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ORIGINAL RESEARCH ARTICLES

Bedside ultrasound training at Muhimbili National Hospital in Dar es Salaam, Tanzania and Hospital San Carlos in Chiapas, Mexico

Formation en échographie au chevet du patient à l'Hôpital national Muhimbili à Dar es Salaam, Tanzanie et à l'Hôpital San Carlos au Chiapas, Mexique

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Introduction: In resource-rich settings, bedside ultrasound has rapidly evolved to be a crucial part of emergency centre practice and a growing part of critical care practice. This portable and affordable technology may be even more valuable in resource-limited environments where other imaging modalities are inaccessible, but the optimal amount of training required to achieve competency in bedside ultrasound is largely unknown. We sought to evaluate the feasibility of implementation of a mixed-modality bedside ultrasound training course for emergency and generalist acute care physicians in limited resource settings, and to provide a description of our core course components, including specific performance goals, to facilitate implementation of similar initiatives.
Methods: We conducted a standardised training course at two distinct sites—one large, urban tertiary hospital in Tanzania with a dedicated Emergency Centre, and one small, rural, hospital in southern Mexico with a general, acute intake area. We report on pre-training ultrasound use at both sites, as well as pre- and post-training views on most useful indications.
Results: Overall, participants were very satisfied with the course, although approximately one-third of the providers at both sites would have preferred more hands-on training. All participants passed a standardised exam requiring image acquisition and interpretation.
Discussion: Introducing bedside ultrasound training in two distinct resource-limited settings was feasible and well-received. After a brief intensive period of training, participants successfully passed a comprehensive examination, including demonstration of standardised image acquisition and accurate interpretation of normal and abnormal studies.

Introduction: Dans les contextes riches en ressources, l'échographie au chevet du patient a rapidement évolué pour devenir un élément essentiel de la pratique en centre d'urgence et un élément d'importance croissante de la pratique des soins de courte durée. Cette technologie portable et abordable peut être encore plus précieuse dans des environnements limités en ressources où d'autres modes d'imagerie sont inaccessibles, mais la quantité optimale de formation nécessaire pour atteindre une compétence suffisante en échographie au chevet du patient est largement inconnue. Nous avons cherché à évaluer la faisabilité de la mise en œuvre d'un cours de formation en échographie au chevet du patient à modes mixtes pour les médecins de soins de courte durée d'urgence et généralistes dans un contexte aux ressources limitées, et à fournir une description des composantes de notre cours fondamental, notamment en termes d'objectifs de performance spécifiques, afin de faciliter la mise en œuvre d'initiatives similaires.
Méthodes: Nous avons effectué un stage de formation normalisé sur deux sites distincts - un grand hôpital urbain tertiaire en Tanzanie équipé d'un Centre d'urgence dédié, et un petit hôpital rural au sud du Mexique ayant une zone d'admission de soins généraux intensifs. Nous établissons un rapport sur l'utilisation de l'échographie en pré-formation sur les deux sites, ainsi que sur les avis formulés avant et après la formation à propos des indications les plus utiles.
Résultats: Dans l'ensemble, les participants étaient très satisfaits du cours, bien qu'environ un tiers des fournisseurs sur les deux sites auraient préféré plus de formation pratique. Tous les participants ont réussi un examen normalisé requérant une acquisition et une interprétation d'images.
Discussion: La fourniture d'une formation en échographie au chevet des patients dans deux contextes distincts aux ressources limitées était faisable et bien reçue. Après une brève période intensive de formation, les participants ont réussi un examen complet, incluant notamment la démonstration de l'acquisition d'image normalisée et de l'interprétation exacte d'études normales et anormale.

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African relevance

- Point-of-care ultrasound training is feasible and valued by providers in Africa.
- Ultrasound provides bedside clinical decision-making support in settings where access to other imaging modalities is delayed or nonexistent.
- Equipment and maintenance costs of portable ultrasound are dropping, making its use ever more feasible in Africa.

