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Original Article

A feasibility study to determine if minimally trained medical students can identify markers of chronic parasitic infection using bedside ultrasound in rural Tanzania

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BACKGROUND: Parasitic infections pose a significant health risk in developing nations and are a major cause of morbidity and mortality worldwide. In the Republic of Tanzania, the CDC estimates that 51.5% of the population is infected with one or more intestinal parasites. If diagnosed early, the consequences of chronic parasitic infection can potentially be avoided.

METHODS: Six first-year medical students were recruited to enroll patients in the study. They underwent ten hours of formal, hands-on, ultrasound which included basic cardiac, hepatobiliary, renal, pulmonary and FAST scan ultrasound. A World Health Organization protocol with published grading scales was adapted and used to assess for pathology in each patient's liver, bladder, kidneys, and spleen.

RESULTS: A total of 59 patients were enrolled in the study. Students reported a sensitivity of 96% and specificity of 100% for the presence of a dome shaped bladder, a sensitivity and specificity of 100% for bladder thickening, a sensitivity and specificity of 100% for portal hypertension and ascites. The sensitivity was 81% with a specificity of 100% for presence of portal vein distention. The sensitivity was 100% with a specificity of 90% for dilated bowel.

CONCLUSIONS: Ultrasound has shown a promise at helping to identify pathology in rural communities with limited resources such as Tanzania. Our data suggest that minimally trained first year medical students are able to perform basic ultrasound scans that can identify ultrasonographic markers of parasitic infections.

KEY WORDS: Parasitic infection; Bedside ultrasound; Computed tomography; Tanzania

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INTRODUCTION

Parasitic infections pose a significant health risk in developing nations and are a major cause of morbidity and mortality worldwide.[1,2] The World Health Organization (WHO) estimates that 1.5 billion people worldwide are infected with soil-transmitted helminth infections.[3] In the Republic of Tanzania, the CDC estimates that 51.5% of the population is infected with one or more intestinal parasites including entamoeba, giardia, hookworms, and ascaris.[4] Poor hygienic conditions, lack of access to clean water and poor public health program infrastructure greatly exacerbate this problem.[5] If diagnosed early and appropriately treated, the negative consequences of chronic parasitic infection, including impaired cognitive development, poor nutritional status and stunted physical growth can potentially be avoided.[2]

Historically, most parasitic infections are diagnosed by microscopic detection of parasites and eggs in urine and stool samples.[6] While serologic and immunologic testing is also possible, it is not feasible or cost-effective in endemic, rural settings with limited resources. Thus, both urine and stool for detecting ova and parasites remain the gold standard for diagnosing schistosomiasis infections in these regions.[7] Computed tomography (CT) and magnetic resonance imaging (MRI) are excellent diagnostic imaging modalities but are not available in rural hospitals. Liver biopsy for detection of schistosomiasis-related fibrosis and granulomas is invasive and requires a high level of training and expertise.[8] These limitations pose significant difficulties in monitoring disease progression and preventing adverse outcomes in these patients.

Previous studies have shown that ultrasound can be useful in evaluating the liver, bladder, spleen, and kidneys for monitoring of the long-term effects of schistosomiasis infection.[9–12] In these studies, schistosomiasis infection was associated with hepatomegaly, splenomegaly, periportal fibrosis, portal vein dilation, portal hypertension, and calcification of the bladder. These studies demonstrated that ultrasound is useful for monitoring long-term pathological changes in chronically infected individuals and may also be useful in detecting both acute pathology and chronic effects from high parasite burden.[9–12] However, there is little value of using ultrasound for screening for schistosomiasis since stool sample analysis is more economical and has a high specificity.[13] We believe that these scans can be easily taught and performed in rural and underserved settings with transportable ultrasound machines.

We sought to qualitatively describe the value of ultrasound examination in evaluating patients who are chronically exposed to schistosomiasis. A secondary objective is to determine if first year medical students with basic ultrasound training can effectively perform scans to screen the effects of chronic parasitic infections in rural Tanzania. The study did not attempt to validate the WHO ultrasound protocol as a screening tool for schistosomiasis infection, but rather determine if minimally trained operators can perform the protocol. This study is the first step in determining the feasibility of using ultrasound to monitor parasite-induced morbidity by minimally trained individuals, such as local nurses and clinical officers.

