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Barriers and facilitators to implementation of point-of-care lung ultrasonography in a tertiary centre in Benin: a qualitative study among general physicians and pneumologists

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ABSTRACT

Objectives Owing to its ease-of-use and excellent diagnostic performance for the assessment of respiratory symptoms, point-of-care lung ultrasound (POC-LUS) has emerged as an attractive skill in resource-low settings, where limited access to specialist care and inconsistent radiology services erode health equity.

To narrow down the research to practice gap, this study aims to gain in-depth insights in the perceptions on POC-LUS and computer-assisted POC-LUS for the diagnosis of lower respiratory tract infections (LRTIs) in a low-income and middle-income country (LMIC) of sub-Saharan Africa.

Design and setting Qualitative study using face-to-face semi-structured interviews with three pneumologists and five general physicians in a tertiary centre for pneumology and tuberculosis in Benin, West Africa. The center hosts a prospective cohort study on the diagnostic performance of POC-LUS for LRTI. In this context, all participants started a POC-LUS training programme 6 months before the current study. Transcripts were coded by the interviewer, checked for intercoder reliability by an independent psychologist, compared and thematically summarised according to grounded theory methods.

Results Various barriers– and facilitators+ to POC-LUS implementation were identified related to four principal categories: (1) hospital setting (eg, lack of resources for device renewal or maintenance–, need for POC tests+), (2) physician's perceptions (eg, lack of opportunity to practice–, willingness to appropriate the technique+), (3) tool characteristics (eg, unclear lifespan–, expedited diagnosis+) and (4) patient's experience (no analogous image to keep–, reduction in costs+). Furthermore, all interviewees had positive attitudes towards computer-assisted POC-LUS.

Conclusions There is a clear need for POC affordable lung imaging techniques in LMIC and physicians are willing to implement POC-LUS to optimise the diagnostic approach of LRTI with an affordable tool. Successful integration of POC-LUS into clinical routine will require adequate responses to local challenges related to the lack of available maintenance resources and limited opportunity to supervised practice for physicians.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study offers context specific in-depth insights into the barriers and facilitators of point-of-care lung ultrasound implementation.
⇒ Identification of real-life pragmatic challenges.
⇒ First study to discuss the perceptions on future computer-assisted lung-ultrasound in a low-resource context.
⇒ Participants are limited to urban physicians working in a single tertiary centre. Further research should be more inclusive and include healthcare workers with diverse profiles and patients in both rural and urban settings.
⇒ All interviewees are inexperienced lung sonographers. Future research should include both novice and experienced sonographers.

INTRODUCTION

Even before the COVID-19 pandemic, lower respiratory tract infections (LRTIs) including pneumonia, were the world's most deadly communicable disease, ranking as the fourth leading cause of death worldwide. While the statistic is global, the effect is particularly concentrated in low-income and middle-income countries (LMIC) where LRTIs rank second before malaria, tuberculosis (TB) and HIV/AIDS in terms of causes of mortality.[1] These deaths are frustratingly preventable with simple interventions, one of the most important being accurate and timely diagnosis.[2] Point-of-care lung ultrasound (POC-LUS) is widely used by emergency physicians in high-income countries to evaluate patients with dyspnoea.[3] Its role to differentiate cardiogenic and pneumogenic dyspnoea is well established. LUS is highly effective in detecting lung consolidation in pneumonia[4–6] and guidelines recommend LUS as an alternative to chest X-ray for pneumonia diagnosis. With

Figure 1 Portable one-probe point-of-care ultrasound device compatible with smartphone or tablet computer that was used during training and further practice.

the development of ultrasound-on-a-chip technology, ultrasound is now available as a portable, pocket-sized mobile health device.[7] Owing to its ease-of-use, affordability and low maintenance and consumable requirements, POC-LUS has emerged as an attractive skill in resource-low settings, where limited access specialist care and inconsistent radiology services erode health equity.

