Task shifting for point of care ultrasound in primary healthcare in low- and middle-income countries-a systematic review

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Summary

Low-and middle-income countries (LMIC) are faced with healthcare challenges including lack of specialized healthcare workforce and limited diagnostic infrastructure. Task shifting for point-of-care ultrasound (POCUS) can overcome both shortcomings. This review aimed at identifying benefits and challenges of task shifting for POCUS in primary healthcare settings in LMIC. Medline and Embase were searched up to November 22nd, 2021. Publications reporting original data on POCUS performed by local ultrasound naÿve healthcare providers in any medical field at primary healthcare were included. Data were analyzed descriptively. PROSPERO registration number CRD42021223302. Overall, 36 publications were included, most (*n* = 35) were prospective observational studies. Medical fields of POCUS application included obstetrics, gynecology, emergency medicine, infectious diseases, and cardiac, abdominal, and pulmonary conditions. POCUS was performed by midwives, nurses, clinical officers, physicians, technicians, and community health workers following varying periods of short-term training and using different ultrasound devices. Benefits of POCUS were yields of diagnostic images with adequate interpretation impacting patient management and outcome. High cost of face-to-face training, poor internet connectivity hindering telemedicine components, and unstable electrici'ty were among reported drawbacks for successful implementation of task shifting POCUS. At the primary care level in resource-limited settings task shifting for POCUS has the potential to expand diagnostic imaging capacity and impact patient management leading to meaningful health outcomes.

Keywords: Point of care; Ultrasound; Task shifting; Low- and middle-income country

Introduction

Low- and middle-income countries (LMIC) are faced with healthcare challenges that disrupt successful implementation of health services creating inequitable access to care and entailing poor health outcome.[1] Core to these challenges are lack of specialized health workforce and diagnostic infrastructure.[2–6] Combining task shifting and point-of-care diagnostics can overcome these shortcomings.

The World Health Organization (WHO) recommends task shifting as one strategy to strengthen and expand health workforce.[7–9] By task shifting, specific tasks are moved from highly qualified health workers to health workers with shorter training and less qualifications in order to increase efficiency of available human resources for health.[7] Key elements, including quality assurance mechanisms, standardized training and certification have been recommended to ensure a safe, efficient, effective, equitable and sustainable task shifting approach.[7]

Diagnostic imaging plays an important role in time-sensitive management of many conditions. In LMIC, diagnostic imaging services are limited and the quality of service varies significantly.[4,10,11] Factors associated with limited availability and varying quality of diagnostic imaging in LMIC include the lack of or inadequate diagnostic imaging equipment, the lack of skilled human resources to operate and maintain equipment, and insufficient training capacity in diagnostic imaging.[4]

Progress in technology has advanced the development of portable, easy to use and affordable point-of-care ultrasound (POCUS) devices that allow imaging at the patient's bedside.[4,11] POCUS is a promising task shifting approach moving sonographic imaging from

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radiology departments to frontline healthcare.[12] POCUS improves health outcomes by improved and timely diagnosis resulting in expedited clinical decision-making, and reduces lengths of hospital stays, need for referrals and costs.[12–14]

In this review we focus on benefits and challenges of POCUS tasks shifted to ultrasound naÿve care providers at the primary level of care in LMIC. We thereby apply a comprehensive concept of task shifting for POCUS that is not limited to the fundamental task shifting of sonographic imaging away from radiology services to the bedside clinician but also includes further task shifting of sonographic imaging to health workers with shorter training and less qualifications than clinicians.

Methods

We reviewed literature following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[15] The electronic databases Medline (Ovid, 1946 to present) and Embase (Ovid, 1947 to present) were searched on 23rd of January 2021; a search update was performed on 22nd November 2021. Key search terms included 'point of care', 'ultrasonography' and 'low- and middle-income countries' (Appendix 1). Synonyms for 'Point of care' included 'handheld' or 'hand-carried' or 'portable' or 'mobile' or 'focused' or 'pocket' or 'bedside'. LMIC was defined using the World Bank definition of developing countries[16] and the synonyms 'resource limited setting' or 'developing country' or 'remote setting' were applied. Synonyms of ultrasonography included 'ultrasound' or 'echography' or 'sonography'.

The study was exempt from institutional review board approval and the review protocol was published on PROSPERO with registration number CRD42021223302.

Eligibility criteria for inclusion of publication

Task shifting for POCUS was defined as focused bedside ultrasound performed by health care providers with ultrasound training limited to the respective POCUS examinations. We included publications describing POCUS performed at the primary care level in all medical fields in LMICs by local healthcare providers (including primary care physicians, nurses, midwives, clinical officers, medical assistants, radiology technicians and community health workers) who had not primarily undergone ultrasound training. We excluded studies on POCUS performed by healthcare professionals whose formal training includes training in ultrasound (i.e. specialized or specializing doctors emergency medicine, obstetrics/gynaecology and cardiology, as well as specialized or specializing radiologists or sonographers), on POCUS performed by healthcare workers with basic ultrasound training according to WHO,[17] and studies on POCUS training only without clinical application. Publications without original data (editorials, comments, and conference abstracts) and non-human studies were excluded. We made no restrictions regarding language of publication, year of publication nor patient population.

Data selection and extraction

We organized publications in ENDNOTE X9.[18] Title and abstract screening were performed with Rayyan QCRI, a web and mobile app for systematic reviews.[19] Two reviewers (SKA, LCR) performed title and abstract screening based on the pre-specified eligibility criteria. Discrepancies were resolved by a third reviewer (CCH). We performed full text screening of potentially eligible publications after title and abstract screening. Two independent reviewers (SKA and LCR) screened all full texts. Disagreement on full text assessment was also resolved by discussion with a third reviewer (CCH).

Following satisfactory non-discrepant comparison of a random 15% of data extraction performed by two reviewers (SKA, CCH), data of the other 85% citations were extracted by one reviewer (SKA or CCH) and checked by the other reviewer (SKA or CCH). The following data were extracted: first author, title, year of publication, study design, country, type of POCUS examination, type of ultrasound device, duration of POCUS training, mode of delivery of POCUS training, condition examined, outcome measured, type of healthcare providers performing POCUS, benefits of POCUS, and drawbacks of task shifting for POCUS.