Introduction

In resource-rich settings, bedside ultrasound has rapidly evolved to be a crucial part of Emergency Centre practice[1–6] and a growing part of critical care practice,[7–10] serving to diagnose life threatening conditions[11–17] and guide resuscitation and invasive procedures.[18,19] Relative to computed tomography and magnetic resonance imaging, ultrasound is a low-cost technology, both in terms of initial capital investment and recurrent costs associated with its use.[19–22]

This portable and affordable technology may be even more valuable for practitioners in resource-poor environments where other imaging modalities are either geographically or economically inaccessible and where early diagnosis may be critical for timely transfer to higher-level facilities.[23–37] In Rwanda[38] and Liberia,[39] pilot studies have shown that training in bedside ultrasound is both feasible and well received, and that its use changes diagnosis in up to 30–60% of cases.[40] A recent review of ultrasound use (including bedside and radiology-based) in low- and middle-income countries (LMIC) identified 58 articles published between 2000 and 2011 that describe initiatives in over 25 countries, and shows a dominance of obstetric and non-traumatic abdominal indications.[27]

Despite exploding interest in the use of this technology in LMICs, the optimal amount of training required to achieve competency in bedside ultrasound is largely unknown. The second edition (years 2011–2013) of the World Health Organization's Manual of Diagnostic Ultrasound no longer includes the specific training parameters that were included in the first edition (1998). The first edition included a general pronouncement that training should include ''lectures and practical demonstrations'' over three to six months with 300–500 scans, that the examinations should be ''appropriate for the disease profile of the country or region where the training is conducted'' and that ''in most countries, an appropriate distribution of examinations would be: abdominal examinations (50%); obstetric examinations (20%); gynaecological examinations (20%); and examinations of other parts (10%)''.[41] These parameters are not specific to bedside ultrasound (i.e. performed at the site of clinical care by the treating provider), and are well beyond any protocols described in the recent literature on training initiatives in LMICs.[42]

The American College of Emergency Physicians (ACEP) has published a policy statement ''Emergency Ultrasound Guidelines'' in which residency-based and practice-based pathways for achieving ultrasound competency are described.[43] A minimum of sixteen hours of didactic and hands-on training is recommended for initial competency. Post-training completion of a proctored hands-on exam, coupled with a formal written exam including image review, are recommended for quality assurance. To be considered fully credentialed under these guidelines, trainees must submit 25 exams of each core application for quality review.

While they do specifically address bedside ultrasound in the acute care setting, the ACEP guidelines were developed in and for environments in which continuous proctored exams are possible and in which other confirmatory diagnostic studies are readily available, and they remain largely unvalidated recommendations. The optimal content and duration of ultrasound training in environments where ultrasound has been recently introduced and where an experienced sonographer is present only intermittently or for initial training is unknown. The few studies that do document ultrasound training in resource-limited settings do not elaborate a particular training structure, making these interventions difficult to compare or generalise.

In the present study, we sought

(1) to evaluate the feasibility of a bedside ultrasound training course for emergency and generalist acute care physicians in limited resource settings,
(2) to provide a description of our core course components to facilitate implementation of other similar initiatives,
(3) and to report on participant views on setting-specific priority indications for ultrasound.

In order to evaluate the suitability of our curriculum to diverse environments, we conducted our evaluation at two distinct sites—one large, urban tertiary hospital in Tanzania with a dedicated Emergency Centre, and one small, rural, hospital in southern Mexico with a general, acute intake area.

Methods

A standardised ultrasound training programme was implemented at Muhimbili National Hospital (MNH), in Dar es Salaam, Tanzania, and Hospital San Carlos (HSC), in Altamirano, Chiapas, Mexico.

The 1500-bed Muhimbili Hospital is the main tertiary care government hospital in Tanzania, treating 1000–1200 outpatients weekly and the same number of admitted patients daily.[44] MNH serves patients from the Dar es Salaam area and those referred from across the country. MNH has limited formal (i.e. radiology-performed) ultrasound capacity for inpatients, and prior to our study, minimal bedside (i.e. provider-performed) ultrasound was available for patients presenting to the Emergency Centre. A larger, non-battery powered ultrasound (Mindray DP3300) was available, and bedside ultrasound was occasionally performed for trauma, as providers had previously received brief one to two day training in the Focused Assessment with Sonography in Trauma (FAST) exam. Providers had received no formal training in other ultrasound applications. All 14 MNH study participants were registrar doctors in their first year out of general internship and were assigned permanently to the recently-established Emergency Centre – Tanzanian registrars do not have specific specialty designations by training, but are usually assigned to work in a specific department or practice area. Training at MNH was conducted in English.