Although POC-LUS images are easy to acquire, interpretation suffers from interuser bias, with results varying across experience.[8] Thus, POC-LUS is a promising candidate for automated interpretation and computer-assisted diagnosis (CAD). Artificial intelligence (AI)-powered tools could facilitate the implementation of POC-LUS in general medicine and decentralise its use even to remote areas.

While research on POC-LUS and CAD in POC-LUS is evolving, it is not yet available and very few studies address barriers and facilitators to their implementation in LMIC with their own context-specific challenges such as low-resource availability, difficult access to training, climate, connectivity and weak healthcare structures.[9 10] Understanding these factors, however, is key to bridge the evidence-to-practice-gap and eventually improve POC-LUS uptake by frontline healthcare workers.[11 12] With the current study, we therefore aim to gain in-depth insights in the perceptions on POC-LUS and CAD POC-LUS for the diagnosis of LRTIs in LMIC.

METHODS

Design and setting

This qualitative study is based on face-to-face semi-structured interviews of physicians participating in a prospective cohort trial on the diagnostic and prognostic accuracy of POC-LUS in TB endemic regions (the TrUST study; pre-results stage, *ClinicalTrials.gov identifier: NCT05423847*) launched in October 2021 in the National Teaching Hospital for Pneumology and Tuberculosis in Cotonou, Benin (West Africa). This 100-bed hospital acts as a referral centre for respiratory diseases and hosts the country's national TB programme for case detection and treatment. At the time of the study, the centre's GeneXpert MTB/RIF positivity rate was 11%.[13] There is no universal health coverage and routine patient-care (such as chest X-ray, doctor consultation, therapeutic interventions) depends on out-of-pocket expenditures.

A team of eight treating physicians is active in the hospital: five general physicians and three pneumologists. The entire team started POC-LUS training in April 2021 starting with informal group-directed learning in the field and passed a standardised POC-LUS skills and theory course with a final test in September 2021 (details of the training available in online supplemental table 1). Each doctor had access to a personal portable ultrasound-on-chip probe connected to a smartphone or a tablet computer (figure 1). Physicians were contacted to plan the interview between 4 and 10 September 2021. If necessary, phone contact was used to confirm or remind the interview. All but one pneumologist (who was absent at the time of the study) participated and provided written consent.

Participant characteristics

A total of eight physicians participated in this study: three pneumologists and five general practitioners (table 1). The pneumologists worked at the hospital for more than 10 years. The five general practitioners joined the team less than 10 years ago (between 1 and 10 years). Seven men and one woman between 20 and 50 years old participated. Half of the team had some ultrasound experience before the 2021 POC-LUS training, the pneumologists having had past conventional pleural ultrasound experience during their resident training and one general practitioner with recent conventional abdominal ultrasound training. The other half of the team started their ultrasound experience with the 2021 POC-LUS training. Between group directed learning initiation in April and the interviews in September after the formal training, the physicians used POC-LUS between once a week and once a month.

Data collection

A trained health psychology student (SGDC) conducted face-to-face semi-structured interviews, supervised by

Table 1 Summary of participant's characteristics

	N (%)
Sex	
Female	1(10)
Male	7 (90)
Age	
Less than 30 years old	4 (50)
More than 30 years old	4 (50)
Professional function and years of practice	
Generalist (less than 10 years)	5 (62.5)
Pneumologist (more than 10 years)	3 (37.5)
Previous ultrasound experience	
Yes	
No	4 (50)

an expert in health psychology (FF), in a quiet separated office room in the hospital. She had no prior relationship with the participants and had previous interview experience with structured interviews and specific training for semi-structured interviews. Participants were aware of the interviewer's purposes and background. An interview guide developed by FF, SGDC and experienced field clinicians (VS and NB-B) contained open questions indicating broad areas of discussion, and specific probing questions (available in online supplemental table 1). The core focus of the interview guide was to explore the needs in clinical practice, barriers and facilitators of implementation, influence on patient dynamic and perceptions on CAD POC-LUS. The interview guide was pilot tested on an external clinician. After this interview, SGDC, VS and NB-B analysed the adequacy of the interview grid, in relation to the relevance of the contents of the discourse. After an interjudge agreement with FF, the same grid was used for all interviews.