Assessment of risk of bias

The methodological quality and risks of bias were assessed by two independent reviewers (SKA, LCR) for each publication using a modified National Heart, Lung and Blood institutes protocol for observational studies (Appendix 2, 3) and National Heart, Lung and Blood institutes protocol for controlled randomized studies (Appendix 4).[20]

Data analysis

Findings were analysed using Microsoft Excel 365 (version 16.57) and presented in a descriptive way in text and tables; sums and percentages were calculated or extracted from original studies, where appropriate.

Role of the funding source

There was no funding source in developing the study protocol; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication. All named authors

had access to the data, contributed to the drafting and revising of the manuscript and agreed to submit for publication.

Results

The database search yielded 3873 unique publications. One hundred and forty-one publications were retrieved for full text screening after title and abstract screening. Thirty-six publications were selected for synthesis (Figure 1).[21–48] Thirty-five studies were prospective observational studies and one randomized controlled trial.[30] The majority of the included publications (n = 20) were conducted on the African continent,[21,22,31–35,37,39,40,42–44,46,47,49–53] nine studies originated from the Americas,[24,27,29,38,41,45,54–56] two from Asia,[26,36] and three from Oceania[23,28,57] as shown in Figure 2. Two studies were multi-national studies.[30,58]

Risk of bias assessment

Of the 35 observational studies, ten were of high, twenty-two of moderate and three of low methodological quality (Appendix 2). Most studies were found with high risk of bias for sample size justification (selection bias) as shown in the supplementary material (Appendix 3). Twenty-one (60%) of the studies were associated high risk of bias regarding controlling for confounders and eight (23%) were associated with a high risk of detection bias as blinded assessment was not performed. The randomized controlled trial was of moderate methodological quality but associated with high risk of bias as concealed allocation of intervention and blinding assessment was not used (Appendix 4).

Applications of task shifting POCUS

There was a substantial range of clinical areas and conditions for which task shifting for POCUS was applied.

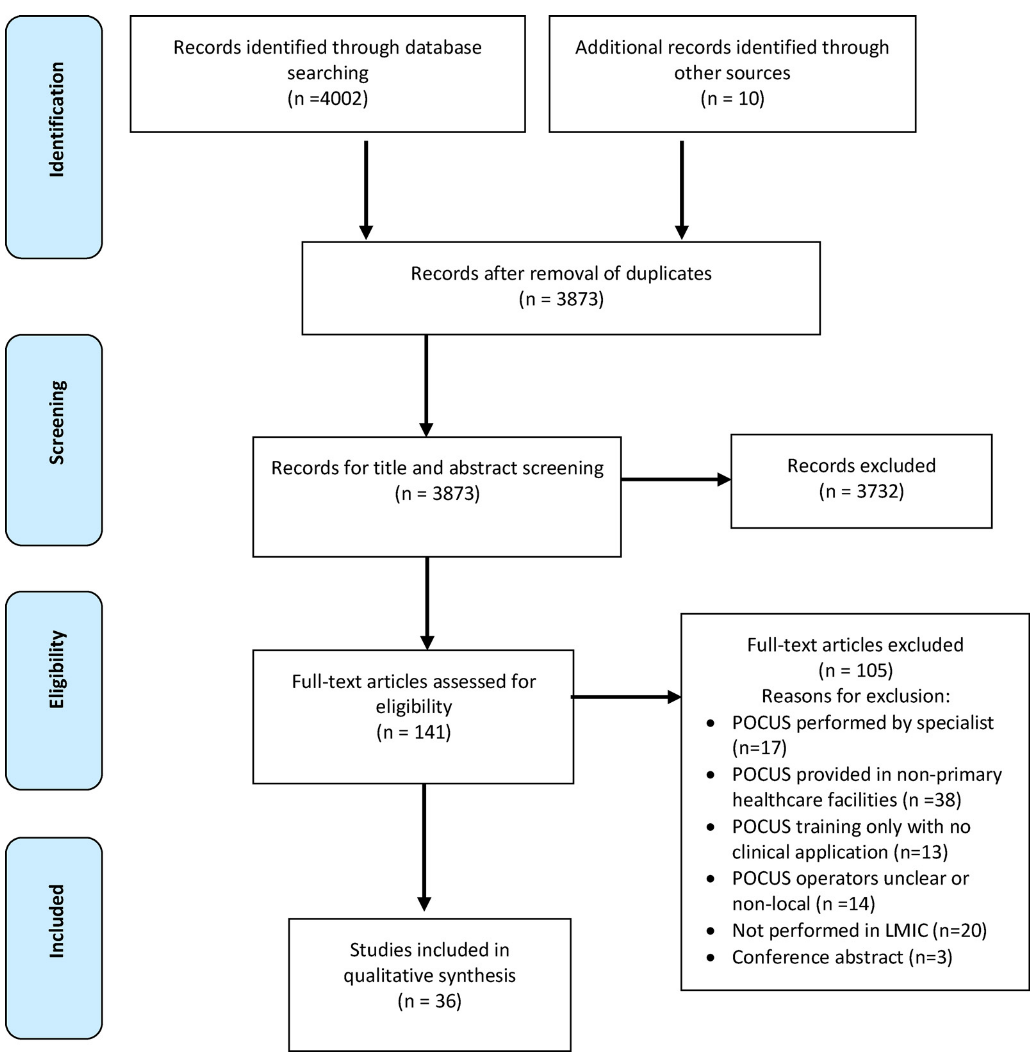

Figure 1. PRISMA Flow diagram of study selection.

Figure 2. Medical fields and conditions of task shifting for POCUS studies identified by this review across continents. The outer circle displays POCUS applications, the inner circle continents where POCUS applications were applied. The relative sizes of cells indicate the frequency of studies evaluating respective POCUS applications and the continent origin, respectively. (POCUS: point-of-care ultrasound, FAST: focused assessment with sonography for trauma, FASH: focused assessment with sonography for HIV-associated tuberculosis, FASE: focused assessment with sonography for echinococcosis).

