# Role of AI-enabled Ultrasound Imaging in a Resource Limited Intensive Care Unit

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**Abstract.** Ultrasound imaging (US) is affordable, portable and safe, and can be used to investigate many body organs. As a result, US can be an invaluable tool in a resource limited ICU setting. However, US requires extensive experience from the operator to be carried out effectively. Such expertise is scarce in low and middle income countries (LMIC), where there is a lack of specialists and formal US training is uncommon.
Artificial intelligence (AI) can help make US more accessible to non-expert operators by assisting in the operation of the machine and the interpretation of the acquired images, therefore has the potential to improve practice in resource-limited ICUs. In this paper we explore the key difference of these clinics compared to their high–income countries counterparts, and identify and discuss areas where AI can have a relevant role.

## 1 Background

Optimal management of critically ill patients requires rapid and reliable evaluation of vital organ function. Previously, this has required expensive and invasive equipment but, increasingly, ultrasound (US) is used in intensive care units (ICUs) across the world [1–3]. US is safe, affordable, portable and can be used for many body organs, for example in cardiac evaluation and may have superior performance to X-ray in the assessment of several acute lung pathologies [4, 5]. In resource-limited settings, point-of-care US, is especially attractive [6].

A major disadvantage of US is the need for specialist training in order to reliably obtain and interpret images [7], preventing non-specialist operators to use it in the ICU. Lack of specialists may result in US examinations not being carried out. Sometimes, availability of US equipment encourages non-experts to use it resulting in sub-optimal examinations. Under these circumstances, the relative affordability and availability of US can be a disadvantage if clinical decisions are based on this data. For instance, guidelines for echocardiography (echo) in the ICU have been developed to ensure accurate quantification and interpretation of cardiac function, but the final analysis remains reliant on the operator having the experience and knowledge to adhere to these guidelines [7, 8]. For example, guidelines recommend quantitative measures of cardiac chambers and valves during assessment to inform clinical decision making. However, in busy clinical environments such as acute emergency settings and ICUs, quantitative analysis may not be practical because of the additional time required for manual tracing and difficulty obtaining images of sufficient quality to do this. As a result, it is acknowledged that visual estimation remains the mainstay of rapid functional assessment in many areas of clinical practice, although it requires considerable experience [9, 10].

In the case of low middle-income countries (LMIC), where specialist training is not widely available, the use of artificial intelligence (AI) offers huge potential as it can support inexperienced operators in performing and interpreting US examinations.

In this paper, we provide an overview of the utility of US imaging in LMICs and point out the key differences and challenges with respect to high-income countries. We then identify where and how artificial intelligence (AI)-enabled US can be used to circumvent these challenges.

## 2 High income countries and LMICs: key differences in ICU settings

Despite increased numbers of ICU beds in many LMICs, compared to high income settings, ICU capacity in most LMICs remains limited, with between 0.1 and 2.5 ICU beds per 100,000 population compared to between 5 and 30 ICU beds in high income countries. ICUs in LMIC typically suffer from lack of sufficient equipment (monitors, imaging devices, etc) and the equipment available may be old or even obsolete [11]. These ICUs typically manage different patients compared to high income settings, often with a very different disease profile for example dengue, tuberculosis and HIV [12].

ICU staff in LMIC are typically less well trained, especially in imaging. Of the 99 ICUs that responded to a survey by Rajamani et. al [13], 75 had no basic critical care echocardiography (BCCE) training. In the remaining 24 ICUs, the teaching process was widely variable.

## 3 The potential use of ultrasound in the ICU in LMICs

US performed and interpreted at the bedside can quickly establish a diagnosis and guide therapy in ICU patients. As cardiac and lung pathologies are common and important reasons for critical illness throughout the world, echocardiography and lung US are rapidly gaining value in ICUs. Echocardigraphy enables a comprehensive hemodynamic assessment as well as diagnosis of cardiac pathologies like tamponade, valvular diseases, left ventricle hypertrophy. Lung ultrasound (LUS) can evaluate lung aeration, which can help in management of patients with many lung pathologies. In addition, LUS has been demonstrated to be superior to chest X-ray in detecting pneumothorax, pleural effusion, pneumonia, and interstitial syndromes.

In LMIC, alternative imaging modalities are often unavailable in ICUs and therefore US is a particularly valuable tool in managing many critically ill patients in these countries. For example, Acute Respiratory Distress Syndrome (ARDS), a severe lung condition occurring in many critically ill patients was initially defined using criteria which included computed tomography (CT) scan findings. However, the Kigali modifications to the original (Berlin) criteria allow for diagnosis in resource-limited settings and include the identification of pulmonary pathology with US instead of chest x-ray (CXR) or CT [14].

