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Review Article

Applications of ultrasound in the low and middle income countries

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ABSTRACT

With the easy availability, portability and durability of ultrasound, rapid improvement in bedside and Radiologist-performed ultrasound is seeing increasing use in rural, underdeveloped parts of the world. Physicians, and medical officers have demonstrated the ability to perform and interpret a large variety of ultrasound exams, and a growing body of literature supports the use of point-of-care ultrasound in developing nations. We review, by countries, the existing literature in support of ultrasound use in the countries with low and middle income group and training guidelines currently in use, and highlight indications for emergency ultrasound.

Keywords: Ultrasound, Low and middle, Income

INTRODUCTION

Over the past decade, however, the use of clinician-performed, hand-carried, bedside ultrasound has gained increasing popularity as a useful imaging modality worldwide, helping to boost the diagnostic capacity of rural district hospitals in resource-limited settings. It is generally accepted that in rural and remote areas of low- and middle-income countries (LMICs) diagnostic imaging is often insufficient, and in some instances completely lacking.[1] The increase in ultrasound services provided by nonradiologists is likely due to several factors, including the increased affordability, availability, portability and durability of ultrasound machines. In addition, many new laptop-based machines are now in production. Improvements in battery life for hand-carried machines, and the lack of film, chemical developers and dedicated technicians, allow for use of ultrasound in health missions to remote areas of the developing world. Because of this evolution in technology and the growing body of literature to support its use, ultrasound has gained increasing recognition as a valuable diagnostic tool for resource-limited settings by the ministries of health in LMICs, several non-governmental organizations and the World Health Organization (WHO).

PREVIOUS STUDIES

There have been a multitude of small studies depicting novel uses of ultrasound in the developing world, but only a few studies have looked at the impact of ultrasound use on clinical management and patient outcomes, and whether ultrasound may be a sustainable modality for use in LMICs.

In a study of patients in the Amazon jungle, a group of American emergency physicians found that ultrasound examinations changed treatment in 28% of patients, including appropriate referrals for more definitive care in some cases and avoiding a potentially dangerous 2-day evacuation for additional medical care in others.[2] The consulting physician's differential diagnosis was narrowed after reviewing the ultrasound results in 72% of cases, with diagnostic certainty achieved in 68% of cases.

In a study from Rwanda, ultrasound was introduced at two rural district hospitals, and the impact on patient care was assessed by asking providers to identify if ultrasound changed patient management plans. Of the first 345 ultrasounds performed, the majority of scans 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 exams. In 43% of patient cases, ultrasound findings changed the initial patient management plan, with the most common changes cited as: performing a surgical procedure, medication changes, clinic referral and cancelling of a planned surgical procedure.[3]

In 2004, a study by radiologists sought to demonstrate that portable ultrasound could enhance the medical management and clinical outcomes of patient care in a variety of clinical settings (surgeon's office, hospital operating room and clinics) in the Sekondi-Takoradi area, Ghana. In clinic settings, the most frequent ultrasound examinations were musculoskeletal (46%), with the remainder being obstetric, pelvic and genitourinary. In the hospital setting, abdominal, pelvic and genitourinary ultrasounds were the most frequent exams done to assess bladder masses, prostate and uterine size, and kidney abnormalities. A total of 67 ultrasound examinations were performed with abnormal findings in 54 (81%). One hundred percent of these abnormal ultrasounds were thought to add to the clinical diagnosis, and 40% (27) influenced the outcome or decision regarding treatment for these patients.[4]

Despite its limitations, the impact of ultrasound is beginning to become clear, and this tool has become indispensable for the examination of cardiac, abdominal, obstetric, vascular, traumatic and musculoskeletal complaints in the developing world. Given the prevalence of poverty-related diseases, such as tuberculosis, malaria and dehydration due to diarrheal illness, in the developing world, it is no surprise that emerging uses for ultrasound in LMICs include these diseases.[5] We summarize here, by region, some of the highlights of diagnostic ultrasound research for specific diseases in resource-limited settings in LMICs.