All studies primarily examined the impact of task shifting for POCUS as a diagnostic or screening tool in LMIC as shown in Table 1. Ten publications reported on task shifting for POCUS in obstetric care, examining pregnancy and pregnancy related complications.[24–26,30,31,34,35,43,46,47] Nine and three publications reported on task shifting for chest POCUS for cardiac and pulmonary conditions respectively, including rheumatic heart disease screening, diagnosing cardiac structural anomalies, aneurysms and deep vein thrombosis,[23,28,30,36,38,39,45,55,57,58] and lung examinations to diagnose conditions such as pneumonia, tuberculosis, pleural effusion and atelectasia.[29,53,59] Further reported task shifting for POCUS applications included abdominopelvic examination for liver, gallbladder diseases, and kidney diseases, prostate hypertrophy and urinary tract infection,[21,32,41,42,44,54] breast and axillary examination for breast cancer screening,[40,56] examination in trauma patients for pneumothorax and internal haemorrhage,[48] examination for HIV associated tuberculosis,[33] and screening for abdominal cystic echinococcosis.[22,27]

POCUS training and POCUS operators

Duration and mode of training of POCUS operators in respective POCUS applications were described by all publications except one.[33] Training included theoretic sessions, hands-on practice, and supervised and unsupervised scans sessions. Duration and scope of training varied between studies (Tables 2–5). Most trainings were provided face-to-face, but online training was also reported. Most of the trainers were non-local POCUS trainers, who subsequently provided remote support for the trainees. Healthcare providers that were trained as POCUS operators included nurses, general physicians, residents, medical students, medical graduates, midwives, clinical officers,

Medical field/Organ system	Application
Obstetrics and perinatal care	• Screening in pregnancy[24,31,34]: e.g., foetal presentation (vertex or breach), foetal heart rate, placental location, number of gestations, and gestational age based on biparietal diameter and femur length • Congenital anomalies[30] • Identification of high-risk pregnancies[25,26,30,43,46,47]: e.g., low lying placenta and placenta previa, multiple gestation, intra-uterine growth restriction, amniotic fluid abnormalities including oligohydramnios
Gynaecology	• Screening for breast mass and axillary lesions[40] • Identification of the aetiology of abnormal vaginal bleeding[46]: e. g., complete abortion and incomplete abortion, blighted ovum, ectopic pregnancy • Identification of the aetiology of uterine masses[21,31,96]: e.g., uterine fibroids, ovarian cyst
Cardiac and vascular US	• Screening for rheumatic heart disease [23,28,38,39] • Identification of cardiac pathological[21,36,44,45]: e. g., mitral regurgitation, structural cardiac abnormality, heart failure, abdominal aortic aneurism, pericardial effusion, right ventricular dilation, vegetation, HIV associated cardiomyopathy • Identification of deep vein thrombosis[44]
Lung	• Identification of acute lower respiratory tract infections in children[97] • Identification of interstitial syndrome, pleural effusion, atelectasis[29] • Identification of correlates of pulmonary tuberculosis[29,42]
Emergency/Trauma	• Identification of internal haemorrhage and pneumothorax (FAST/eFAST)[21,42,98] • Identification of severe dehydration[37]
Abdomen	• Screening of liver, spleen, and pancreas[21,42] • Identification of the aetiology of vesico-urinary diseases[21,44,51,96]: e. g., kidney stones, prostate hypertrophy, urinary tract infection, HIV associated nephropathy • Identification of ascites[32,44] • Identification of the aetiology of liver and gall bladder diseases[21,44]: e.g. hepatomegaly and cholecystitis, hepatic cysts or abscesses, abdominal tumour evaluation and biliary ultrasound
Infectious diseases	• Identification of features of HIV-associated extrapulmonary tuberculosis (FASH) [33] • Screening for cystic echinococcosis (FASE)[22,27] • Diagnosis and surveillance of *Schistosoma haematobium* related lesions[51]

***Table 1*: Overview of medical fields and conditions of task shifting POCUS applications in primary care in LMIC identified by this review**
POCUS: point-of-care ultrasound, LMIC: low- and middle-income countries, eFAST/FAST: (extended) focused assessment with sonography for trauma, HIV: human immunodeficiency virus, FASH: focused assessment with sonography for HIV-associated tuberculosis, FASE: focused assessment with sonography for echinococcosis.

technicians, nursing assistants, and community health workers (CHW).

Clinical benefits of obstetrics POCUS

Ten publications reported on task shifting for POCUS in obstetric care (Table 2). POCUS interventions aimed at sonographic identification of high-risk pregnancy, increased accuracy of obstetric diagnoses, POCUS-guidance on clinical decision-making, increased utilization of antenatal care services, increased deliveries by skilled birth attendants and in healthcare facilities, and reduced maternal and neonatal mortality.[24–26,30,31,34,35,43,46,47] High risk pregnancies such as foetal mal-presentation, placenta previa, amniotic fluid abnormalities, multiple gestation and intra-uterine growth restrictions were identified by midwives and nurses during the prenatal period,[24,31] and at labour.[43] Task shifting for POCUS services improved accuracy of diagnosis when compared with clinical exam only; midwives applying POCUS corrected their diagnosis in around 7% of examinations[46] or changed their clinical decision making in 17% following POCUS examinations.[35] Task shifting ultrasound increased utilization of antenatal care (ANC) services and motivated women to comply with the recommended ANC schedule and complete four ANC visits.[34] An increase in facility-based deliveries and obstetric referrals to Comprehensive Emergency Obstetric Care facilities (CEmOC) were reported by this study.[34] A study from the Philippines showed that 6.3% of maternal deaths and 14.6% of neonatal deaths were averted by introducing task shifting for POCUS services by CHW.[26] On the contrary, a multi-country cluster randomized controlled trial, reported that introducing task shifting for POCUS services as routine antenatal ultrasound did not increase the use of ANC and the rate of hospital births for women with complications, nor did it improve the composite outcome of maternal, and neonatal mortality, and near-miss maternal mortality.[30]