METHODS

Ethics statement and study design

The study was approved by the University of California Institutional Review Board. Written informed consent in both English and Kiswahili was obtained from all patients recruited for the study. We recruited a convenience sample of patients from Mwananichi Hospital, a local hospital in the city of Mwanza, Tanzania and Nansio District Hospital, a rural hospital on Ukerewe Island, Tanzania. Study participants completed a health data sheet in the presence of a Tanzanian medical student, physician, or translator and provided health information on age, alcohol consumption, viral infections, known parasitic infections, and other known chronic diseases. We excluded patients who reported hepatitis B, hepatitis C, or HIV infection, current malaria infection, or a history of liver, kidney, or bladder disease. Pregnant women and children under 5 years old were also excluded from the study.

This was a prospective, observational study utilizing a convenience sample where six first year medical students enrolled at UC Irvine School of Medicine were recruited via announcements and flyers for the study. All of the six students had completed an entire first year of medical education which included human physiology, human anatomy, cardiac anatomy and basic ultrasound education. Their ultrasound education required ten hours of supervised hands-on training in addition to pre-session podcast on eight separate organ systems of medical ultrasound. This included basic cardiac, hepatobiliary, renal, and pulmonary ultrasound.

In addition to their training outlined above, we then trained this subset of six medical students on the "Ultrasound in Schistosomiasis" protocol of the World Health Organization. We adapted the published grading scales and assessed for pathology in each patient's liver, bladder, kidneys, and spleen (Table 1). Because of the length of the protocol and the lack of clinical application of some scans as determined by UCI ultrasound technicians, several measurements from the original protocol were excluded. Excluded measurements included liver surface irregularities, left parasternal longitudinal view for liver shape and size of left liver lobe, right mid-clavicular view, portal vein score, and measurement of collateral veins. However, students were trained on the most clinically applicable scans described in the protocol, and all other measurements were completed.

To ensure a full bladder, as necessary for protocol, each patient was given a 503 mL bottle of water to drink while completing the consent process and health data form. The students performed a total of eleven scans using the Sonosite Nanomaxx (FUJIFILM Sonosite Inc) with a curvilinear probe. Images were captured for each scan in the protocol. Each subject's visit lasted approximately

Table 1. World Health Organization "Ultrasound in Schistosomiasis" protocol with published grading scales

i) Transverse view of the bladder – The probe was placed in transverse orientation above the pubic symphysis to visualize the bladder. Each bladder was assessed for shape, lesions, masses, pseudopolyps, and calcifications of the bladder wall. Per the WHO grading system, a score of 0 was assigned for bladders that were in a rectangular shape, while 1 was assigned for a rounded, distorted bladder. Bladders without lesions, masses, pseudopolyps, and calcifications were assigned 0 in each category. If present, each category was graded as follows: bladder wall lesions (focal=1, multifocal=2); masses (single=2, multiple=*n*+2 where *n* is the number of masses); pseudopolyps (single=2, multiple=*n*+2 where *n* is the number of pseudopolyps); calcifications (visible=1). Finally, bladder width and depth were measured with calipers in transverse orientation and recorded for later calculation of post-void residual bladder volumes.
ii) Longitudinal view of the bladder – From the transverse view of the bladder, the probe was rotated 90 degrees to capture the longitudinal view of the bladder. As above, the bladder was assessed for lesions, masses, pseudopolyps and calcifications. Bladder length was measured with calipers and recorded for later calculation of post-void residual bladder volumes.
iii and iv) Right and left coronal for lateral views of the kidneys – The probe was placed in coronal orientation between the mid axillary and posterior axillary lines to visualize the kidney and if visible, the proximal ureter. Dilation of the ureters was graded 0 if absent or not visualized, 3 if visualized at proximal or distal third, and 4 if dilated more than for standard visualization. This was repeated on the left side. While in this orientation, patients were also assessed for presence or absence of fluid in Morrison's Pouch and the splenorenal recess.
v and vi) Right and left kidneys in cross section – From the coronal orientation, the probe was rotated approximately 90 degrees to obtain a cross-section of the kidney. While in this orientation, the kidneys were assessed for hydronephrosis or dilation of the renal pelvis. Grading was as follows: not dilated=0, moderate dilation with conserved parenchyma (renal pelvis to capsule>1 cm)=6, severe dilation with absence of parenchyma=8. In addition, the renal pelvis was also evaluated for fibrosis based on presence or absence of echodense structures along the borders of the pelvis. If absent, a score of 0 was assigned; if present, a score of 1 was assigned.
vii) Liver view with probe placement at the right anterior axillary line – Probe was placed vertically at the right anterior axillary line for measurement of the right liver lobe using calipers. Presence or absence of ascites was also noted.
viii) Liver view with probe placement between the anterior axillary and midaxillary lines – Liver was scanned between anterior axillary and mid axillary lines to find a portal vein for evaluation of portal flow. Color mode was used in two axes to determine if there was reversal of flow due to portal hypertension. Red was recorded as normal; blue was recorded as reversal of flow. Presence or absence of ascites was also noted.
ix) Substernal transverse view – Probe was placed in transverse orientation just below the xiphoid process for visualization of the left liver lobe.
x and xi) Post-void transverse and longitudinal view of the bladder – Patient's bladder was rescanned in transverse and longitudinal orientation after voiding. Post-void bladder width and depth were measured with calipers and recorded for later calculation of post-void residual bladder volumes.

