The Impact of Systematic Point-of-Care Ultrasound on Management of Patients in a Resource-Limited Setting

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Abstract. Although target point-of-care (POC) ultrasonography has been shown to benefit patients in resource-limited settings, it is not clear whether a systematic POC ultrasound assessment in these settings can also lead to similar changes in patient management. A predefined systematic set of POC ultrasound scans were performed on inpatients at a tertiary referral hospital in Tanzania to see if this resulted in changes to patient management. Of the 55 patients scanned, an abnormality was detected in 75% ($N = 41$), and a change in patient management was recommended or implemented on the basis of POC ultrasound findings in 53% ($N = 29$). The main impact was earlier initiation of treatment due to more rapid and accurate diagnosis. Further research is warranted to determine whether systematic POC ultrasonography would result in improved patient outcomes in resource-limited settings.

INTRODUCTION

Point-of-care (POC) ultrasonography examinations are brief, targeted, and clinician-directed imaging studies performed at the patient's bedside, which allow the clinician to rapidly answer specific clinical questions, optimize patient care, and expedite management.¹ POC ultrasonography is used in emergency departments in the developed world for a range of presentations including trauma, undifferentiated shock, and acute abdominal pain. The past decade has seen advances in affordability, durability, and portability of ultrasound technology. Given that it is relatively inexpensive and produces no ionizing radiation,² it has come to be considered by some as the "stethoscope of the 21st century."³ Furthermore, studies have shown ultrasound to be superior to other radiographic modalities in detecting certain pathologies. A recent study demonstrated ultrasound had greater sensitivity, specificity, and accuracy compared with chest radiograph (CXR) for diagnosis of community-acquired pneumonia in the emergency department, with 94.6% versus 77.7% ($P < .001$) specificity, 98.5% versus 94% ($P < .001$) sensitivity, and 96.1% versus 83.8% ($P < .001$) accuracy.⁴ Meta-analysis found POC ultrasonography was superior to CXR in detecting pneumothorax,⁵ and another study demonstrated POC ultrasonography to be more effective than computed tomography for diagnosing pneumothoraces.⁶

The use of POC ultrasonography has increased in resource-limited settings where its rapid, noninvasive, and safe profile makes it an ideal diagnostic adjuvant for improving health-care outcomes.⁷ There is no consensus on the duration or extent of training required for clinicians to be deemed competent to perform unsupervised POC ultrasonography, with recommended numbers of supervised scans ranging from 10 to 250.^{8,9} Nevertheless, there is evidence to suggest that minimal targeted train-

ing can allow clinicians to positively impact on patient care through the use of specific scanning protocols.⁸ A study in rural Rwanda concluded that POC ultrasonography targeted to certain clinical conditions changed initial patient management in 43% of cases, with the most frequent management change being a plan to take the patient for an interventional procedure.¹⁰

The aim of this study was to determine whether application of a systematic POC ultrasound scanning protocol applied to inpatients in a resource-limited setting impacted patient management. It was conducted at a tertiary referral hospital in Mwanza, Tanzania, which services a population of approximately 12 million.

CASE 1

A 50-year-old male presented with a 9-day history of intermittent fever, hematemesis, and right lower extremity swelling. He had a past history of esophageal varices secondary to portal hypertension from chronic schistosomiasis. On admission, he was anemic with a hemoglobin of 4 g/dL. The working diagnosis was deep venous thrombosis (DVT), and the patient was due to be started on warfarin. A systematic POC ultrasound exam showed no evidence of DVT (Figures 1 and 2), and findings were consistent with cellulitis in the patient's right leg (Figure 3). The remainder of the scan confirmed periportal changes consistent with his underlying diagnosis of schistosomiasis. Anticoagulation was averted, and the patient was started on intravenous antibiotics for treatment of his cellulitis.

CASE 2

A 17-year-old male transferred from a peripheral hospital with a 3-day history of abdominal distension and vomiting. Abdominal flat plate obtained at the district hospital showed evidence of a small bowel obstruction. On arrival to the referral hospital, the initial management plan was for continued conservative treatment of bowel obstruction with nasogastric suction. POC ultrasonography demonstrated a significant amount of complex free fluid in the

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FIGURE 1. Left femoral vein and artery.

abdomen as well as findings suggestive of free air (Figure 4). These features were consistent with bowel perforation, presumably from typhoid; antibiotics were initiated and he was referred to the surgical team for emergency laparotomy.

MATERIALS AND METHODS

Under the oversight of local physicians, 10 doctors from the United Kingdom, Australia, Canada, New Zealand, Malawi, Botswana, and Tanzania performed systematic POC ultrasonography on inpatients at Bugando Medical Center (BMC), Mwanza, Tanzania, over a 1-week period as part of an ultrasound training course (Basic Skills in Clinical Ultrasound in a Resource-Limited Setting) run by BMC and the London School of Hygiene and Tropical Medicine in September 2015. A convenience sample of patients from the medical wards, general pediatrics ward, pediatric and adult intensive care units, and those requiring admission from the emergency department were included in the study. All patients admitted to these locations during the 1-week period were eligible to be included in the study.