Clinical benefits of chest POCUS

Task shifting for cardiac and lung POCUS were described in nine[23,28,36,38,39,45,55,57,58] and three[29,52,53] studies respectively. Cardiac examinations focused on using handheld echocardiography to screen structural cardiac abnormalities and was primarily performed by nurses (Table 3). Cardiac POCUS was used to screen for rheumatic heart disease (RHD) in pediatric populations by obtaining qualitative images of pathologies such as

First author /Year	Country/ Setting	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation.
Kimberly et al. 2010[35]	Zambia/ Rural health centres and provincial hospital	Midwives	Sonosite 180; Sonosite Inc., Bothell, WA, USA	Didactics courses, hands-on instruction, supervised scanning 3 weeks	Change in clinical decision-making in 17% (74/441) examinations	Heavy workload impeding integration of POCUS in daily care Difficulty in learning skills Absence of supervision
Greenwold et al. 2014[31]	Mozambique/ Rural Health centres	Nurse, Clinical officer	2 M-Turbo (Sonosite, Bothell, WA, USA)	Lectures, hands-on training 8 weeks	Identification of high-risk pregnancies and uterine fibroids in 23.5% (407/1734) leading to a change in management Referral of 3.6% (62/1734) women to district hospital Primary caesarean section in 1% (21/1734)	None reported
Swanson et al. 2014[46]	Uganda/ Rural health centres	Midwives	GE Logiq E ultrasounds (GE Healthcare Clinical Systems, Wauwatosa, WI, USA)	Lectures, small-group tutorials, audio-visual material, supervised scanning 6 weeks	Change in diagnosis in 11% (100/939) 18/25 patients referred based on POCUS findings were confirmed with pathology	None reported
Kawooya et al. 2015[36]	Uganda/ Rural health centres	Midwives	LOGIQe ultrasounds (GE Healthcare Clinical Systems, Wauwatosa, WI, USA)	Lectures, small group tutorials, audio-visual materials, supervised scanning 3 months	Increased utilization of and adherence to ANC services Increase in facility-based deliveries and obstetric referrals	None reported
Crispín Milart et al. 2016[24]	Guatemala/ Rural communities	Nurse	Laptop and USB ultrasound probe	Theoretical lessons, supervised practical sessions with pregnant women 1 week	No maternal mortality in intervention group compared to 5 maternal mortalities in control group 64 % reduction in neonatal mortality in intervention group Non-urgent referral recommended in 9.2%	Training is demanding and requires regular reinforcement
Viinayak et al. 2017[47]	Kenya/ Rural clinics	Midwives	Tablet-sized ultrasound scanner VISIQ (Philips Ultrasound, Inc., Bothell, WA, USA)	Daily lectures, daily hands-on work 4 weeks	Correct identification of high-risk pregnancies and referral to appropriate facility for further management	None reported
Goldenberg et al. 2018[30]	Zambia, Kenya, DRC, Pakistan, Guatemala / Rural and semi-urban health facilities	Ultrasound naïve health providers	Not reported	Didactic lectures, hands-on training 2 weeks	US-naïve providers were successfully trained to conduct basic obstetric POCUS examination No benefits of task shifting POCUS identified	None reported

Table 2 *(Continued)*

First author /Year	Country/ Setting	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation.
Dalmacion et al. 2018[26]	Philippines/ Rural and Urban communities	General physician, nurse, midwives	GE Vscan US	Lecture, hands-on training with pregnant women 3 days	6.3% of maternal deaths and 14.6% of neonatal deaths were possibly averted by POCUS screening	None reported
Crispin Milart et al. 2019[25]	Guatemala/ Rural communities	Nurse	Laptop and USB ultrasound probe	Theoretical and practical sessions Duration not reported	Identification and referral of most risk-pregnancies in time	None reported
Shah et al. 2020[43]	Uganda/ District hospital and health centres	Midwife, registered nurse	Not reported	Didactic and practical components2 weeks	Confidence and skills to detect high-risk conditions in pregnancy	Delay in feedback due to limited internet Power outages High cost of internet bundle affects data transfer

Table 2: **Overview of studies applying task shifting POCUS in obstetric care in primary care in LMIC.**

mitral and aortic regurgitation with satisfactory interobserver agreement when compared with experienced reviewers.[23,28,38,39,55,57] Task shifting for cardiac POCUS was also used to diagnose heart failure and hypertensive heart disease in the adult population.[36,45]

Task shifting POCUS for lung examination was reported to be a feasible tool for both, healthcare facility and community-based diagnosis of lung pathologies, including pneumonia, pleural effusion, atelectasis, and tuberculosis for both in the pediatric and adult population.[29,52,53]

Clinical benefits of multi-organ POCUS

Six studies applied task shifting for POCUS to examine a combination of different organ systems comprising abdominal/pelvic, heart, lung, and soft tissue POCUS.[21,32,41,42,44] Task shifting for POCUS by CHW in Sierra Leone led to changes in the initial diagnosis in 34% (196/ 584) of examinations and changes in patient management in 29% (171/584) of the patients (Table 4).[41] A study from Rwanda observed similar findings with change in patient management in 81.3% of patients after POCUS by general physicians[32]; most common changes in patient management related to medication administration (42.4%), admission (30%), change in surgical procedure (23.3%), and transfer to a higher level of care (28.1%).

Clinical benefits of POCUS for emergency care, trauma, infectious diseases, and breast cancer

Three studies reported the use of task shifting for POCUS for trauma (FAST); one study focused exclusively on FAST,[48] while the other two performed FAST as part of multi-organ examinations.[21,42] General physicians and non-physician clinicians including medical students, clinical officers, and CHW obtained quality ultrasound images and accurately interpreted the findings. Together with feedback from specialists, diagnostic accuracy of FAST examinations improved patient management.

