TEACHING POINT-OF-CARE-ULTRASOUND IN THE RESOURCE LIMITED SETTING

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Introduction

Point-of-care-ultrasound (POCUS) has been established as a useful diagnostic tool for any physician or physician extender in clinical practice.[1-3] The medical assessment value of POCUS is so generally recognized that it has become part of the curriculum of cardiology, obstetrics, emergency medicine and surgery, anesthesia, internal medicine, pediatrics, and family practice residency training.

The proven usefulness of POCUS was initially recognized in the settings of resource wealthy countries. Its usefulness is now also established in resource limited settings (RLS) as well. [4,5] Only 220 million people in developing countries, which includes over five billion people, have access to basic radiology care. The World Health Organization (WHO) estimates 60% of the world's population do not have access to basic x-ray, computed tomography, or other imaging services.[7,16,20] This has led the WHO to recommend ultrasound be used in RLS because "it is portable, inexpensive, non-invasive, safe, and provides immediate information." However, whereas POCUS has been embedded into the teaching curriculum in resource wealthy countries with required standards established, the standardization for the teaching and the application of POCUS in RLS has not occurred. The question then becomes, are the teaching methods, curriculum and standards of POCUS as established in resource rich countries and found in modern western cultures appropriate in RLS? Can POCUS be effectively taught in RLS that lack the resources necessary to teach it as it would be taught in resources rich settings?

Factors limiting the use of this valuable medical technology was initially the cost and availability of the equipment, as well as access to the physicians and technicians who could perform the studies. Advances in technology has now made possible the commercial development of smaller and less expensive ultrasound devices removing two of the initial barriers, namely cost and access to technology, for POCUS to be utilized in RLS.[2] Ultrasound units now available are also portable and more durable, important factors for use in RLS. These advances in technology make the last remaining major barrier to wide-spread use of POCUS in RLS the existence of health care providers who are sufficiently skilled in the use of POCUS and the availability of instructors to teach them.

The purpose of this literature review is to evaluate what has been published in the medical literature with regard to teaching POCUS in RLS and thereby increasing the number of health care providers who have sufficient skills in its use. For inclusion in the review, POCUS needed to be 1) relevant to the treatment decisions being made and 2) easily and accurately applied by the health care provider applying ultrasound without the necessity of extensive ultrasound training. These two features must be true in order to make the most significant advancements in providing a higher level of care to the people in resource limited settings with the use of POCUS.

PubMed was used to identify studies that have been published pertaining to efforts to train health care providers in POCUS as it has been done in RLS. Only articles that were free of cost to the reviewer and involved teaching POCUS in RLS were included. Fifteen publications were identified. Fourteen were prospective [6-8,10-19, 21] in nature, one was retrospective [9]. Their geographical settings, methods and results are summarized and discussed. Questions to be answered from these studies are: 1) can POCUS be efficiently and effectively taught in RLS; 2) what educational formats were used; 3) will local health care providers effectively use POCUS after training; 4) what happens to their skills over time; 5) can teaching POCUS in a RLS lead to improved diagnosis and clinical management; 6) has POCUS been shown to have a positive impact on reducing morbidity and mortality. These questions will be answered by initially outlining 1) who did the teaching; 2) who was taught; 3) what structure and teaching modalities were used; 4) how was POCUS skill evaluated; 5) what were the results.

Summary of Conclusions of the Literature Review

1) Who did the teaching?

A variety of instructors were used in these studies ranging from ultrasound sonographers from departments of radiology[12,13,21] to board-certified specialist with completed or while completing POCUS fellowships or even those with a simple "interest in POCUS"[7,9-11,13-15,17,18] to medical students with only 10 hours of hands-on POCUS instruction themselves[19]. Most commonly, the instruction was done by physicians with either emergency medicine, pediatric or obstetric training with completed or partially completed POCUS fellowships. These fellowships were generally one year of focused work in POCUS although many were not described in the articles.

2) Who was taught/trained?

