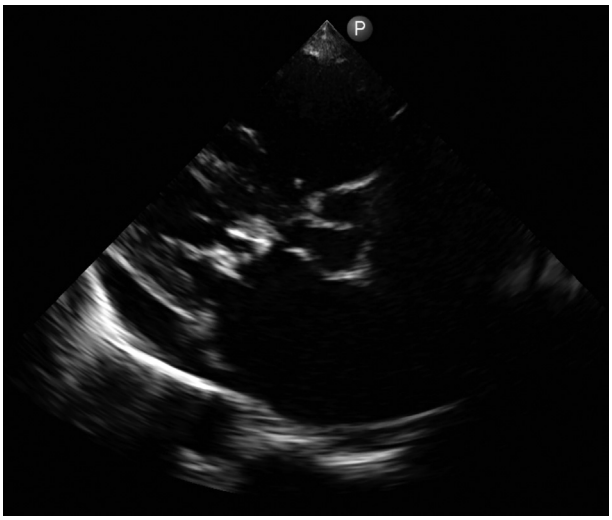


Figure 1 Parasternal long-axis view by two-dimensional transthoracic echocardiography showing restriction of the anterior and posterior mitral leaflets at end-diastole. The left atrium and right ventricle are both noted to be significantly dilated. There is a small pericardial effusion.

in POCUS were able to identify mild RHD in schoolchildren without heart failure.[12] Free online training material is available that teaches nonexpert providers to identify all stages of RHD (https://wiredhealthresources.net/EchoProject/). The use of POCUS and a heart failure management protocol integrated into a chronic care clinic in rural Rwanda as part of the PEN-Plus strategy has been found to be cost effective for implementation even in very low resource settings.[13] Formal certification processes and avenues for reimbursement are needed to encourage widespread training and use of this technology in sub-Saharan Africa.

Cloud-based image archiving and image review by experts are important in our setting, complementing the clinical history and interpretation of nonexpert clinicians, and are an important difference

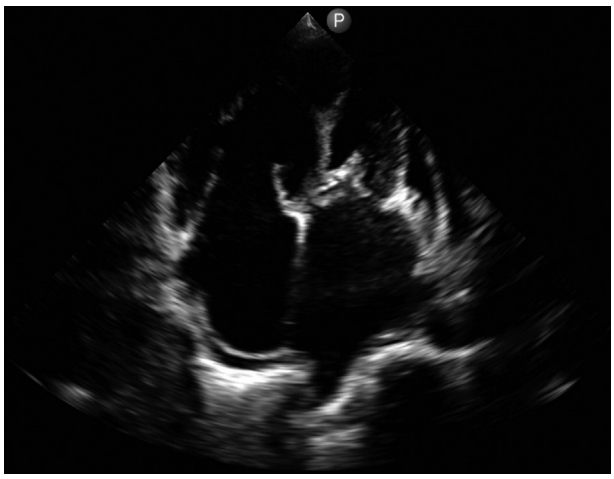


Figure 2 Apical four-chamber view by two-dimensional transthoracic echocardiography showing mitral leaflet calcification and thickening in diastole. There is restricted motion of the mitral leaflets compared to the tricuspid leaflets. Both atria visually appear dilated. The right ventricle appears dilated, while the left ventricular cavity appears small. There is a small pericardial effusion.


Figure 3 Parasternal long-axis view by two-dimensional transthoracic echocardiography in mid-diastole showing mitral leaflet thickening and posterior leaflet restriction. The left atrium is significantly dilated.

between POCUS and conventional echocardiography. Cloud-based image archiving was not available for either of the cases we present, and it is not known how many rural district hospitals in sub-Saharan Africa have POCUS image archiving systems. POCUS devices often have limited storage capacity, leading to deletion of patient studies once device memory is full. Images taken by nonexpert providers benefit from review by experts, particularly given the advanced severity of illness in these settings and the complex nature of cardiac ultrasound image interpretation. Image review also helps reinforce the interpretation skills of nonexpert providers. Through image review, mentorship for skill maintenance and improvement can be provided. A remote review system may also allow local cardiologists at tertiary care centers in limited-resource settings to review patient images during patient transfer from rural areas. In contrast to conventional echocardiography


Figure 4 Parasternal long-axis view by two-dimensional transthoracic echocardiography in mid-systole showing mitral leaflet thickening and a coaptation gap between the anterior and posterior leaflets. The aortic leaflets also appear thickened. The left atrium is significantly dilated.

laboratories, POCUS images are often not reviewed on site but are digitally shared for expert review, which occurs asynchronously from the patient's clinic or hospital visit. Given this work flow, internet access and a remote reporting system should be considered inseparable from the ultrasound technology when considering POCUS in resource-limited settings. Because of this, POCUS in resource-limited settings should be considered a different echocardiographic modality instead of simply a "limited echocardiogram."

The type of device must also be amenable to use in rural low-income settings, which may not have consistent electricity, are prone to power surges, and can be equatorial in climate. Devices used in these settings must have prolonged battery life, must not be prone to overheating, must be robust enough to not require frequent biomedical servicing, and would benefit from being charged with surge protection equipment. In addition, in settings where a POCUS device may be the only ultrasound device servicing the entire hospital and possibly the entire region, it must be portable so that it can be carried to differing hospital units and may be equipped with linear- and curved-array as well as phased-array transducers for multiple uses. Biomedical support of many common POCUS devices remains a challenge in the African region.

## CONCLUSION

POCUS is a powerful diagnostic tool, particularly in rural and resource-limited settings in sub-Saharan Africa where heart failure is common. POCUS coupled with simplified heart failure management protocols can significantly improve access to cardiac care for the rural poor in sub-Saharan Africa using a task-shifting approach, as demonstrated in our cases. In both cases, POCUS was performed in the context of clinical suspicion for heart failure, revealed severe mitral valve dysfunction caused by RHD, and guided further medical management, all without a cardiologist or full echocardiography laboratory on site. There are many specific considerations in the use of POCUS in this setting, and unique needs exist compared with POCUS use at hospitals in high-income countries. We advocate for the continued implementation and study of POCUS in resource-limited settings in order to better understand POCUS use in settings such as ours.

## SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.case.2022.04.012.

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