Utilization of task shifting for POCUS for tuberculosis (FASH) in Malawi was reported as an important adjunctive diagnostic tool to augment clinicians' ability to diagnose tuberculosis.[33]

Task shifting for POCUS for screening cystic echinococcosis (FASE) in Morocco and Patagonia were performed with good accuracy by general practitioners and residents for detection of cyst.[22,27]

Similarly, in Rwanda and Peru nurses, midwives, and general practitioners used POCUS to supplement clinical examination for breast cancer and associated axillary lesions[40,56] and assess for signs of severe dehydration in children with diarrhoea and/or vomiting by examining the aorta and inferior vena cava ratio,[37] and

First author/Year	Country/Setting	Type of POCUS	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation
Colquhoun et al. 2013[23]	Fiji/ Rural primary schools	Cardiac US	Nurses	Portable Mindray machine (Mindray Diagnostic Ultrasound System Model M5, Mahwah, New Jersey, United States of America)	Workshop to follow screening protocol, supervised hands-on training 3 weeks	Skills to operate portable echocardiography and competence to detect findings suggestive of rheumatic heart disease with high sensitivity and reasonable specificity	Lack of algorithm to guide rheumatic heart disease echocardiographic
Engelman et al. 2016[28]	Fiji/ Schools	Cardiac US	Nurses	M-Turbo portable ultrasound machine (SonoSite Inc., Bothell, WA)	Classroom-based workshops, practical training 8 weeks	Generation of adequate images in 96.6% Detection and measurement of regurgitation with adequate reliability feasible	None reported
Shah et al. 2016[45]	Haiti/ Regional referral centre	Cardiac US, Lung US	Residents	Sonosite Micromaxx (SonoSite Inc., Bothell, WA)	Didactic training, supervised practice 3 weeks	POCUS examination changed diagnosis in 15.4% (18/117) patients POCUS changed management modality in 19.6% (23/117) patients	None reported
Nascimento et al. 2016[38]	Brazil/Primary and secondary schools	Cardiac US	Nurse, biomedical technician, imaging technician	Vivid Q® or VSCAN®, GE Healthcare (Milwaukee, WI, USA)	Online education, hands-on training 12 weeks	High quality imaging achieved Telemedicine useful to support non-expert team remotely in interpretation Lower costs of handheld devices permit concurrent work of more screeners	None reported
Ploutz et al. 2016[39]	Uganda/ Public primary schools	Cardiac US	Nurses	Vivid Q® and VSCAN®, GE Healthcare (Milwaukee, WI, USA)	Didactic session, hands-on training 2.5 days with previous limited 6 months experience	Sensitivity of around 90% for identification of definite RHD and adequate specificity	Technical issues due to overheating and short battery life
Kirkpatrick et al. 2018[36]	Vietnam/ Village health clinic	Cardiac US	Nurses	Laptop-sized device (M7; Midray Shenzhen, China)	Lecture, image review, practice1 day	POCUS augmented nurse examination with electrocardiography increased accuracy in diagnosis to 91.5%	None reported

Table 3 *(Continued)*

First author/Year	Country/Setting	Type of POCUS	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation
Nadimpalli et al. 2019[96]	South Sudan/ District hospital	Paediatric lung US	Clinical officer	Philips Lumify linear probe 5−12 MHz (Bothell, WA) and Nvidia Shield 2 tablet (Santa Clara, CA)	Didactic session, bedside teaching, practice 2 days	POCUS algorithm to diagnose pneumonia and other pulmonary diseases in children < 5 years old through a focused, field-based training is feasible	
Fentress et al. 2020[29]	Peru/Not specified	Lung US	General practitioners	Sonosite Micromaxx (FUJIFILM Sonosite, Bothell, WA)	Not specified 30 hours training	Possible role in screening and diagnosing PTB in areas without ready access to CXR	None reported
Salisbury et al. 2021[52]	Tanzania/Rural and urban health facilities	Paediatric lung US	Clinicians	Mindray DP-10 model	Theoretical and practical training on lung ultrasound Refresher IMCI training Supervised practical training 6 weeks	Lung ultrasound plays a role in misdiagnosis (underdiagnosis and overdiagnosis) of childhood pneumonia	None reported
Muhame et al. 2021[58]	Médecins Sans Frontières sites − multi-site study	Cardiac US	Clinicians	Not reported	4 weeks of face to face didactic lectures 50 hours of scanning	Change in management occurred in 75% (122/163) cases in whom a diagnosis was possible on focussed cardiac ultrasound including addition and removal of medications, changes to drug dosing, initiation of other supportive therapies or withdrawal of care	None reported
Voleti et al, 2021[57]	Republic of Palau/ School Setting	Cardiac US	Nurses, Physicians, Medical student, Patient care technician	Vscan Extend ultrasound machines (General Electric, Milwaukee, WI, USA)	2 weeks web-based curriculum Two hands on session (1.5 hours each) 11 hours of face-to-face, hands-on learner training	Non-experts' cardiac POCUS for the screening and detection of RHD can be achieved with reasonable sensitivity and specificity. Novel educational tool is a useful real-time adjunct to traditional computer-based training in enabling novice learner screening for RHD	This tool potentially has less utility in users whose routine practice with handheld ultrasound has been established

Table 3 *(Continued)*

First author/Year	Country/Setting	Type of POCUS	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation
Nascimento et al, 2020[55]	Brazil	Cardiac US	Nurses and Technicians	(VScan®, GE Healthcare, Milwaukee, WI)	at least 32 hours of hands-on practice utilizing hand-held machines	Implementing task shifting for POCUS (ECHO) in prenatal care is feasible Integrating prenatal cardiovascular screening into the primary care level may be essential to improve heart disease diagnosis	None reported

***Table 3*: Overview of studies applying task shifting chest POCUS in primary care in LMIC.**
US: ultrasound, IMCI: Integrated management of childhood illness, CXR: Chest X-ray, RHD: Rheumatic heart disease.

in Senegal for surveillance of *Schistosoma haematobium* morbidity[51] (Table 5).