A wide range of health care providers, both physicians and non-physicians, were reported to have participated in POCUS training. Non-physicians ranged from nurses to midwives to providers with one to three years of technical training to various physician extenders utilized in the country where the POCUS training took place. Physician participants ranged from primary care physicians with only one year of post graduate supervised training to residents still in specialty training to board certified specialists.

Not only was there a range of health care providers taught, but there was also every combination possible. Some studies included only one specific kind of non-physician [6, 7, 9, 15] while others included a spectrum of non-physicians.[8] While these studies focused on teaching POCUS to only non-physicians, others included participants who were both physician and non-physicians.[14,21] Eight studies instructed only physicians. [10-13, 16-19]

3) How was the training structured and what teaching techniques were used?

All the studies which described their curriculum used the basic format of didactic lectures followed by hands on training. For every one hour of didactic instruction there were anywhere from two to four hours of hands-on experience. The hands-on training used only healthy volunteers[8,16] in some settings, others progressed to using volunteers with pathology[17,18] while still others made patients seen in the course of usual clinical practice[6,7,9-15,21] a part of the training and evaluation.

The length of training occurred over a time period of as little as one day,[8] to as long as nine weeks.[10] If the duration of training was short, the area of POCUS being taught was specific and focused.[11,15] Training courses of longer duration attempted to teach multiple areas and aspects of POCUS to include cardiac, obstetrics, abdominal, lung, musculoskeletal and procedure guidance.[9,10,12] The more extensive and encompassing courses were all taught to physicians only[12] whereas more focused trainings were to the entire range of health care providers, both physicians[11] and non-physicians.[15]

Some studies included all the didactic instruction, and initial hands-on training, in an initial block of time, lasting anywhere from one day[8] to one month.[6] Other studies described intermittent training over as long a time frame as two years.[9] Several studies used on site instruction and evaluation in the initial portion of training then showed changing to remote instruction, consultation and review of images could be done effectively.[6,10,12]

Wanjiku[8] et al described their curriculum material as multimedia videos embedded into an instructional manual. Stolz[9] et al described their lectures as "tailored to care providers' knowledge base … delivered intermittently over the 2-year curriculum …. Supplemented with demonstrations, hands-on session, proctored examinations, instructional videos, and textbooks for independent study. Other studies either did not describe the curriculum material for the didactic portion of the instruction or only mentioned written material was provided to be studied and used along with a lecture format.[19]

4) How was POCUS skill evaluated?

Eight of the studies[6-8,13,14,16,18,19] reported the results of pre- and post- instruction written tests. Eight [6-8,11,13,14,19,21] reported hands-on test evaluations via observed structured clinical evaluations (OSCE). Six reported the post testing was done immediately after the material had been taught, four [8,13,14,16] reported the results anywhere from three to twelve months later in an effort to show the presence or absence of any decline in knowledge and/or skills.

All of the studies had some assessment of the actual clinical skill achieved during the training or as part of the study. As with the written test, some hands-on skill testing by OSCE was measured as part of the training and measured immediately at the end of the course or some finite period of time afterwards ranging from 3 months to 4.5 years. Six of the articles [6,9,10,13,16,17] focused on whether or not participants in the training would use POCUS after the training ended. Five of the studies [7,10,11,17, 21] reported if the use of POCUS led to changes in diagnosis and/or patient management. Two studies [10,13] reported the impact POCUS had on the subsequent clinical job satisfaction of the trainees.

All of the studies used the opinion of "experts" in POCUS as the gold standard in the assessment of the appropriate use of POCUS, the quality of the scans and the correctness of scan interpretations done by the trainees. Due to the lack of availability of other imaging, nowhere in these RLS was other x-ray, CT scans or other imaging available to be used as the gold standard. In only three of studies were the experts blinded.[10,11,15] No randomization was done in any of the studies.