The 70-bed Hospital San Carlos (HSC) is a private, non-profit rural hospital in southern Mexico, treating 1300 outpatients monthly and approximately 3200 inpatients per year. HSC serves a predominantly indigenous population in one of the poorest regions in the country. The majority of patients are treated by young generalist physicians without residency training. No formal radiology services are available, and prior to our intervention, a large model non-battery powered ultrasound (Siemens Sonoline Prima) was intermittently available and occasionally used by an obstetrician consultant in the evaluation of pregnancy and by an internist consultant for abdominal ultrasound. No other providers had formal training in the use of ultrasound. The nine study participants were generalist physicians in their first year post-internship at the time of our study. Training at HSC was conducted in Spanish.

This study was approved by the Committee on Human Research of the University of California, San Francisco; the Muhimbili University of Health and Allied Sciences Research Ethics Committee; and the hospital Ethics Committee at Hospital San Carlos. All participants provided informed written consent on a form approved by these ethics boards.

All doctors staffing the acute intake areas at both sites were invited to participate in the ultrasound training course, and all agreed. At MNH, all 14 registrar physicians staffing the Emergency Centre at the time of the study completed the course. At HSC, all nine generalist physicians staffing the hospital's acute intake area completed the course.

Prior to the initiation of training, a pre-test questionnaire was administered to assess participants' prior experience with ultrasound, their baseline utilisation of ultrasound, and the ultrasound applications they anticipated to be most useful (Table 1).

The course consisted of 16 days of combined didactic and hands-on instruction in bedside ultrasound (Table 2) taught by United States ultrasound fellowship-trained instructors. At MNH, the course was delivered in two sessions over eight weeks. Trainees alternated clinical shift days with course days. Overall, the full course was delivered twice, but each trainee only attended each session once. At HSC, the course was delivered in a single four-week session, with sessions four days per week. All instructions were provided on high quality, portable machines (NanoMaxx, Sonosite, Bothell, WA) initially loaned by Sonosite, and then purchased at reduced humanitarian pricing for both sites. The machines included a curvilinear low-frequency transducer, an intracavitary transducer, and a high-frequency linear transducer. At MNH, providers were divided into two groups, alternately providing clinical staffing and attending training sessions (two full course sessions were run). Providers at HSC were trained in a single group. All participants attended 24 h of structured sessions including didactic lecture and hands-on practice on live models (volunteers or other course participants). In addition, each participant was required to do at least 15 h of proctored scanning time in the clinical setting. Actual proctored scan time ranged from 15 to 30 h, depending on participants' availability and competing clinical duties, and varied at both sites.

Each didactic presentation covered a single ultrasound application via a standardised series of components (Table 2). In addition to training in the ultrasound technique itself, every session included a basic anatomy review and active interpretation of normal and abnormal images by each participant.

Core sessions at both sites included examination of the gallbladder, aorta, and thorax (for pleural fluid and pneumothorax), soft tissue evaluation, basic echocardiography, FAST,

Table 1 Pre-training ultrasound use.

	% trainees at MNH (n = 14)	% trainees at HSC (n = 8)*
Requested consultant-performed ultrasound^		
At least weekly	50	50
At least monthly	64	100
Never	7	0
Performed ultrasound yourself		
At least weekly	93	13
At least monthly	93	38
Never	7	38
Indications for current use of any ultrasound		
	Trauma (100)	Obstetric (75)
	Obstetric (71)	Hepatobiliary (63)
	Abdominal masses (57)	Renal/urinary (38)
	Cardiac (43)	Evaluation of spleen (13)
	Hepatobiliary (43)	Gynaecologic (non-pregnant) (13)
	Renal/urinary (36)	
Most commonly cited indications expected to be useful for provider-performed bedside ultrasound		
	Trauma (100)	Obstetric (88)
	Obstetric (93)	Hepatobiliary (63)
	Procedures (78)	Gynaecologic (non-pregnant) (38)
	Hepatobiliary (57)	Renal/urinary (13)
		Evaluation of spleen (13)

MNH, Muhimbili National Hospital; HSC, Hospital San Carlos; US, ultrasound.
* One trainee was not available for pre-course survey, but completed all sessions.
^ Radiology department at MNH or specialist consultant at HSC.

Table 2 Components of the course.