Benefits and drawbacks of task shifting POCUS

The many clinical benefits of POCUS on patient management have been described within the above sections; in summary the major clinical benefits include improved diagnosis and support in clinical decision making leading to better bedside management but also adequate referral, increased use of health services, and ultimately better health outcomes. Additional benefits identified include availability of imaging at primary health care level, empowerment of frontline health care workers, saving of costs by identifying needless referrals. Challenges of task shifting for POCUS including drawbacks to successful implementation and sustainability were described in 13 (37%) of the publications.[21,23,24,27,32,35,39,41,43,44,50,54,57] The common constraints of working in resource limited settings including poor quality of the healthcare system paired with lack of local healthcare providers to lead and sustain ultrasound programs,[44] a high turn-over of local supportive supervision,[27] and unstable electricity[43,54] were identified as barriers. These factors led to reduced frequency of POCUS examination, incomplete data log, loss of data, loss of ultrasound images and interpretations.[50] Other barriers included training constraints and lack of an algorithm to guide POCUS screening and diagnosis.[23] Face-to-face training sessions were reported to be expensive as costs for services of experienced trainers including travelling are high.[24]

Poor internet connectivity was reported to pose serious challenges to both implementing e-training and remote supervision as this translated into delays in exchanging POCUS information between POCUS operators and reviewers.[21,43,54] Language barrier was also identified as a challenge to POCUS training.[41]

Discussion

This systematic review is the first to collate benefits and challenges of task shifting POCUS in primary healthcare in LMIC. Most studies included in this review report favourable effects of task shifting POCUS on clinical management at the primary care level in LMIC. Although the clinical value of POCUS is generally well established, collated evidence by this review needs to be appreciated with caution as studies originate from heterogenous settings and methodology is limited by uncontrolled study designs and constrained reference standards. More generally, there may be relevant publication bias with disappointing task shifting experiences less likely being published. Nevertheless, available literature indicates that task shifting for POCUS can make a difference in patient care in major medical fields of LMIC and highlights the pronounced potential of task

First author /Year	Country/ Setting	Type of POCUS	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation.
Adler et al. 2008[21]	Tanzania/ Refugee camp	Abdominal, cardiac, lung, obstetric, trauma, soft tissue	Clinical officers	SonoSite Titan® (SonoSite Inc, Seattle, WA, USA)	Didactic and practical sessions 4 days 20 or more supervised exams	Useful diagnostic tool mostly for pelvic and obstetric conditions Good distinction between ovarian cysts and uterine fibroids Useful for identifying (twin) pregnancies and progression of pregnancy	No qualified sonographer going forward Unable to transmit images due to lack of internet access No comparison with "formal" ultrasound or CT Quality data decreased over time due to poor supervision
Shah et al. 2009[44]	Rwanda/ Rural hospitals	Abdominal (Hepato- biliary & renal), cardiac, vascular, obstetric, DVT, vascular access, abscess (drainage)	Physicians	SonoSite Micromaxx® (SonoSite Inc, Bothell, WA, USA)	Lectures followed by practical hands-on scanning 9 weeks	Useful diagnostic tool especially in women's health and obstetrics May influence patient management; 43% change in management Most common changes: a) indication for surgical procedure (caesarean section, biopsy, minor surgery), b) medication changes (adding furosemide), c) referral to specialist Ultrasound program led by local health care providers can be sustainable	None reported
Kolbe et al.,2014[96]	Nicaragua/ Village clinic	Abdominal, pelvic, obstetric	Two physicians, clinic nurse, nursing assistant	Sonosite, Titan®, Seattle, WA, USA	Didactic sessions, practical workshops Duration not reported	After POUCS 52% received a new diagnosis With a change in management in 48%	Unreliable electricity supply Poor internet connection Knowledge to maintain the ultrasound machiner Risk of theft and vandalism
Henwood et al. 2017[32]	Rwanda/ Provincial hospitals	Abdominal, cardiac, lung, obstetric, soft-tissue	General physician	Not reported	Not specified • 10 days • Follow-up training every 6 weeks for 6 months	Most frequently used for abdominal and obstetric examination Change in management in 81.3% Most common changes: a) medication (42.4%, mainly diuretics), b) admission (30%), c) transfer to higher level of care (28.1%), d) procedures (23.3%) FAST had a strong impact on management Long-term use of POCUS	Cost of training, training ultrasound device, maintenance of ultrasound device and image archiving (Technical) problems with image archiving

Table 4 *(Continued)*

First author /Year	Country/ Setting	Type of POCUS	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation.
Rominger et al. 2018[41]	Mexico/ Rural clinics	Obstetric, abdominal, pelvic, lung, soft tissue, musculo-skeletal, cardio-vascular, ocular Obstetric, abdominopelvic	General physician	Sonosite nanomaxx	Lectures, hands-on training 4 days training, recurring every 3–4 months for 1 year3–4 month	Most frequently used for obstetric and abdominal examination POCUS changed diagnosis in 34% and clinical management in 30% In unsupervised scanning POCUS changed the diagnosis in 34% of scans and changed clinical management in 31%	Incomplete ultrasound log Problems with archiving images High turnover of supervision Possible language barrier between local physicians and supervisors
Sabatino et al. 2020[42]	Sierra Leone/ Rural hospital	Lung, abdominal, pelvic, trauma	Community health officers	Esaote® MyLab™Alpha	Theoretical and hands-on training course 2 weeks	Abdominal (66.3%) and chest (24.5%) ultrasound most frequently performed 17.1% change of diagnosis after POCUS, leading to change in management	To keep ultrasound programme sustainable, successful training programs for local practitioners should be implemented

Table 4: **Overview of studies applying task shifting multi-organ POCUS in primary care in LMIC.**

shifting for POCUS for primary healthcare settings in LMIC where diagnostic imaging is otherwise barely accessible to large proportions of the population.

In LMIC, maternal mortality is the leading cause of death among women of childbearing age[60] and 98% of the global neonatal mortality rate occur in LMIC.[61] Antenatal sonographic examinations are integral to identifying high-risk pregnancies and for initiating time-sensitive management to reduce maternal and neonatal morbidity and mortality. Consequently, the WHO recommends at least one ultrasound examination for pregnant women.[62] Task shifting for obstetric POCUS provided by midwives, nurses or birth attendants at the primary care level may be essential to increase access to antenatal ultrasound for pregnant women in LMIC. Obstetric POCUS studies reported considerable impact of POCUS on management and clinical care of pregnant women including improved diagnosis of high-risk and complicated pregnancies, increased number of deliveries by skilled birth attendants, more deliveries in healthcare facilities and a reduction in maternal and neonatal mortalities.