5) Results

All the studies[6-8,13,14,16,18,19] reporting written test scores showed statistically significant improvements when pretest results are compared with post course test results. This was true regardless of who did the teaching and who was taught. All the studies[6,9,10,13,16,17] which reported on whether or not POCUS was used in clinical practice after the training, found POCUS was used, although some findings indicated continued follow up and feedback was needed[6,9,13,16] to achieve this while one study did not find either to be necessary.[10] Continued usage of POCUS and confidence in using it was reported as far out from training as six months[6] to 4.5 years.[9]

There were five studies which measured any change in diagnosis or patient management with the use of POCUS. All five [7,10,11,13,21] found some statistically significant change in both areas. POCUS resulted in a change of diagnosis in 15.4% [7] to as much as 52% of patients scanned, [11,21] while a change in management occurred in 19.6% to as many as 48% of all cases.[11,21] When more focused analysis was done excluding cases involving obstetrics [21], 66% of cases resulted in a change of diagnosis and a change in management in 61%.

The two studies [10,13] which reported the impact POCUS training had on the subsequent clinical job satisfaction of the participants found there was a positive increase in clinical job satisfaction.

DISCUSSION

1) Can POCUS be efficiently and effectively taught in RLS?

All the articles reviewed showed POCUS can be effectively and efficiently taught in a wide range of RLS which were spread geographically from South America to Africa to Indonesia to the subcontinent of India.

Just as the studies were varied in their geographic locations, they were varied in the clinical issues being addressed. For example, Nadimpalli[15] et al used a focused application of POCUS in a refugee camp in South Sudan to diagnosis lower respiratory illnesses in children < 5 years of age as either viral bronchiolitis verses bacterial pneumonia to assist in better treatment management and more appropriate use of limited supplies of antibiotics. In this setting, local health care personnel, called "clinical officers", were taught lung ultrasound. These clinical officers were described as mid-level clinicians with three years of medical education. Their

POCUS training consisted of twelve hours of field-based instruction with both didactic and practical components. At the other end of the spectrum, Dreyfuss[12] et al used ultrasound instructors from academic institutions in the United States to instruct Peruvian emergency room trained physicians over a two-week period in the capital city of Lima using both lectures and hands on training covering both basic and advanced ultrasound. The instruction then moved on to emergency room settings in two remote hospitals, one in the Amazon jungle and the other isolated in the Andes mountains, where further practical training was done remotely with instructors in Lima or back in the United States. In the South Sudan [15] setting, the objectives of the training were focused to meet an immediate specific need i.e., the diagnosis of lower respiratory illnesses in children < 5 years of age and to assist in the efficient use of limited antibiotics. In the case of teaching POCUS in the situation in Peru[12], a more extensive use of time and resources were used to teach health care providers who had a higher level of training with the intention of making the trainees into POCUS experts themselves in other more remote RLS.

The most common applications of teaching POCUS in RLS lies in between these two settings. Most commonly, the instruction was to nurses, mid-wives, or primary care physicians, who were providing health care to urban poor or in a rural setting with the purpose of helping them to provide more accurate health care to those they normally serviced. In all these different settings, these studies showed POCUS can be effectively and efficiently taught.

2) What educational formats were used?

Again, the educational formats varied depending on the objectives of the teaching, the knowledge base and level of training of the participants and the clinical settings. A shorter period of training could be used if the learning expectations were more focused.[11,15] Shorter periods of time could also be used if course material was provided before class time in order that the participants could study and have some knowledge base when the course began.[8] In studies where the participants were physicians in practice,[13,16,17,18] it was felt to be better to break up the curriculum and teach 1-3 days a week over many weeks to allow the providers to continue to provide care in their clinics. Instruction given to nurses and midwives[6,14] was more likely to be provided in continuous blocks, while making that time free from clinical responsibilities. However, intermittent instruction [9] was provided to non-physician providers as well.

All the studies adhered to the basic structure of didactic instruction in lecture format followed by hands on training. The curricula were taught by health care providers educated in resource rich countries using western culture education techniques and methods and presented in English. Only three studies[13,19, 21] mentioned the advantage that could be realized if the education was presented in the native language. Only two [19,21] actually provided written material in the national language and only one used an interpreter during the hands-on training.[21] In most of the studies, it was noted that the participants volunteered to take the course knowing it would be predominately, and usually exclusively, in English. A language barrier will likely exist for many health care providers in RLS, thereby limiting the number of participants and thereby the broader use of POCUS. This language barrier is most likely to result in the exclusion of non-physician

health care providers thereby limiting access to those health care providers who should be the main target for teaching POCUS.