## 4 How can AI support the use of ultrasound imaging in resource-limited ICUs?

Artificial intelligence (AI) is a rather liberally used term describing computational methods, often data-driven, that can be constructed to perform complex tasks that would typically require intelligence, such as data classification or parameter estimation. In that sense, AI methods can help towards use, interpretation and quantification of US imaging, tasks which would normally be taken up by experts. As a result, the main role of AI in LMIC, where availability of experts is scarce, formal training is lacking, and staff normally cares for a very large number of patients, is to make US examinations easier, quicker and more reliable, as well as more accessible for less experienced operators.

There are still relatively few studies focused on the use of AI in LMIC. For example, in echocardiography, Madani et al. applied a CNN algorithm to automatically classify 15 standard echocardiographic views [15]. EchoNet-Dynamic was recently proposed to estimate left ventricular ejection fraction (LVEF) and classify patients with heart failure with similar accuracy to that of experienced cardiologists [16]. Caption Health recently released a tool that provides real-time guidance to position and manipulate the US transducer on a patients' body and automates measurements for point of care US [17]. Beyond cardiac applications, Malena et al, applied neural networks to automatically detect lung consolidation and diagnosis pneumonia without requiring an expert radiologist in resource limited setting in South America [18].

## 5 Challenges for the adoption of AI-enabled ultrasound in resource limited ICUs

Whilst AI has advanced rapidly over the past decade, deployment of AI to address real clinical problems in LMICs is still in its infancy. The major impediments for scale-up and adoption are:

a. **Infrastructure -** The use of AI into healthcare in wealthy countries is increasing, whereas most LMICs do not even have basic digital infrastructure in their healthcare systems. The absence or insufficiency such infrastructure (US machines, DICOM servers, Picture Archiving and Communication System (PACS), cloud services, local area networks, and Wi-Fi) in most LMICs represents a significant challenge in AI implementation.
b. **Education and personnel** – Effective AI integration into clinical workflows in LMIC's health institutions, requires the adoption by physicians, radiologists, and clinicians and close collaboration with biomedical engineers with expertise in AI. Clinical professionals should be trained to interpret and factor in AI-enabled tools together with the rest of clinical information for effective patient management. An initiative that is being implemented with positive results is to establish AI workshops and case-based education for LMIC hospital partners to try out AI algorithms. These workshops should be integrated with other education and infrastructure deployments, to incorporate AI education into resource-limiting settings, and to provide feedback to practitioners.
c. **Data collection, algorithm development and validation -** A significant challenge to accelerating the use of AI algorithms in LMICs relates to the quantity and quality of the available data. Algorithms are currently trained mostly with data from high-income countries (HICs), which may not be representative of LMIC populations. This means that even if AI algorithms are approved commercially, the efficacy and translatability of such algorithms may still be inhibited by the lack of data from LMICs. This should be addressed both through novel computational methods that can learn from small amounts of data, and through improvements in local resource and infrastructure that allow for more ambitious data collection initiatives.
d. **Regulation** – Because AI in US is an emerging field, many LMICs also lack a comprehensive and consistent regulatory framework for storage, anonymization, access, transfer, and processing of imaging data, particularly for AI companies outside of the health facilities. It is crucial to create clear guidance from multilateral organizations and governments on how and when regulation on AI applications should be applied.
e. **Trust in AI -** When it comes to AI-based approaches for the use in medical decision making, it is important to provide transparency and clarity in the methodology to facilitate trust and adoption by medical professionals.

In order to explore and appropriately accelerate the use of AI-assisted medical imaging in global health, it is critical to develop translational networks and innovations in LMICs, which will allow development and scalability of the new approaches. It is crucial to understand the challenges and identify gaps in the settings where AI approaches will be implemented, therefore, the strategy of promoting local innovations in more likely to be sustainable.

## 6 Summary

AI in US is an exciting prospect and has the potential to optimize existing resources and help overcome the workforce shortages, by assisting in operation of the US system, measurement of biometric parameters from images, assessing severity of disease, and providing insight that can help patient management. As a result, AI can greatly improve US practice and ultimately patient outcomes in resource-limited settings. Although there are barriers to deploying AI-enabled US at scale in LMICs, strategy of promoting local innovation and initiative can made accelerate the efficiently sustainable AI-enabled US implementation.

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