The duration of the interviews was between 25 and 45 min. Each interview was audio recorded and transcribed by SGDC. FF reviewed the transcribed interviews for accuracy. The transcripts were not returned to the participants. Saturation (defined as no emergence of new concepts or sentiments compared with those previously expressed) was reached after eight interviews without a need for repeat interviews.

Data analysis

SGDC read and coded the transcripts independently using the three stages of coding of the grounded theory method (GTM): open, axial and selective coding. After the interviews and the transcripts, SGDC also kept memos to explore her own reflexions, feelings and links to the collected data. This allows for in-depth exploration of the specific motivation behind an individual's actions.[14 15] SGDC read and coded all transcripts. FF independently read and coded the first interview. Then compared her result with SGDC. The codes were derived from the content of the interview and memos. They were grouped into subcategories as GTM requires. After an individual analysis of each interview by SGDC, the results of all interviews were checked for intercoder reliability with FF, compared and thematically summarised. This process enabled them to build the emerging theoretical framework from the data and to elaborate the core category. The Standards for Reporting Qualitative Research[16] was used for reporting.

Patient and public involvement

There are no patients involved in this study.

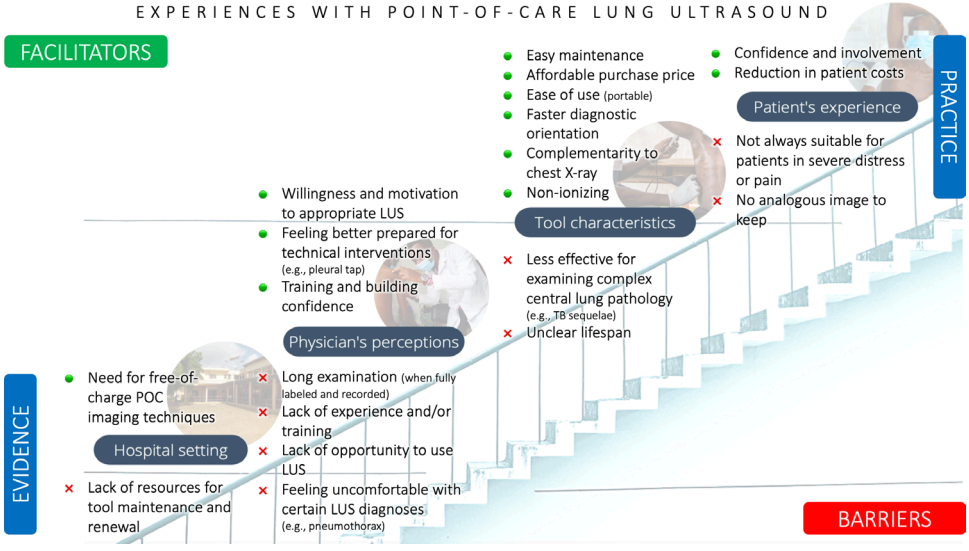

Figure 2 Overview of main barriers and facilitators for the implementation of point-of-care lung ultrasound that need to be taken into account when stepping up from research evidence to real practice. LUS, lung ultrasound; POC, point-of-care; TB, tuberculosis.

RESULTS

We observed barriers and facilitators to POC-LUS implementation related to four principal categories: (1) hospital setting, (2) physician's perceptions, (3) tool characteristics and (4) patient's experience. These principal categories further lead up to the identification of the 'core category': experiences with POC-LUS approach. Results are summarised in figure 2. Finally, as CAD POC-LUS is a future technique not yet practiced by the participants and thus falling outside the core category, its perceptions are reported separately.