None of the studies mentioned any consideration in their training for the importance of cultural differences between resource rich western educational systems and RLS in non-western educational systems. Consideration should also be given to the cultural and social/economic differences between these RLS as they will vary from an urban setting in Indonesia such as Bandung, to tribal rural setting in Africa to rural Hispanic cultures of central and South America. For example, training that lasts all day with 30 to 60 minutes available for the noon time meal, will be ill adapted to cultures where this meal is expected to be in the home with family and lasting at least two hours. Half day sessions would be required in these cultural settings. For example, if the training is for mid-wives, and this being a female dominated occupation, accommodating the role of the mother in the home will be required.

3) Will local health care providers continue to effectively use POCUS after training?

Some of these studies addressed this question in their original design whereas others did not. Terry[6] et al prospectively found the use of POCUS dropped off during a four-month period after one month of initial training when no instruction nor feedback was given. This four-month hiatus in training occurred because of equipment malfunction and the prolonged time to get repairs. However, when feedback was provided by a remote connection with local guidance, the use of POCUS increased to the level initially present after training and over the next six months increased even further.

Henwood[13] et al as well as Shrestha[16] et al reported prospectively the continued use at a level similar to what was expected at the end of the training up to one year later, but this was only through self-reporting through the surveys of those who responded.

Stolz[9] et al retrospectively reported a continued high level of usage of POCUS over a 4.5-year period of time in the clinical setting of an emergency department where a department of radiology also existed and was available during usual clinic hours. However, the use of POCUS out-numbered studies done by the department of radiology by a ratio of 3:1.

Rominger[17] et al showed an increase in the use of POCUS over a 12-month period. This study noted a decrease in usage of POCUS during the intervals between the training sessions with an immediate increase of usage after each session.

All other studies reported continued use of POCUS during the duration of the study, however the use was only reported during the time period of the training and evaluation.

Whether or not POCUS continues to be used after training does need to be studied as noted above. However, as noted by Stolz [9] et al, the many significant advantages of POCUS, such as the immediately known results, not having to schedule an exam in the radiology department, convenience of not having to transport patient to the radiology suite, not having to find and wait on results etc. lend POCUS to be a preferred mode of imaging in many clinical settings.

Also of significance, the two studies [10,13] which reported greater job satisfaction of participants in POCUS training would logically imply there would be continued use of this imaging modality. What clinician would stop using something that made them feel better about the work they are doing?

4) What happens to their skills over time?

Overall, the time period over which the retention of POCUS knowledge and skill was reported ranged from three months [8] to 4.5 years.[9] All the studies showed an increase of knowledge as measured by written/multiple choice question exams and practical evaluations done by observation of ultrasound done on volunteers as observed structured clinical evaluations (OSCE).

Four studies [6,10,13,14] reported maintenance of skills during a time period including continued feedback. Sepulveda et al[18] noted maintenance of skills over a 12-month period which included two refresher courses.

Rominger et al[17] had four sessions interspersed through the course of a year to review previous skills as needed and introduce a new subject area. This was shown to be effective in maintaining a high level of skills. Shrestha et al[16] reported an increase in self-reported confidence which was used to infer usage and skill. Hall et al[14] reported continued improvement in OSCE at 19 weeks and 27 weeks during their 12-month study. Terry et al[6] noted improved sensitivity and specificity over an 11-month period but only with continued remote feedback during the time period. Kolb et al[21] reported improved skills with feedback over two 6-week periods of time.

Shah et al[10] did not provide any further training after the initial sessions. The study found a high concordance rate of 96% between the interpretation of the Rwandese physicians trained and the ultrasound-trained quality review physician 11 months after the trainers left with no follow-up feed-back or interim training.

5) Can teaching POCUS in a RLS lead to improved diagnosis and clinical management?