Cardiovascular diseases (CVDs) are on the rise and are the leading cause of mortality globally; over three quarters of CVD deaths occur in LMIC.[63,64] Patients with heart diseases often present late with symptoms of heart failure that do not allow for distinguishing the underlying etiology of heart disease.[65] In the recent past, increasing experience has become available on the benefits of cardiac POCUS by non-cardiologists to evaluate structural and functional heart pathology.[66] The studies on cardiac POCUS showed the need for imaging capacity at the primary care and that task shifting for POCUS can partly fill this gap. A broader cardiac POCUS yet context tailored approach to identify most prevalent etiologies underlying heart failure and to guide clinical management in LMIC has been suggested[65]; its feasibility and diagnostic utility in routine care remain to be evaluated.

Road traffic trauma constitutes a global health challenge, particularly in LMIC where 90% of the world's fatalities on the roads occur.[67] Multi-sector approach including improved post-crash care in the health sector is required in addressing challenges of road trauma victims.[67] Focused assessment with sonography for trauma (FAST) is part of resuscitation of trauma patients in most high-level care settings and recommended by international panel consensus.[68–70] FAST and eFAST (extended FAST (eFAST)) are highly accurate for identification of free fluid and pneumothorax.[71,72] Comparatively, few publications on FAST application in LMIC were identified by this review. FAST in LMIC can play an important role in the management of trauma patients given the limited access to other cross-sectional imaging modalities. FAST in a pre-hospital setting allows targeted referral of trauma patients requiring surgery or transfusion.

First author /Year	Country	Type of POCUS	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation.
Levine et al. 2010[37]	Rwanda/ District hospital	Aorta inferior - vena cava ratio (severe dehydration)	Physicians	Sonosite Micromaxx (Bothell, WA)	Didactic presentation, hands-on scanning Duration not reported	Aorta inferior - vena cava ratio is a relatively accurate and reliable predictor of severe dehydration in children with diarrhoea and/or vomiting POCUS may be a useful adjunct to clinical exam in guiding management	None reported
Bonnard et al. 2011[51]	Senegal/ Rural communities	Vesico-urinary	Clinician versus radiologist	GE LOGICe	Not specified 8 days	Diagnosis and surveillance of Schistosoma haematobium related lesions	None reported
Del Carpio et al. 2012[27]	Patagonia, Chile, Argentina /Rural communities	Abdomen (FASE)	General practitioners, residents	Not reported	Lectures, practice 20 hours	Identification of cystic echinococcosis Minimization of social and health care costs	High turnover of rural doctors
Chebli et al. 2017[22]	Morocco/ Rural communities	Abdomen (FASE)	General practitioners	Not reported	Lectures, hands-on training 24 hours	Accurate diagnosis of abdominal cystic echinococcosis	None reported
Terry et al. 2019[96]	Uganda/ Rural emergency centre	FAST	Medical students, medical graduates	Sonosite Micromaxx (Bothell, WA)	Lecture, hands-on training Dispersed training over one month	Increased utilisation of POCUS for patient management with Remotely delivered quality assurance fosters skills and continued use of POCUS	Loss of POCUS data Delayed feedback
Kahn et al. 2020[33]	Malawi / Private health care centre	FASH	Clinical officer, medical doctor	Philips ClearVue 650	Not reported	POCUS supported clinical decision making in 76% of encounters POCUS augments the clinician's ability to make a timely diagnosis	None reported
Raza et al. 2021[40]	Rwanda/ Rural hospital	Breast	Nurse, midwife, general practitioners	Fujifilm Sonosite, (Bothell, Washington)	Didactic lectures, practical session, remote mentorship 9 weeks	POCUS supplements clinical breast examination in the absence of mammography POCUS facilitates accurate patient triage, improves patient access to diagnostic services, and optimizes use of limited resources	None reported

Table 5 *(Continued)*

First author /Year	Country	Type of POCUS	POCUS Operator	POCUS device	Training and duration of training	POCUS benefits identified in publication	Drawbacks of POCUS implementation.
Aklilu et al. 2021[56]	Peru/ Rural primary care center	Breast	Primary care physician	VINNO E30 (Sozhou, China) or SAMSUNG MEDISON ACUVIXXG (Seoul, Korea).	Didactic sessions and practical sessions 8 hours daily for 2 days	Task shifting for POCUS combined clinical breast examination led to change in management in 29.2% of cases (mostly increasing biopsies), and 66.7% with condensed and full BI-RADS (mostly decreasing biopsies)	None reported

***Table 5:* Overview of studies applying task shifting POCUS in primary care in LMIC for emergency care, trauma, infectious disease, and breast cancer.**
FAST: focused assessment with sonography for trauma, FASH: focused assessment with sonography for HIV-associated tuberculosis, FASE: focused assessment with sonography for echinococcosis.

In LMIC, lower respiratory tract infection is a leading infectious cause of morbidity and mortality particularly in children under 5 years.[73] Chest ultrasound for the diagnosis of pneumonia has been reported as an imaging modality with sensitivity and specificity superior to chest-x-ray (CXR) for the diagnosis of childhood pneumonia.[74] The substantial inter-rater agreement between POCUS operators and experts for lung consolidation and the almost perfect inter-rater agreement for viral lower respiratory tract infection encourages that locally trained lung POCUS can become a feasible tool to diagnose pneumonia and other pulmonary diseases in children under 5 years old in LMIC.[52,53]

POCUS for imaging pulmonary tuberculosis (PTB) has recently been subject of various studies,[75] but only one study from Peru could be included in this review. The potential role of POCUS in screening and diagnosis of PTB in areas without access to CXR is also supported by other studies; a specific sonographic pattern of tuberculous lung infection is being discussed and could help differentiate between tuberculous and non-tuberculous pneumonia.[76] Accurate diagnosis of tuberculosis (TB) in HIV-coinfected people is difficult. HIV patients have higher rates of extrapulmonary tuberculosis (EPTB), and the diagnosis of TB is often limited to clinical findings and imaging results, if imaging services are accessible. Focused assessment with sonography for HIV-associated TB (FASH)[77] aims at detecting common EPTB manifestations and has become one of the most applied POCUS modules in settings with high TB/HIV burden.[78,79] Of the many studies that evaluated EPTB-focused POCUS in adult and pediatric patients either as a diagnostic or treatment monitoring tool,[80–85] only one met the inclusion criteria for this review; most studies were excluded because POCUS was performed by non-locals and at higher care levels. Included and excluded studies conclude that FASH can augment the clinician's ability to make a timely diagnosis of TB and monitor treatment response. Adoption of TB-focused POCUS and TB diagnostic algorithms can support its rollout in primary care setting, but to date data on its utility at primary care are limited.