Barriers of POC-LUS implementation

Barriers related to the hospital setting

A factor hindering the long-term integration of POC-LUS is the possible lack of financial resources to renew and maintain the equipment.

> […] when the device will be worn out, we must already think of renewing the stock […] it is perhaps a question of means, how to make it sustainable, it is perhaps a question of means to equip the center.
>
> When the devices wear out, they have to be renewed. For the moment it's not billed, we haven't set up a recovery system […]. So when the device wears out, when the ultrasound wears out, we have to renew it within the structure and that will call for a cost […]

According to some participants, this financial burden could be solved by charging for the examination. However, the possibility of having to charge the patient for POC-LUS could in turn discourage the physician from offering POC-LUS during the consultation.

Typical quotes that explain this are:

> […] this cost must be shared by the patient because that's our system, or by the health insurance system and so we will have to bill the patient.
>
> Now if it were to have a cost yes it can limit, it can limit.

Barriers related to the physician's perceptions

The hospital is regularly confronted with an overload of patients, which could make it more difficult to carry out POC-LUS systematically. A typical quote is:

> […] when you have 20 patients to see, question, examine and then go and do the ultrasonography for each one, it's not easy.

All physicians identified that the lack of opportunity to practice hinders the appropriation of the tool.

> If you don't consult, if you get sent to other activities, other program activities, you don't use it so I think that's all that can hinder its use.

With their previous practical and theoretical training, some physicians report that they are not completely comfortable detecting all types of pathology (especially pneumothorax) and others lack comfort in handling the tool.

> It's just the pneumothorax and then the interstitial syndrome that take time, you have to see several, several, to compare to be reassured.

Some report that they feel completely at ease in performing the examination, while others report a lack of practical experience.

Barriers related to the tool's characteristics

In terms of diagnostic performance, some participants explain that POC-LUS is less effective in examining lesions of patients with TB sequelae of the lungs.

This is explained in this quote:

> […] in these sequelae of tuberculosis, it is often a magma of lesions, you have several types of lesions and in this case, ultrasonography may have some limitations when we have to see these patients.

In terms of its use in daily life, most physicians question the lifespan of the equipment. This is illustrated in a quote:

> The tablets we received, the device, what is its lifespan? How long does it take to pay for itself?

Barriers related to the patient's experience

Some physicians describe a reluctance to use POC-LUS in patients with severe pain, linked to the time it takes to perform the examination.

> If I take, for example, a patient who comes, who is suffering and who has, for example, pain, dyspnea, if the ultrasound is long, if the examination is long, on the other hand, he may develop a feeling of reluctance towards this examination, do you understand?

Patients, being more accustomed to radiography, may also be reluctant to the examination because the results are not material.

Indeed, as is explained by this quote, with POC-LUS:

> […] there is no picture that comes out, there is nothing…with chest X-ray, it is something that he will be able to possess, thanks to the images he brings everywhere whereas with the ultrasonography you just have the images in your machine and he doesn't have it, that can make him decide to get a chest X-ray.

Facilitators of POC-LUS implementation

Facilitators related to the hospital setting

In terms of needs, all physicians report that, despite the presence of a radiography service, the medical centre lacks POC) paraclinical examinations and technological devices.

A typical quote is:

> […] the challenges that we have in the needs in the management of patients are mainly challenges of a paraclinical nature…paraclinical meaning all the tests necessary to correctly establish a diagnosis within

a short timeframe in order to be able to provide rapid management and in terms of imaging it is also these examinations that we need but they are technically unavailable.

Another quote is:

The other thing is that in the center for the moment, the [radiology] devices break down every time…

Moreover, most doctors highlight their needs of affordable diagnostic tools as out-of-pocket health expenditures negatively influence their quality of care.