35 minutes including 20 minutes for consent and history taking and 15 minutes for ultrasound imaging. Data collection was done over the span of three weeks.

Subjects for scanning were recruited through community announcements by the hospital doctors or other hospital staff both at Mwananichi and Nansio hospitals. Subjects were ambulatory, but most were interested in the study because of chronic and vague abdominal symptoms. Although the subjects were not compensated monetarily, parasitic testing was covered by the study and subjects were referred to medical specialists for follow up.

During the scanning process, the medical students completed the WHO grading form and saved all scanning images under a de-identified patient number assigned during the consent process. Following the ultrasound, patients were sent to the hospital lab to provide stool and urine samples for ova and parasite assessment. All scanning images from each de-identified patient were later assessed by a board-certified physician and a licensed ultrasonographer who was blinded to the medical students' grading assessment and completed a separate analysis of the images. Since the protocol was simplified and not used for schistosomiasis screening, specificity and sensitivity were not relevant. Analysis focused on the accurate assessment and capture of the ultrasound images by the medical students.

Data collection and statistics

Data collected from the grading forms included the following markers: bladder shape, bladder wall lesions, bladder masses, bladder pseudopolyps, bladder calcifications, post-void residual volume, right ureter dilation, left ureter dilation, right kidney renal pelvis dilation or hydronephrosis, left kidney renal pelvis dilation or hydronephrosis, right kidney renal pelvis fibrosis, left kidney renal pelvis fibrosis, right liver lobe size, portal hypertension, and ascites.

Patients that presented to the free clinics were eligible for enrollment in the study and patients were enrolled utilizing a convenience sample. Ultrasound grading scores were compared between the medical students and ultrasound trained physician to determine the accuracy of medical students' ability to correctly assess markers of pathology with ultrasound. The number of markers correctly identified by the medical students was tallied and a total score for the medical student was assigned for each patient for determining their accuracy.

RESULTS

The six medical students enrolled a total of 59 patients (28 men and 31 women). The average age of the patients was 36 years and seven patients had known

Table 2. Demographics of the patients

Parameters	Schistosomiasis (*n*=34)	No schistosomiasis (*n*=25)
Gender		
Female	13	18
Male	21	7
Age	Mean=41.3; range=7–77	Mean=30.43; range=9–53
Location		
Mwanza	8	3
Ukerewe	26	12
Known liver pathology	7	0
Praziquantel trials	1.1 STD=1.35	0
Concurrent parasites	4 (2 hookworm, 1 amoeba, 1 malaria)	7 (1 helminth, 2 ascaris, 2 hookworm, 1 yeast, 1 amoeba)
Other pathology	3	5