Five of the studies reported results to this important question. In one study, Shah[11] et al reported in a prospective blinded study training and subsequent use of POCUS led to a change in 15.4% of diagnoses and a change in management in 19.6% of patients. In another study Shah[10] found POCUS changed patient management plans in 43% of patients with the most common change leading to a surgical procedure. Rominger[17] et al found a change in 34% of diagnosis and 30% of management plans as a result of the availability and use of POCUS. It was also felt in this study, since a change in diagnosis led to a change in patient management, there was a total of 78.4% of cases where POCUS was used, an overall change of patient management occurred. Kolbe[21] et al felt the use of POCUS resulted in a new diagnosis in 52% of patient and a change of management in 48%. Sabatino[7] et al found POCUS change the initial diagnosis in 17% of patients.

Conclusions and Action Recommendations

One of the advantages of teaching POCUS in RLS is the ability to modify the curriculum to fit the objectives of learning, the training level of the participants and the available resources and staff to teach. Instruction should be modified by surveying the participants and reviewing local health records before what will be included in the course is determined as was done by both Shah[10] et al and Rominger[17] et al. This should be done everywhere POCUS is to be taught. Learning objectives can thereby be appropriately defined and be made relevant to the treatment decisions being made. The curriculum should be tailored to the level of knowledge and training of the trainees and the clinical situations and settings the participants will face every day. When this was not done, as in the case of Henwood[13] et al, disruption in the training occurred as described when participants did not know required basic anatomy nor how to operate a laptop computer.

More consideration must be given to accommodating language and cultural barriers if excellence in teaching and learning POCUS is to be achieved as suggested by Lee[19] et al and Henwood[13] et al. Furthermore, given the profound lack of physicians in RLS, emphasis on training physician extenders is paramount. Participants in these studies were predominately "volunteers", meaning the curriculum was simply offered, resulting in some health care providers to sign-up. As previously noted, eight of these fifteen studies were to physicians only. It is the experience of this author that physicians in RLS are more likely to have proficiency in English compared to non-physicians. To encourage more participation of non-physicians, training in native languages will need to occur thereby removing the language barrier.

A number of other challenges to the introduction of POCUS education in RLS still exist. Although the costs of ultrasound machines have decreased dramatically, along with the physical size, even this lower cost still remains an obstacle in most RLS. Machine repair is presently dependent on transporting the equipment back to a developed country, as there are no local vendors or repair agencies. Electricity is sporadic resulting in reliance on battery back-up and local generators. Theft of these devices, if not kept in strict and secure locations, will be a problem. Some of these obstacles may lessen as the market for POCUS in RLSs increases.

Ultimately, the goal of any newly introduced diagnostic or therapeutic technology is to decrease morbidity and mortality. Further studies, with larger populations of patients over longer periods of time, will be necessary to accomplish this. Other research could also be done to measure significant contributions resulting from the use of POCUS to a population's length of hospital or care center stay, re-admission rates and decrease in complication rates from procedures done using it.

Shah [10] et al felt any successful ultrasound program would require a local ultrasound coordinator to ensure there continues to be enthusiasm, further program development and on-going quality assurance, and imaging feedback via web-based teaching tools. Dreyfuss[12] et al felt part of their success was due to the time and effort spent building relationships with the local hospital and national medical society. Dreyfuss[12] skillfully noted that such measures were culturally

imperative in their RLS. This kind of cultural nuance will undoubtedly be necessary in most, if not all, RLS.

Also, using POCUS to identify patients with diagnoses not previously known to exist, for which no effective treatment available in a RLS, will fail in the goal of reducing morbidity and mortality. This emphasizes the importance of pre-program surveys and hospital record reviews of diagnoses and chief complaints. This will lead to a curriculum that is tailored to the treatment decisions health care providers are facing and effect a positive outcome. A curriculum in place in a resource rich country should not be used simply because it exists, as it will likely be ill adapted to RLS to a significant degree.

It is my assessment the best format for when the training objectives are extensive and encompassing many aspects of POCUS, would be one where the training is done intermittently over a period of 1-2 years. The time period of instruction will likely be one to three days with repeat sessions every two to four months. This would break up what is commonly felt to be a large amount of unfamiliar material into smaller more "digestible" segments. This also provides a period of time for the initial material to be applied, leading to problems and question to be addressed at the start of the subsequent sessions, before proceeding to the new material. When the objective of the training is very focused and specific, the training could be done in one to three days of didactic and hands on training with subsequent follow up of clinical application to assure quality standards.