A typical quote is:

The problem we often have in the department is that we have a lung radiography service but it's a cost, it's a cost and most patients can't pay […]

[…] we start treating tuberculosis without necessarily knowing what the pulmonary effusion is behind it, as long as the patient does not have the means to do a chest X-ray we remain blocked […]

Facilitators related to the physician's perceptions

All participants perceive the tool as being accessible at the patient's bedside and improving the preparation of technical gestures (eg, a pleural tap).

[…] with ultrasound you can easily make the diagnosis for example of pleurisy.

It is emphasised that training and continuous practice is needed to build up confidence as illustrated by the following quotes:

[…] by practicing slowly, confidence is being established.

Since their POC-LUS training, they report feeling able to make a therapeutic decision based on the interpretation of the images collected with POC-LUS. Some physicians explained that they felt more comfortable using POC-LUS to confirm or invalidate a diagnostic hypothesis and felt more comfortable in the technical performance of the examination.

We got some tips on how to do, to better place the probe, to have a good image, how to see the areas, certain areas where we had difficulty identifying well on ultrasonography.

In terms of appropriation of the tool, the physicians report motivation to use it.

We are enthusiastic, it's a new instrument, we want to make it our own.

Facilitators related to the tool's characteristics

Most participants report that POC-LUS is less expensive than radiography. Consequently, the tool allows for a reduction in the cost of patient care.

A typical quote is:

Not all patients can afford a chest X-ray, whereas with ultrasonography we could say yes.

In terms of its use in daily life, the POC-LUS equipment is available and practical. In fact, the doctors say that it is a portable and light tool, so.

[…] easy to carry and use […]

Using the portable ultrasound device on their smartphone or tablet as a POC test, most participants mention direct integration into clinical reasoning, which improves the diagnostic approach leading to a faster patient's orientation and management without having to move the patient around the hospital.

[…] can already help you orient the diagnosis […]

It allows for a reduction in the decision time and, consequently, in the management time.

[…] there you move the patient less to do an examination and you do the ultrasound at the same time in the patient's bed and that helps you with the management at the same time, less travel that will help at several levels.

[…] you move the patient less to do an examination and you do the ultrasonography at the same time at the patient's bed and it helps you to take care of the patient at the same time.

[…] help to clear the ground a bit as we say, to see more clearly on respiratory pathologies where we have doubts even with a classical imaging and maybe a scan.

They finally note the absence of radiation as a reason to privilege POC-LUS over radiography, especially in children and pregnant women.

Indeed, a quote explains this:

[…] knows that by going to a radiography, he is being irradiated and with ultrasonography there is no risk, perhaps he would choose ultrasonography.

Facilitators related to the patient's experience

Most physicians describe a heightened sense of patient confidence when the doctor uses POC-LUS. It strengthens the patients–physicians relationship. Indeed, as illustrated by a typical quote:

[…] a patient comes in and the doctor takes all his time to examine him first and then he takes a device, a tool, he puts it down, he looks, he observes, it will relieve the patient, he says to himself, 'Oh, this doctor is sure to find my disease'. He is already cured; he is already 50% cured.

The patient's feeling of confidence is also increased through the observations made and the information transmitted on the examination by the doctor. As a result, the physicians report a better disease awareness by the patient.

> As soon as the patient has the information and understands it, it will inevitably improve the relationship between the caregiver and the patient, so it will be necessary to communicate, to explain the importance of ultrasound for the diagnosis, for the follow-up of the pathology and this will inevitably improve.

A feeling of satisfaction on the part of the patients is also observed, linked to the absence of financial cost generated by the examination.

> […] we tell them it's not expensive, it's free, it's free and they're happy.

Thus, health professionals feel that the tool could bring them closer to their patients, which could have a positive influence on the doctor–patient relationship.

Then, some doctors state that the modern care offered to patients induces changes in the beliefs they have about the divinatory origins of their illness and may lead them to choose to go to the healthcare centre rather than to a traditional therapist.