Table 3. Concordance information

Characteristics	Medical student	Ultrasound director	Concordance (%)
Dome shape bladder	27	28	Sensitivity (96.4) Specificity (100)
Bladder thickening/irregularity	12	12	Sensitivity (100) Specificity (100)
Presence of bladder mass	0	0	Sensitivity (0) Specificity (100)
Visualization of ureters	1	0	Sensitivity (0) Specificity (98.2)
Portal hypertension	6	6	Sensitivity (100) Specificity (100)
Portal vein distention	9	11	Sensitivity (81.8) Specificity (100)
Presence of ascites	4	4	Sensitivity (100) Specificity (100)
Dilated bowel	20	16	Sensitivity (100) Specificity (90.7)

pathology of their diseases. Full demographics of the patients are illustrated in Table 2. The students recorded the presence of dome-shaped bladder, bladder thickening, presence of bladder mass, visualization of ureters, portal hypertension, portal vein distention, presence of ascites, and dilated bowels. The most common pathology noted were as follows: bladder shape, bladder wall thickening and dilated bowel; of those patients with these pathologies, 7 had current schistosomiasis and 8 had a history of schistosomiasis. Since the full WHO protocol was not performed, the full screening score could not be calculated and the results were not compared to stool analysis (gold standard). However, as mentioned before, it is of little practical value in using ultrasound for schistosomiasis screening. The accuracy of the students' ultrasonography is listed in Table 3. The trained physician agreed with the student's assessment up to 100%, with the biggest discordance in visualization of ureters and biggest agreement in presence of ascites, bladder thickening and portal hypertension.

DISCUSSION

According to the WHO, parasitic infections are a major public health problem in developing countries; however there is no agreed program to help monitor such patients.[14] In our study, most subjects had a history of parasitic infection which occurred for many times. This reality is evident in Tanzania, the largest country in East Africa. Without funding or infrastructure, nearly 2/3 of the population have no access to primary health care.[15] Additionally, due to lack of urbanization, 80% of the population live in rural areas and do not have access to clean running water.[15] This creates an environment favoring both larval skin penetration and fecal-oral transmission. Without access to healthcare providers, these conditions become chronic, causing significant morbidity and mortality of the local population. The chronic infections have been associated with hepatomegaly, splenomegaly, periportal fibrosis, urinary bladder obstructions, and bladder cancer.[16–18] Although being difficult to accurately quantify, parasitic infection has been shown to be a causal factor for hepatomegaly and splenomegaly in the region. These morbidities have shown a strong relationship.[19] In this study we determined if minimally trained practitioners can use ultrasound to identify acute pathology of chronic infections in rural Tanzania.

Medical imaging is often financially or logistically unavailable and lacking in lower and middle income countries given the low access to sufficient health care.[20] Ultrasound has emerged as a convenient and portable method of imaging in rural communities and austere environments. Ultrasound is becoming a popular choice for imaging in the developing world due to its affordability and transportability in comparison with CT and MRI.[20] In Mwanza, Tanzania, the setting of the current study, the cost of a CT scan was 350 000 shilling and 50 000 shilling for an ultrasound. The greatest barriers to radiology include availability of trained radiologists (1 radiologist to 1.5 million people in Tanzania), maintenance difficulties due to lack of infrastructure, and uneven distribution of resources between the private and public hospitals.[20] Use of portable ultrasound improves accessibility and removes some of the constraints of upkeep. Studies[15–20] have shown that the introduction of ultrasound can significantly alter treatment plan. In 43% of cases in Rwanda, ultrasound changed the initial management plan, involving surgical procedure, medication, clinic referral and others.[20]

There are studies[20] on the feasibility of training midwives and other healthcare professionals in using ultrasound, i.e. in an obstetric setting and training programs ranging from 6 months to 1 year. These studies showed a high concordance rate between trainee images and radiologist assessment (>90%).[20–22] Furthermore, ultrasound can be used in numerous medical assessments. In the same study in Rwanda, of the first 345 ultrasounds performed, the majority were performed for obstetrical purposes (102), followed by abdominal (94), cardiac (49), renal (40) and pulmonary (36), along with a few procedural usages, soft tissue and vascular examinations. The present study contributes to the growing literature on ultrasound training for a novel purpose, the assessment of parasitic infection. With this study in mind, we used a medical school based training protocol with 10 hours of formal training, supplemented with podcasts. This type of shortened training program could be easily introduced into rural and urban hospitals in resource poor settings.