No one would argue with the idea, that the longer the follow-up period to assure quality and continued improvement of skills, the better. However, the problem becomes one of time and money to continue this with on-site instruction. Several studies did accomplish this by transitioning remotely and using virtual communications. This appears to be able to be done effectively despite having to overcome some obstacles such as adequate band-with in the internet connection as well as interruption of the electrical grid.

None of the articles' results have been reproduced in an exact manner. Only three studies included "blinding" of the evaluators of the images. The majority of the studies being "un-blinded" would possibly allow some degree of bias as the reviewer might want the findings of the teaching to be confirmed to be effective. Randomization to show a benefit in using POCUS, verses not using it, will not occur as having a control group who does not have the opportunity to achieve the known health benefit would be unethical. However, different methods and curriculum could be compared in side-by-side trials in a randomized fashion.

Personal Application

My personal goal, which is to continue to contribute to the advancement of the quality of care provided to people living RLS, will be enhanced by being skilled in POCUS. My ability to effectively and efficiently teach POCUS to other healthcare providers with a range of medical backgrounds and training will greatly magnify this goal. My experience at Baptist Medical

Center (BMC) in Nalerigu, Ghana leads me to believe this would be a good place to start. Imaging at BMC is limited to chest x-ray and bones of the extremities, and these are commonly of poor quality. Simple flat and upright views of the abdomen are not done. To get an X-ray, the patient must be able to be easily transported by poorly maintained wheelchairs to a building approximately 1,000 to 2,000 feet from the open wards where they are treated. Part of this trip to the X-ray building goes through areas that are not enclosed so cannot be done if it is raining. X-ray is also commonly not available either because of equipment failure or lack of supplies approximately 20% of the time. Presently, ultrasound is available for only a short period of time during the day and then only for routine antenatal assessment when the sole ultra-sonographer decides not to take the day off. Ultrasound is also similarly only available to rule out retained products of conception. The ultrasound suite is also located in a different building only accessible by poorly functioning wheelchairs or ambulatory patients. All of these issues of unavailable imaging and difficulty in the transportation of patients will be overcome by the use of POCUS on the ward.

When I preformed POCUS in the ward during by recent time at BMC, I found all of the staff, from the physician house officers to the various levels of nurses, were eager to watch and learn. I have no doubt a well thought out curriculum for POCUS would be welcomed and effective in improving the health care at this facility.

REFERENCES

1. Moore CL, Copel JA. Point-of-care ultrasonography. *N Engl J Med*. 2011;364(8):749-757. doi:10.1056/NEJMra0909487

2. Frederiksen CA, Juhl-Olsen P, Sloth E. Advances in imaging: ultrasound in every physician's pocket. *Expert Opin Med Diagn*. 2012;6(3):167-170. doi:10.1517/17530059.2012.669368

3. Andersen CA, Holden S, Vela J, Rathleff MS, Jensen MB. Point-of-Care Ultrasound in General Practice: A Systematic Review. *Ann Fam Med*. 2019;17(1):61-69. doi:10.1370/afm.2330

4. Sippel S, Muruganandan K, Levine A, Shah S. Review article: Use of ultrasound in the developing world. *Int J Emerg Med*. 2011;4:72. Published 2011 Dec 7. doi:10.1186/1865-1380-4-72.

5. A review of training opportunities for ultrasonography in low- and middle-income countries. LaGrone LN, Sadasivam V, Kushner AL, Groen R Trop Med Int Health. 2012 Jul; 17(7):808-19.