Finally, the participants explain that the tool arouses the patient's interest in how it works.

Perceptions on CAD POC-LUS

Contrary to chest X-ray, CAD for POC-LUS and AI powered tools are still under development and not yet available in routine clinical practice.

In terms of perceptions of a future integration of AI into their medical practices, all physicians report that it could accelerate clinical reasoning and optimise the quality of diagnosis. A typical quote explains this:

> It's going to make interpretation easier and at the same time more specific.

Moreover, all doctors perceive the introduction of AI as a contribution to routine diagnostic work-up, especially in remote areas without trained doctors.

However, some participants highlight the need to consider the risk of errors in the creation of algorithms and affirm that AI cannot replace the physician's responsibility. Technology only comes in to support their medical practice, but the final decision comes back to the doctor. This is explained by this quote:

> He can make mistakes, that's why the man must always be behind.
>
> […] the doctor always has his place, the doctor always has his place and the device only comes to help the subject, but the final word always comes back to the doctor, I am not against it, it's just an aid.

Considering the doctor–patient relationship, the patient's sense of reassurance is increased with the introduction of a machine that confirms the physician's observations.

A typical quote demonstrates this:

> He will be more confident, he says to himself, he checks a lot of things. He checked himself and he still used a machine, so he'll say to himself, well, that's going to reassure me more […]

However, some physicians say that the introduction of AI devices can lead to patient distrust of the physician's skills. Indeed, the errors that the tool might produce can influence the way patients believe the doctor's opinion. This is illustrated in this quote:

> […] for some patients in any case it is according to intellectual and socio-cultural levels, he can say but your machine, but if your machine is wrong, you are wrong too.

DISCUSSION

As chest X-ray facilities are lacking in primary care settings in LMIC and only available in a median of 68% of hospitals,[17] POC-LUS is an interesting alternative imaging technique to explore. Our study offers in-depth insights into the barriers and facilitators of POC-LUS implementation in a sub-Saharan African country. It also provides physicians' perceptions on AI-guided POC-LUS.

Experiences with POC-LUS can be hindered or facilitated by several factors related to the hospital setting, the physician's perception, the tool's characteristic and the patient's experience.

Major facilitators of POC-LUS implementation are linked to the local needs and the intrinsic characteristics of the technique. In our study setting, there was a clear need for an affordable lung imaging technique using low maintenance materials. This is consistent with qualitative findings from studies in Pakistan, Mozambique and Kenya.[9 10] POC-LUS is integrated in clinical reasoning at the bedside and can speed up a first diagnostic orientation even when chest X-ray is available. POC-LUS is thought to refine clinical hypothesis or reduce doubts based on a chest X-ray alone (eg, characterising pleural effusions). This streamlining of the workflow is consistent with previous qualitative findings in a paediatric setting.[9] Its lack of radiation also makes it an interesting technique for pregnant women and children.[18]

Other facilitators at the physician's level are willingness and motivation to appropriate the technique, better preparedness for technical interventions (eg, a pleural tap), training and experience and building confidence in its interpretation. A recent systematic review shows that an accurate diagnosis of pneumonia is highly feasible in the hands of non-imaging specialists.[19] Qualitative data from Denmark highlight that general practitioners that use ultrasound on a daily or weekly basis to answer simple clinical questions, are comfortable and confident with the technique and its interpretation.[20] At the level of patient's experience, interviewed physicians identified facilitators such as the heightened sense of confidence and involvement, and possible reduction in diagnostic costs. Qualitative studies from affluent countries also indicate that POC

ultrasound provides reassurance, strengthens the physician–patient relationship and improves patient satisfaction[21 22]