While ultrasound is emerging for general use, there has been little headway into using ultrasound for identification of parasitic infection despite existence of established protocols. There are established protocols using ultrasound in identifying pathology related to bacterial, viral and parasitic infection.[23] The varying sensitivity and specificity are dependent on the microbe. For *C. Sinensis* infection identification, the sensitivity was 52% and the specificity 51%; however for ascaris infection the sensitivity in the biliary tract was 92%. For schistosomiasis the exact sensitivity and specificity of an ultrasound protocol were different. Although ultrasound has a high specificity and sensitivity for identification of many tropical infections, ultrasound is still not used as a gold standard in resource poor countries.[24]

With the expansion of ultrasound into medical education, it is believed that minimally trained practitioners can identify pathology using point of care ultrasound. To date, physician education in diagnostic sonography was previously withheld until residency and varied widely between specialties.[25] Studies[26–28]showed that pre-clinical medical students can obtain a resident-level understanding of ultrasonography given proper means and methods of training. Specifically in Tanzania, previous studies[24,29] have demonstrated the importance of ultrasound in low-resource settings and the success of training programs in rural Tanzanian hospitals and clinics. It is expected that with expanded resources and continued training, ultrasound can become a standard tool for the identification of pathology in rural populations.

In our study, the students demonstrated the understanding of anatomic structures on ultrasonographic images compared with a trained ultrasonogropher. Additionally, medical students were able to understand the technical aspects of ultrasonographic images, including terminology, machine settings, and transducer frequencies. Our data suggested that minimally trained medical students with one-year medical school-based ultrasound training can competently perform ultrasound scans to identify pathological changes indicative of chronic or acute parasitic infections. The students are also able to perform major ultrasound examinations needed to assess schistosomiasis morbidity according to the WHO protocol. Further large scale studies are needed to determine if ultrasound alone can be used to detect pathologic conditions associated with parasitic infections and if a shortened and simpler protocol is adequate for assessment. We hope that the training of local Tanzanian clinical officers and health care providers to perform ultrasound scans in this protocol would be feasible to initiate a community-wide screening program for detecting pathological entities from chronic parasitic infections. Ultrasound would also serve as an important diagnostic technology in resource-limited settings and enable providers to tailor care for their patients based on point-of-care ultrasound findings.

Limitations

There are several limitations to this study. We enrolled a small number of patients (*n*=59). The patients had to provide consent form and answer questions in their native languages. Some lab tests were unable to be done due to lack of resources. Lack of centralized medical records meant that not all patient history could be confirmed. Hand-held portable ultrasound machines may not be able to produce high quality images.

In conclusion, parasitic infections are a significant cause of morbidity and mortality in the developing world. Ultrasound has shown a promise to identify pathological entities of a disease and monitor its progression in rural communities with limited resources such as Tanzania. Our data suggest that minimally trained first year medical students are able to perform basic ultrasound scans and can identify ultrasonographic markers of parasitic infections. These results are promising, suggesting that similar ultrasound training for local Tanzanian health providers enables them to perform scans and monitor long-term disease progression in their patients. Future studies should therefore assess the ability of local health officials who have received similar ultrasound training to perform ultrasound scans and similarly to compare their scores with those of licensed ultrasonographers. Given our small enrollment, larger-scale clinical trials are needed to confirm the promising conclusions.

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Ethical approval: The study was approved by the University of California Institutional Review Board. Written informed consent provided in both English and Kiswahili was obtained from all patients recruited for the study.

Conflicts of interest: The authors declare that there are no conflicts of interest relevant to the content of the article.

Contributors: Barsky M analyzed the literature and drafted the manuscript. All authors contributed to the design and interpretation of the study and to further drafts.

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