6. Terry B, Polan DL, Nambaziira R, Mugisha J, Bisanzo M, Gaspari R. Rapid, remote education for point-of-care ultrasound among non-physician emergency care providers in a resource limited setting. *Afr J Emerg Med*. 2019;9(3):140-144. doi: 10.1016/j.afjem.2019.05.004

7. Sabatino V, Caramia MR, Curatola A, et al. Point-of-care ultrasound (POCUS) in a remote area of Sierra Leone: impact on patient management and training program for community health officers. *J Ultrasound*. 2020;23(4):521-527. doi:10.1007/s40477-019-00426-w

8. Wanjiku GW, Bell G, Wachira B. Assessing a novel point-of-care ultrasound training program for rural healthcare providers in Kenya. *BMC Health Serv Res*. 2018;18(1): 607.Published 2018 Aug 6. doi:10.1186/s12913-018-3196-5

9. Stolz LA, Muruganandan KM, Bisanzo MC, et al. Point-of-care ultrasound education for non-physician clinicians in a resource-limited emergency department. *Trop Med Int Health*. 2015;20(8):1067-1072. doi:10.1111/tmi.12511

10. Shah S, Noble VE, Umulisa I, et al. Development of an ultrasound training curriculum in a limited resource international setting: successes and challenges of ultrasound training in rural Rwanda. *Int J Emerg Med*. 2008;1(3):193-196. doi:10.1007/s12245-008-0053-z

11. Shah SP, Shah SP, Fils-Aime R, et al. Focused cardiopulmonary ultrasound for assessment of dyspnea in a resource-limited setting. *Crit Ultrasound J*. 2016;8(1):7. doi:10.1186/s13089-016-0043-y

12. Dreyfuss A, Martin DA, Farro A, et al. A Novel Multimodal Approach to Point-of-Care Ultrasound Education in Low-Resource Settings. *West J Emerg Med*. 2020;21(4):1017-1021. Published 2020 Jul 9. doi:10.5811/westjem.2020.4.45928

13. Henwood PC, Mackenzie DC, Rempell JS, et al. Intensive point-of-care ultrasound training with long-term follow-up in a cohort of Rwandan physicians. *Trop Med Int Health*. 2016;21(12):1531-1538. doi:10.1111/tmi.12780

14. Hall EA, Matilsky D, Zang R, et al. Analysis of an obstetrics point-of-care ultrasound training program for healthcare practitioners in Zanzibar, Tanzania. *Ultrasound J*. 2021;13(1):18. Published 2021 Apr 8. doi:10.1186/s13089-021-00220-y

15. Nadimpalli A, Tsung JW, Sanchez R, et al. Feasibility of Training Clinical Officers in Point-of-Care Ultrasound for Pediatric Respiratory Diseases in Aweil, South Sudan. *Am J Trop Med Hyg*. 2019;101(3):689-695. doi:10.4269/ajtmh.18-0745

16. Shrestha R, Blank W, Shrestha AP, Pradhan A. Evaluation of Interdisciplinary Emergency Ultrasound Workshop for Primary Care Physicians in Nepal. *Open Access Emerg Med*. 2020;12:99-109. Published 2020 Apr 29. doi:10.2147/OAEM.S246656

17. Rominger AH, Gomez GAA, Elliott P. The implementation of a longitudinal POCUS curriculum for physicians working at rural outpatient clinics in Chiapas, Mexico. *Crit Ultrasound J*. 2018;10(1):19. Published 2018 Aug 15. doi:10.1186/s13089-018-0101-8

18. Sepulveda-Ortiz V, Warkentine F, Starr-Seal R, Rominger A. The effectiveness of a longitudinal ultrasound curriculum for general pediatricians working in a Puerto Rican emergency department: a pilot study. *Ultrasound J*. 2020;12(1):20. Published 2020 Apr 21. doi:10.1186/s13089-020-00169-4

19. Lee JB, Tse C, Keown T, et al. Evaluation of a point of care ultrasound curriculum for Indonesian physicians taught by first-year medical students. *World J Emerg Med*. 2017;8(4):281-286. doi:10.5847/wjem.j.1920-8642.2017.04.006

20. Mindel S. Role of imager in developing world. *Lancet.* 1997;350(9075):426–429. doi: 10.1016/S0140-6736(97)03340-0

21. Kolbe N, Killu K, Coba V, et al. Point of care ultrasound (POCUS) telemedicine project in rural Nicaragua and its impact on patient management. *J Ultrasound*. 2014;18(2):179-185. Published 2014 Sep 20. doi:10.1007/s40477-014-0126-1