Didactic sessions (1.5 h)	Focused standard anatomy review with still images and three-dimensional video reconstruction Survey of image acquisition including: –patient positioning –still images and video images of probe placement and movement with attention to surface anatomy Survey of ultrasound anatomy on still and video images Active participant interpretation of normal and abnormal video clips, with use of pointer by each course participant in independent interpretation
Practical sessions (1.5 h)	Supervised exams by each participant on models/trainees Each participant presents exam to peers
Supervised clinical scanning shifts (15–30 h)	Dedicated scanning shifts on patients in the clinical setting Scans performed by both instructors and trainees for comparison
Exam	Practical exam on models to demonstrate components listed below Interpretation exam of normal and abnormal still and video images

and evaluation for ectopic pregnancy. The same didactic training in transvaginal pelvic ultrasound was provided at both sites; at HSC, a Blue Phantom pelvic model task trainer was available during the classroom training session, while at MNH, practical transvaginal ultrasound training was done during proctored clinical scanning time only. Subsequent supplementary sessions based on participant request included renal evaluation for hydronephrosis and inferior vena cava measurement to assess volume status at both sites, and central and peripheral vascular access at MNH, but not at HSC.

At the conclusion of the course, all participants completed a course evaluation survey and a two-part exam (Tables 3 and 4). The practical component of the exam included a demonstration of image acquisition with identification of structures and relevant measurements on volunteer models. The interpretation component of the exam required the identification of relevant anatomy and interpretation of normal and abnormal findings on still and video images.

At MNH, the post-course exam was overseen by the primary investigator and an independent ultrasound-trained emergency physician. Exam results were determined separately by the independent evaluator and the primary investigator. At HSC, the exam was administered by an ultrasound-trained emergency physician who had been involved with the supervised clinical scanning shifts, but not in the course delivery or evaluation research.

Results

The pre-test needs assessment was completed by 14 of 14 course participants at MNH and 8 of the 9 participants at HSC (one staff physician was on leave at the time of the pre-survey but attended all course sessions). At MNH, the pre-training frequency of ultrasound use by course participants to perform FAST was high, with all but one doctor performing FAST at least weekly. Prior to the training, bedside ultrasound was not used for other indications at MNH, except occasionally by consultants from obstetrics or cardiology. At HSC, the pre-training frequency of ultrasound use by course participants was low (Table 1). At both sites, obstetric and hepatobiliary applications were expected to be very useful, while at MNH, trauma was identified by all participants as the most useful indication.

The level of satisfaction with the training course was high, with 13/14 MNH participants and 6/9 HSC participants describing themselves as "Very Satisfied," the highest rating. All other participants described themselves as "Satisfied". At MNH, 57% of participants felt that the balance between didactics and practical skills sessions was good; 36% would have preferred more hands-on training; 7% would have preferred more lecture (Table 4). At HSC, 67% of participants felt there was a good balance between formal didactics and hands-on scanning, and the remaining third desired more hands-on time. At MNH,

Table 3 Exam criteria.

Application	Exam images
FAST	Perihepatic and perisplenic windows including subphrenic space, pericardial (subxiphoid or parasternal long), pelvic views. Accurate identification of normal and abnormal scans on video
Thorax	Identification of soft tissue, pleura and lung in both 2D and M-mode; identification of lung sliding as well as A and B lines. Accurate identification of normal and abnormal scans on video
ECHO	Adequate visualisation and identification of four chambers and pericardium via parasternal long, parasternal short, apical or subxiphoid axes. Accurate identification of normal and abnormal scans on video
RUQ	Visualisation of entire gallbladder in two perpendicular planes. Measurement of wall thickness. Accurate identification of normal and abnormal scans on video
Aorta	Visualisation of the aorta in transverse and longitudinal planes from epigastrium to iliac bifurcation. Measurement of diameter in two planes. Accurate identification of normal and abnormal scans on video
Obstetrical	Transabdominal identification of uterus, bladder and pouch of Douglas; transvaginal identification of uterus, bladder, endometrial stripe. Accurate identification of normal and abnormal scans on video

FAST, Focused Assessment with Sonography in Trauma; ECHO, echocardiogram; RUQ, right upper quadrant.

Table 4 Post-training evaluation.

	MNH (n = 14)	HSC (n = 9)
Balance between formal didactics and hands-on practice	57% right balance 36% need more hands-on 7% need more lecture	67% right balance 33% need more hands-on
Most useful lectures	FAST, OB	FAST, gallbladder
Exams able to perform with greatest confidence	FAST, OB, gallbladder	Gallbladder, OB, FAST

MNH, Muhimbili National Hospital; HSC, Hospital San Carlos; FAST, Focused Assessment with Sonography in Trauma; OB, Obstetric.