Further, infectious diseases with public health relevance in endemic LMIC have been investigated for suitability for POCUS diagnostics. The study from Morocco on POCUS screening for cystic echinococcosis (CE)[22] an infectious disease with a primarily imaging-based diagnosis,[86] proved not only feasible and successful in identifying the disease, but is a good example that POCUS can also support the implementation of disease control activities. POCUS for the detection of urogenital schistosomiasis,[49] POCUS to guide management of severe malaria,[87] POCUS for early detection of vascular leakage in severe dengue[88] and POCUS for visceral leishmaniasis[89,90] have been piloted and discussed, but diagnostic studies from primary care settings in LMIC are not yet available.

An immediate impact of POCUS on patient management relates to appropriate use of anti-microbial medication. Henwood et al. reported that POCUS by local healthcare workers changed treatment modality in 42% of patients and this included administration of antibiotics.[32] Comparably, a change in treatment following POCUS was observed by Chavez et al. for children diagnosed with pneumonia.[59] In TB/HIV co-infected patients POCUS prompted live-saving initiation of anti-tuberculosis treatment, addition of steroids in case of sonographically identified tuberculous pericarditis, and guided initiation of antiretroviral treatment.[81] As mentioned above, POCUS shows also promise as a monitoring tool for treatment response in TB treatment with inadequately long persistence of sonographic findings indicating inadequate treatment dosing, intake, or resistant tuberculosis.[83,91,92]

Challenges relating to basic and continuous training were reported repeatedly. Particularly face-to face training was identified to be expensive. Most POCUS trainers were from overseas and travel related costs were high. Using e-learning methods have been suggested,[43] however, these come with difficulties such as poor internet connectivity and extra costs in procuring internet data for streaming videos and downloading study material.[93,94] The lack of stable internet connection and electricity to access study materials may lead to low motivation among healthcare workers to utilize e-learning platforms.[95] Poor internet infrastructure can also hamper communication between POCUS operators and reviewers which was identified as the commonest method of supervision provided. The extremely broad range of length and type of training in the articles included highlights the need for standardized curricula; given the operator dependency of POCUS, under-training and lack of supervision can endanger patients' safety.

Primary care settings in most LMIC often face power instability, and hot and humid climate conditions that can damage ultrasound devices. Inadequate know-how for maintenance service and lack of close technical service threatens continuous availability of functioning ultrasound devices. Many devices have been used for POCUS in LMIC but no comparative evaluation of device performance under LMIC conditions is available.

Most studies focused on clinical aspects relating to POCUS rather than key determinants of the task shifting approach. Ultrasound devices were not specifically studied for their suitability for task shifted use; user-friendliness including the possibility for setting presets targeted to the specific POCUS applications likely impacts feasibility and quality. Although most studies reported on the basic components of POCUS training it remains unclear to what extent POCUS training had been contextualized to the respective setting. Mention of infrastructure support needed to enable and sustain task shifting POCUS were discussed in relation to challenges with electricity and internet provision; further infrastructure aspects such as availability of ultrasound device servicing or arrangement of favorable scanning conditions (e.g., room darkening) may also play a role. None of the studies assessed cost-effectiveness of task shifting POCUS. Generating data on cost-effectiveness of task shifting for POCUS will, however, be crucial to guide implementation of task shifting for POCUS.

Within the available studies structures, quality management and supervision of task shifting for POCUS have largely been set up for the respective research and included overseas telemedicine components. For an independent and sustainable task shifting program pathways, local quality management and supervision are warranted. The empowerment of health care workers by gaining diagnostic capacities through task shifting for POCUS will likely increase satisfaction and recognition of their work and consecutively promote staff retention, a prerequisite for long term success of task shifting for POCUS.

In summary, seed evidence on task shifting for POCUS encourages further promotion of task shifted frontline POCUS use in LMIC. Establishing and disseminating successful and sustainable task shifting for POCUS programs needs a comprehensive strategy that addresses key aspects of a task shifting approach including definition of suitable technology, contextualized training, infrastructure support, adequate financing, quality management, longitudinal supervision, staff retention strategies, and outcome analysis. Determination of local disease burdens and needs assessment will allow conception of context adapted POCUS programs and POCUS curricula that could become integral part of local health education programs. Operational research on facilitators and barriers of POCUS implementation programs is needed to guide higher level decisions on integration in health sectors.

This review identified multiple studies that showed that shifting ultrasound tasks away from radiology centres to frontline bedside care is a feasible and effective strategy to change patient management at the primary care level in LMIC. Task shifting for POCUS thereby demonstrates that task shifting diagnostics to providers at lower-level facilities is impactful and translates to meaningful health outcomes. Technological advances and affordability of POCUS devices will continue to promote the diffusion of POCUS into frontline care, however, appreciation of POCUS as a diagnostic tool suitable for task shifting is warranted to deliberately enhance sustainable and qualitative implementation of task shifting for POCUS.

Data sharing statement

All data are already publicly available.

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Contributors

SKA and SB conceptualized the systematic review. SKA developed the data extraction tools with input from SB and CCH. SKA, LCR and CCH performed the initial abstract screen and subsequently full text screening. SKA and CCH extracted data from the included publication. SKA and LCR performed the risk of bias assessment. All named authors contributed to drafting, revising, and approving of the final manuscript.

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