ASIA: INDIA

The diagnosis of abdominal tuberculosis is often difficult in the developing world due it its vague clinical features, mimicry of other diseases, and expensive/time consuming workup with CT scan and laparotomy. In Uttar Pradesh, India, investigators sought to assess the accuracy of ultrasound for diagnosis of abdominal tuberculosis in symptomatic patients co-infected with HIV. A retrospective review of 2,543 patients evaluated ultrasound use in an antiretroviral clinic. Patients with persistent fever, change in bowel movements, diarrhea or abdominal distention received an ultrasound evaluating Tb-related pathology such as lymphadenopathy (nodes >15 mm), organomegaly or multiple small abscesses/hypoechoic lesions in abdominal solid organs, bowel wall thickening, peritoneal nodules, mesenteric thickening or ascites as well as other abdominal pathologies. Of the 2,453 patients in an antiretroviral clinic, 373 were evaluated by ultrasound, of which 244 showed features suggestive of abdominal tuberculosis, with lymphadenopathy as the most common finding (64.8%), followed by splenomegaly (27.9%), hepatomegaly (20.1%) and bowel wall thickening (6.1%). Ultrasound was repeated at the end of antitubercular therapy, showing resolution of abnormal findings, which suggests this imaging modality may be useful in the diagnosing and monitoring of HIV-positive patients with abdominal tuberculosis.[6]

NORTH AMERICA

In an attempt to characterize cardiac disease prevalence in the developing world, American cardiologists used hand-carried ultrasound in outpatient clinics in rural San Blas and El Fuerte, Mexico. They performed cardiac ultrasound exams on 126 patients referred to the clinic by their primary care doctors for hypertension, chest pain, dyspnea, edema, murmurs, suspected congenital abnormalities, palpitations and syncope, of which 68% (86) exams were abnormal. The most common abnormal findings included significant valvular disease, left ventricular hypertrophy, dilated aortic root/increased chamber size, congenital abnormalities (including bicuspid aortic valve, PDA, atrial and ventricular septal defects), ventricular systolic dysfunction and regional wall motion abnormalities. In 93% of patients, hand-held ultrasound provided useful information that helped to clarify the clinical problem, in 63% of cases, ultrasound confirmed the cardiac origin of a symptom and in 90% of cases it made conventional echocardiography unnecessary. Hand-held ultrasound can provide useful diagnostic information in the evaluation of patients with potential cardiac disease in resource-limited settings.[7]

AFRICAN CONTINENT

Intrauterine growth retardation (IUGR) is a major contributing factor to perinatal mortality and morbidity in developing countries, and ultrasound may play an important role in early identification of pregnant mothers at risk. In 1988, Mahran et al. demonstrated an 11.8% rate of neonatal growth retardation in 828 pregnant women in Cairo, Egypt. In this group, antenatal ultrasound was able to predict 89.7% of these cases, while only 34.7% were predicted by fundal palpation.[8]

In a 2004 study in Gambia, physicians used a hand-held ultrasound to identify high-risk patients with cardiovascular disease and hypertension. Of the 1,997 patients seen, 17% (342) were found to have elevated blood pressure, and all of these patients underwent echocardiography to identify left ventricular hypertrophy, as a marker for those at highest risk of a cardiovascular event. Sixty-five percent of this hypertensive population demonstrated left ventricular hypertrophy by ultrasound and were started on antihypertensive medications. Patients with borderline hypertension also underwent a cardiac ultrasound examination and were started on antihypertensive medications only if they had evidence of left ventricular hypertrophy. Through this screening and

the identification of high-risk hypertensive patients, ultrasound enabled a more effective use of limited healthcare resources.[9]