FAST and obstetrics were identified as the most useful course topics and as the most likely to be clinically useful applications. At HSC, the FAST and gallbladder exams were identified as the most useful course topics, while obstetric and gallbladder exams were anticipated to be the most clinically useful applications.

All participants at both sites passed the overall exam (though one MNH provider failed to adequately demonstrate acquisition of gallbladder images).

This study was limited to a descriptive evaluation of our training programme. As such, it does not offer evaluation of long-term knowledge and practical skills transfer.

The number of participants in our study was quite small, and thus limits generalisation. However, given that all providers in each relevant cohort participated, there is limited potential for systematic selection bias, as there was no selection. To mitigate this small study size and increase generalisability within our limited capacity, we chose two distinct regions and facility-types. Certainly the results are limited by the inclusion of only two sites, and we hope the results of this small study can be used to inform larger, multi-site studies.

Pre-training utilisation data were acquired via provider report only, which subjects it to substantial bias. Post-training utilisation data will be prospective, but comparisons will be limited by the quality of pre-training data.

The fact that MNH providers had undergone brief training in the FAST exam likely increased confidence in the use of ultrasound for trauma and impacted provider evaluation of its utility.

Finally, while we attempted to separate teaching and examining personnel where possible, a competency exam would ideally be conducted by an entirely independent evaluation team, for which we did not have available onsite personnel. However, at MNH where exams were assessed by two independent examiners, there were no discordant exam results.

Discussion

For a limited set of indications, ultrasound serves both as adjunct to the physical exam and as diagnostic imaging, even when specialised radiologist interpretation is not available. These attributes are ideally suited to resource-limited settings where other imaging may be unavailable, impractical, or exceedingly expensive, and where patient transfer is burdensome or impossible. There is limited available literature to suggest that ultrasound training is possible in these settings, and the present study provides additional evidence that such programmes are both feasible and well-received.

Satisfaction was high at both sites, though lower at HSC. While instructors were fluent in Spanish, they were not native speakers, and this may have impacted satisfaction.

In addition, we attempted to outline specific components of a programme that allows for rapid training of providers to a level of basic competence in a wide range of applications.

Our choice of studies was based on the common basic exams described by the limited professional society documents available at the time, were further informed by investigators' prior practice experience at the sites, and, as described, were later supplemented at local provider request.

Our results show that obstetrical and hepatobiliary exams are identified as useful ultrasound applications in two very distinct clinical settings. While these results are consistent with the limited data available from other limited resource settings, the MNH rating of trauma as the most useful application is notable. As mentioned above, this result may have been impacted by prior training, and it remains to be seen whether this high estimation of the utility of bedside ultrasound for trauma will be confirmed in subsequent clinical impact evaluations.

Subsequent to the training course (though not as part of this study), quality review was conducted continuously for one month and at then at monthly intervals by onsite providers at MNH. At HSC, representative images for each ultrasound performed were submitted electronically for a period of six weeks post-training and reviewed by ultrasound-trained emergency physicians. Because of its cross-sectional descriptive nature and lack of longitudinal follow-up, our study does not allow us to make claims about sustained knowledge transfer. Further research will be needed to evaluate retention of training skills and the appropriate frequency for "refresher" courses.

Introducing bedside ultrasound in two distinct resource-limited settings was feasible and well-received. Providers were very interested in receiving training in bedside ultrasound and completed all course sessions, even though participation significantly increased the length of their workdays. After a brief intensive period of training, participants successfully passed a comprehensive examination, including demonstration of standardised image acquisition and accurate interpretation of normal and abnormal studies. Overall, participants were satisfied with the course, although approximately one-third of providers at both sites would have preferred more hands-on training. Obstetrical, hepatobiliary, and trauma applications were identified as the most useful.

Conflict of interest

The authors declare no conflicts of interest.

Dissemination of results

Results were shared with all department providers in informal group discussions, and were formally presented at department educational conferences and to hospital research committees.

Authors' contributions

T.R., J.N., and H.S. all assisted with study design, data collection and data analysis. G.P. assisted with study design and data collection, A.S. and B.N. contributed to data collection. S.S. assisted with study design, V.M. helped with data analysis, J.S. assisted with study design and data analysis. All authors reviewed drafts of the manuscript and contributed to the final review and preparation.

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