Scans were conducted using a Sonosite Edge (Fujifilm, Burlington, MA), a Terason U 3200T (Teratech Corporation,

FIGURE 3. Left leg: cellulitis.

Burlington, MA), and a Mindray DP6600 (Mindray Medical International Limited, Redmond, WA). Each scan was performed and interpreted by a trainee under the direct supervision of experienced emergency medicine consultants, or by an emergency medicine trainee with formal training in ultrasound with subsequent review by one of two emergency medicine consultants. Every exam thus underwent real-time quality assurance (QA) by an experienced ultrasound clinician. Each scan consisted of 10 views to answer 12 clinical questions (Table 1). Change in management was defined as confirmation or exclusion of pathology or where findings supported a change in the patient's treatment plan. Survey data were kept in a secure filing system. Data analysis was done using statistical analysis program Qualtrics (Qualtrics LLC, Provo, UT).

Cases were prioritized according to clinical indication and requests by the clinical team for ultrasound scan, followed by systematic POC ultrasonography in the remaining patients. All patients had all 10 views performed. A local nurse or doctor was present to obtain verbal consent and to inform the patient of any findings. The findings of each scan were documented in the patient's notes and directly communicated to the clinical team.

Ethics. Verbal consent was obtained before every ultrasound. No identifying data were collected from patients.

FIGURE 2. Fully collapsed left femoral vein.

FIGURE 4. Free air on left side of image and complex-free fluid on right side of image.

TABLE 1
Ultrasound views obtained and corresponding clinical questions answered

View	Clinical question
Subxiphoid view of the heart	Is there fluid around the heart? Does the heart have good contractility?
Subcostal view of the IVC	Is the IVC collapsing?
Anterior–superior thoracic view	Is there a pneumothorax?
Posterior–inferior thoracic view	Is there a pleural effusion?
Subcostal view of the liver	Are any abnormalities in liver echotexture seen?
FAST: right upper quadrant	Is there fluid in the hepatorenal space?
FAST: left upper quadrant	Is there fluid in the splenorenal space?
FAST: suprapubic	Is there fluid in the suprapubic space?
Both kidneys	Is there hydronephrosis?
Both femoral veins at inguinal crease	Is there a DVT in the femoral vein?
	Did the scan change patient management?

DVT = deep venous thrombosis; IVC = inferior vena cava; FAST = focused assessment with sonography in trauma.

Study results were recorded in an anonymous registry of POC ultrasound created by the BMC Department of Medicine for the purpose of improving patient care. Analysis of this registry has been approved by the institutional review boards of BMC, the Tanzanian National Institute for Medical Research, and Weill Cornell Medical College.

RESULTS

A total of 55 patients were included in the study. Fifty-six percent ($N = 31$) were male. Ten patients (18%) were aged less than 13 years (the criteria for pediatric admission at BMC). Patient age ranged from 1 month to 87 years. The number of patients from each department is shown in Table 2.

An abnormality was detected in 75% ($N = 41$) of patients (Figure 5) across the different wards (Table 2). Pericardial effusion was detected in 35% ($N = 19$) of patients, and 15% ($N = 8$) of patients were found to have abnormal cardiac contractility. Inferior vena cava abnormalities were detected in 42% ($N = 21$) and pleural effusions in 26% ($N = 13$). Two patients had pneumothorax (4%).

Focused assessment with sonography in trauma (FAST) intraabdominal scanning detected abnormalities in 37% ($N = 19$). Eleven patients (26%) had free fluid in each of the regions scanned. Seventeen patients had free fluid in the suprapubic space, 15 (29%) in the hepatorenal recess, and 12 (24%) in the splenorenal recess. Hydronephrosis was demonstrated in 8% ($N = 4$), with two patients having bilateral pathology. Six patients (18%) had evidence of DVT.

Although the majority of examinations revealed an abnormality, not all of these resulted in a recommendation for a change in management. Some findings were expected as part of the disease course, for example, the detection of a

pleural effusion in a patient pneumonia, or a small pericardial effusion being detected in a patient receiving treatment of tuberculosis.

Of the 44 abnormalities detected, changes in patient management were recommended in 29 (53% of total scans performed). In 44% ($N = 24$), a suspected diagnosis was confirmed and in 9% ($N = 5$), a suspected diagnosis was excluded. The decision as to whether findings would influence patient management was reached by consensus of the authors with the senior author adjudicating any disagreement. Examples of pathology detection that led to a change in management recommendations included findings such as a large pleural effusion not evident by chest radiography, or findings of intraabdominal free fluid on FAST scan raising suspicion for intraabdominal infection not otherwise suspected. Tables 3 and 4 breakdown the expected impact of ultrasound by diagnosis and ward.

DISCUSSION

Timely and accurate diagnosis is a key factor influencing patient care. This is particularly relevant in resource-limited settings where patients may present to health services with advanced stages of disease.¹⁰ In settings where alternative diagnostic modalities are not easily accessible due to logistical and/or financial constraints, targeted POC ultrasonography has been shown to lead to the avoidance of additional costly investigations and the implementation of futile treatment based on incorrect diagnosis.^{10,11} This study suggests that the application of a systematic POC ultrasound exam by clinicians with limited training can lead to improved diagnostic capabilities influencing the implementation of timely patient management.