As for barriers, important obstacles are encountered related to the hospital setting and the physician's perception. A lack of resources to renew and maintain the devices hampers its successful long-term integration. Another study also found that a lack of institutional goodwill, practice guidelines and protocols poses a barrier.[10] Insufficient confidence with POC-LUS interpretation due to insufficient training or exposure to the technique are also major barriers. In a Kenyan context, physicians were also doubtful whether other clinicians would accept their POC-LUS results.[10] Regarding the tool's characteristics, the participants mentioned the difficulty in examining patients with TB sequelae and central lung involvement. Indeed, as POC-LUS analysis is limited to the pleural line and adjacent pathology, deeper structures which do not communicate with the pleura remain invisible. For TB, this implies that the technique is less suitable for patients with typical TB sequelae such as tracheal deviation, atelectasis and central cavities.[23]

Considering the patient's experience, POC-LUS is deemed less suitable for patients in severe distress. This finding is consistent with other qualitative studies where participants only had limited ultrasound experience.[24] However, in the hands of experienced sonographers, additional discomfort in patients with respiratory distress is very low.[25] In addition, with expanded physician's skills, POC-LUS can be combined with other POCUS examinations (eg, cardiac POCUS for rapid assessment of the left and right ventricular functions) and offers a global diagnostic approach in assessing patients with severe respiratory distress. The lack of an analogous image for the patient to keep and distrust in technology might also form a barrier on the patient level.

We did not observe differences in perceptions between experienced and non-experienced trained physicians. This is probably related to the fact that experienced physicians had a very limited exposure to ultrasonography before the study.

Concerning CAD POC-LUS as a theoretical concept, our study shows enthusiasm from the physician's side to try such an approach, stating it would probably optimise the quality of their sonographic diagnosis, while being aware and critical that it would not simply replace doctor's skills, and might induce patient scepticism. Previous experience with radiologists who adopted CAD shows that the conditions required to implement CAD are sufficient performance, no increase in reading time, seamless workflow integration, regulatory approval and cost-efficiency.[26] Implementing CAD systems into clinical practice has been identified as a key challenge in the field.[27] However, qualitative evaluations remain scarce, and no other studies have been found assessing CAD POC-LUS.

Limitations

The participants in the current study just finished their initial POC-LUS training and had minimal field experience. This might negatively impact their confidence and ease-of-use. Indeed, the length of a full POC-LUS examinations shortens with the experience of the operator,[28] hence more experienced users would find this less of a barrier. Parallel to the development of implementation strategies, it is important to gain insight in the barriers and facilitators of POC-LUS after sufficient real-life experience, particularly focusing on quality control of image acquisition and interpretation a well as on sustainability of the device. However, the purpose of this paper is to give in-depth insight to ultimately facilitate the implementation of POC-LUS into practice in sub-Saharan Africa where most physicians (outside of emergency and intensive care) have little or no experience with POC-LUS. Thus, this group of interviewees does represent an important reality with the initial phase of adopting the POC-LUS technique being the most challenging.

Another limitation of the study is the inclusion of physicians only in a single urban hospital setting. Important perceptions might have been missed. Future research should include healthcare workers from different backgrounds and working in different settings as rural settings, and patients to gain a more comprehensive view. Further experience and research is also needed to identify and define the optimal place for POC-LUS in the diagnostic pathway of LRTI.

CONCLUSION

There is a clear need for POC affordable lung imaging techniques in LMIC. We identified various facilitators for the implementation of POC-LUS such as the integration in clinical reasoning, expedition of diagnostic orientation, complementarity to chest X-ray, positive impact on the physician–patient relationship, but also barriers such as the investment for the hospital and the appropriation and training needs of the physicians. Successfully integrating POC-LUS into clinical routine and scaling-up will require adequate responses to these locally based challenges. Physician's attitudes towards future CAD POC-LUS are positive.

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Correction notice This article has been corrected since it first published. The open access licence type has been changed to CC BY. 17th July 2023.

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experts and revised the manuscript. GA and PW are local experts and made the framework for interviews. VS and NB-B conceptualised the study.

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Patient consent for publication Not applicable.

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