In a district hospital in Karagwe, Tanzania, ultrasound services were studied to determine the impact on obstetric care. Nurse midwives, trained in basic obstetric ultrasound, were available to perform studies 24 h/day, whereas specialized ultrasonographers performing advanced ultrasound (including fetal biometrics) were only available during daytime hours. Five hundred forty-two patients with suspected abnormal findings were scanned over 1 year. When evaluating for twins, fetal heart rate or fetal positioning, the basic exam performed by the midwives had 100% agreement with the sonographer. Overall, ultrasound aided in the diagnosis of 39% (212) of patients and changed management plans in 22% (121). This study demonstrated that 24 hours availability of basic obstetric ultrasonography performed by midlevel providers could be implemented in a rural hospital setting to lessen the workload of a specialist sonographer while improving patient care.[10]

In a large retrospective study from the 1990s, abdominal ultrasound was used to define ultrasound findings of HIV through evaluation of 900 HIV-positive adults in the major tertiary referral hospitals of Lubumbashi, Congo, and Lusaka, Zambia. Ultrasound exams were performed by local practitioners for evaluation of various complaints, including pain, fever and organomegaly, and results of these ultrasounds were compared to age and sex-matched HIV-negative patients. Compared to HIV-negative patients, those with AIDS who underwent an ultrasound examination had significantly higher rates of splenomegaly (24% vs. 35%), hepatomegaly (22% vs. 35%), retroperitoneal and mesenteric lymphadenopathy (11% vs. 31%), biliary tract abnormalities, such as gallbladder wall thickening (12% vs. 25%), gut wall thickening (5% vs. 15%) and ascites (9% vs. 22%). The authors concluded that focused abdominal ultrasound in patients with HIV and AIDS can be a useful tool for diagnosing associated complex gastrointestinal pathology.[11]

SOUTH AFRICA

South African hospitals experience some of the highest trauma volumes in the world, and most have limited imaging capabilities, leading to significant diagnostic and therapeutic challenges. A study at the Ngwelezane Hospital, a busy referral center in rural KwaZulu-Natal, South Africa, examined the use of the FAST (focused assessment with sonography in trauma) exam on blunt and penetrating trauma victims. Over a 12-month period, 72 FAST scans were performed (52 for blunt trauma, 20 for penetrating trauma) with 15 positive scans (20.8%). The overall specificity of the FAST scan was 100%, with a sensitivity of 71.4%, but its sensitivity in penetrating trauma alone was much poorer at 62.5%. This study highlights the valuable role FAST scanning can play in the rapid assessment and timely transfer of appropriate trauma patients to referral hospitals.[12]

ULTRASOUND TRAINING

In 1998, the WHO established standards in ultrasound training and recommended that an appropriate curriculum be adopted for the training of practitioners in the use of diagnostic ultrasound.[13] However, there have been no standardized approaches to length of training, curriculum for general practitioners, qualifications of trainers or mechanism of training published in the literature. As demonstrated in the studies highlighted above, ultrasound can significantly impact the diagnosis and management of patients in LMICs. However, ensuring the sustainability of ultrasound programs in resource-limited settings will also require the implementation of successful training programs for local practitioners and the development of markers for quality assurance. Overall, the available literature suggests that a short but intensive training period is sufficient for preparing clinical officers and physicians alike to perform basic ultrasound exams, especially if the training program includes both lecture and practical experience, and provides opportunity for continued upkeep of skills through review sessions and on-going quality assurance after the training period ends.

ULTRASOUND INDICATIONS IN AREAS LACKING RESOURCES

There is long list of indications for ultrasound in low resource settings, but we focus here on the main emergency ultrasound indications that may help reduce morbidity and mortality in the developing countries.