Despite advancing technologies, the upfront cost of portable and durable ultrasound equipment remains expensive, with poor technical support available in resource-limited settings.¹⁰ This expense remains a key barrier in the implementation of the use of such technologies in hospitals such as BMC. However, these issues are not unique to the use of ultrasound. Advancements in ultrasound technologies and reductions in upfront costs⁸ could lead to routine POC ultrasonography becoming a key diagnostic tool in resource-limited settings.

Systematic POC ultrasonography influenced diagnosis and could be expected to alter management in the majority of participants in this study. This was most prominent in adult

TABLE 2
Numbers of patients scanned in each department

Admitted ward	Number of patients % (n)	Abnormality detected % (n)
General medical	66 (36)	78 (28)
General pediatric	11 (6)	66 (4)
Adult intensive care unit	9 (5)	80 (4)
Pediatric intensive care unit	5 (3)	33 (1)
Emergency department	9 (5)	80 (4)
Total	100 (55)	75 (41)

FIGURE 5. Pathology detected on ultrasound scanning (percentage of all patients scanned).

patients with undifferentiated pathology and severe illness (i.e., adult intensive care and emergency department), where POC ultrasonography was anticipated to influence the management of all patients. Although it was beyond the remit of this study to determine whether this impacted patient outcomes, this study suggests that systematic POC ultrasonography has the potential for greatest impact in these settings, as demonstrated by the cases detailed above.

With regard to pathology, systematic POC ultrasonography had the potential to substantially influence patient diagnosis and management in those patients with intrathoracic abnormalities. This is consistent with previous studies, which have found ultrasound to be superior to X-ray in identifying certain lung and cardiac pathology.^{4–6,11} This further supports the use of POC ultrasonography as the preferred diagnostic modality for these conditions, with the additional advantage of increased availability out of hours and avoidance of ionizing radiation.

Study limitations. The study included a small sample size with a limited data collection time frame. The implementation of appropriate management strategies may be restricted in resource-limited settings. It is not clear whether changes in management resulted in improved patient outcomes.

Although recommendations regarding changes in management were made to the treating physicians, the study did not assess what percentage of these recommendations were implemented. Future research could aim to explore the practicalities of implementing appropriate management strategies based on findings from systematic POC ultrasonography.

TABLE 3

The expected impact of POC ultrasonography on patient management by pathology

Positive pathology findings	Change in management recommended % (n)	No change in management recommended % (n)
Pericardial effusion	63 (12)	37 (7)
Abnormal cardiac contractility	88 (7)	12 (1)
Abnormal IVC collapsibility	62 (13)	38 (8)
Pneumothorax	50 (1)	50 (1)
Pleural effusion	92 (12)	8 (1)
Positive abdominal FAST scan	79 (15)	21 (4)
DVT	67 (4)	33 (2)
Hydronephrosis	100 (4)	0 (0)

DVT = deep venous thrombosis; IVC = inferior vena cava; FAST = focused assessment with sonography in trauma; POC = point-of-care.

A multicenter study with an increased sample size would increase the generalizability of the results. Although scans were performed and interpreted by relatively novice sonographers, supervision by clinicians with extensive ultrasound experience did perform real-time and delayed QA. These results should therefore be applied with caution in situations where novice sonographers do not have immediate access to expert oversight.

CONCLUSION

POC ultrasonography is a powerful tool in helping clinicians to identify and treat a wide range of pathologies, which can improve a patient's management. In addition to the benefits of reduced cost and avoidance of exposure to ionizing radiation, ultrasound is superior to other radiological modalities in detecting certain pathologies. Systematic POC ultrasonography of inpatients by clinicians with relatively little training in ultrasound resulted in improved accuracy of diagnoses and recommendations for changes to patient management in the majority of cases. Further research is warranted to determine whether patient outcomes are improved when systematic POC ultrasonography is part of routine clinical assessment of inpatients in resource-limited settings.

Received March 11, 2016. Accepted for publication September 14, 2016.

Published online December 19, 2016.

Acknowledgments: We thank the patients and staff at Bugando Medical Centre for their assistance with this study; K. Mteta, R. Peck, L. Smart, D. Kaminstein, and the LSHTM for arranging the

TABLE 4

The expected impact of POC ultrasonography on patient management by ward

Ward	Change in management recommended % (n)	No change in management recommended % (n)
General medical	44 (16)	56 (20)
General pediatric	50 (3)	50 (3)
Adult intensive care unit	100 (5)	0 (0)
Pediatric intensive care unit	33 (1)	67 (2)
Emergency department	100 (5)	0 (0)

POC = point-of-care.

ultrasound training course; and D Kaminstein, M. Stephens for their supervision and expert opinion. Robert Peck is supported by the National Institutes of Health (NIH K01 TW010281-01).

Disclaimer: The funder had no role in the preparation of the article or in the decision to publish it.

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