OBSTETRIC ULTRASOUND

Ultrasound can be a valuable tool in all trimesters of pregnancy. In the first trimester of pregnancy, ectopic pregnancy is a leading cause of mortality in women in LMICs, requiring early identification and prompt intervention. Since clinical signs and symptoms are not reliable, ultrasound can play a pivotal role in its diagnosis. Early in their pregnancy, many women seek care for abdominal pain and/or vaginal bleeding. Bedside ultrasound by Emergency Physicians (EPs) in the United States has provided rapid exclusion of ectopic pregnancy by identifying intrauterine pregnancy (visualizing the yolk sac or fetal pole). In one study, instituting a protocol for bedside ultrasound by EPs in evaluating patients with first trimester bleeding decreased the delay to diagnosis of ectopic pregnancy from 43% to 29% and decreased the rate of missed ruptured ectopic pregnancy from 50% to 9%.[14]

Estimating gestational age in second and third trimester pregnancy can be helpful in the diagnosis and management of preterm labor and can be performed successfully by non-obstetric specialists with a high

degree of sensitivity. In one study, after a didactic session and a proctored exam, eight EPs evaluated a sample of pregnant patients (14-40 weeks) showing a high correlation of fetal biometrics obtained by EPs compared with the ultrasound technicians (correlation of 0.96 for biparietal diameter and 0.97 for femur length).[15] In this study, ultrasound was more accurate than fundal height measurement in determining fetal viability (fetal age >24 weeks) with an accuracy of 96% versus 80%.

ULTRASOUND IN BLUNT TRAUMA ABDOMEN

FAST (Focused Assessment with Sonography in Trauma) has been used routinely in the management of trauma patients worldwide as a rapid, noninvasive way to evaluate patients with thoracoabdominal trauma. The FAST scan can be performed within minutes at the bedside and can help in resource-limited settings with decisions regarding which patients require immediate operative care. The FAST exam has been shown to decrease the time to operative intervention in a randomized controlled trial as compared to a standard clinical evaluation. Patients that received FAST had a 64% decrease in the time to operative intervention, and decreased complication rates and hospital length of stay.[16] The sensitivity of FAST scans in detecting intraperitoneal hemorrhage is 75-78% and its specificity is 98-100%, suggesting it is a useful tool to confirm the presence of hemoperitoneum and hemopericardium. Clinically, the FAST scan is particularly beneficial in the hypotensive trauma patient whose source of hypotension is unclear.[17]

Despite the encouraging literature, it is important to remember that all ultrasound, including the FAST exam, is dependent on the training and experience of the clinician. A study evaluating non-radiologist physicians (surgeons and emergency medicine physicians) found that while the initial error rate for FAST scans was 17%, it fell to 5% after performing ten exams.[18] Another study evaluating surgeons, radiologists and technicians found that the learning curve for FAST levelled off after 30 exams.[19]

CARDIAC ULTRASOUND

Focused echocardiography has an important role in assessing patients with cardiovascular compromise. It is useful in diagnosing pericardial effusion, assessing left ventricular ejection fraction, assessing volume status in patients with shock and delineating the etiology of cardiovascular collapse. In one study in the US evaluating patients with dyspnea of unclear etiology (i.e., after ruling out congestive heart failure, pneumonia, COPD, pulmonary embolism), pericardial effusion was found in 13.6% of patients.[20] In a large study evaluating 515 high risk patients with dyspnea, 103 had a pericardial effusion. EPs' bedside echocardiography obtained the diagnosis with sensitivity and specificity of 96% and 98%, respectively.[21] In a hemodynamically unstable patient, early diagnosis of cardiac tamponade can expedite bedside ultrasound-guided pericardiocentesis.

ULTRASOUND EVALUATION FOR DVT

Ultrasound evaluation for DVT has been shown to be successful by nonvascular specialists ranging from novice to advanced users of ultrasound, and can be performed in just a few minutes at the patient's bedside. A study evaluating 56 emergency clinicians (attending physicians, residents and midlevel providers) after didactic training showed an initial sensitivity and specificity of 70% and 89%, respectively. The sensitivity improved to 100% for clinicians who performed three or more scans.[22] A more recent study showed that physicians trained with a brief focused module could achieve sensitivity of 100% and specificity of 99% for detection of DVT with bedside ultrasound with similar studies supporting a high correlation with radiologically performed DVT evaluations.

ULTRASOUND IN SURGICAL EMERGENCIES

Access to specialized vascular surgery may be limited, in settings with limited access to surgical care and computed tomography, ultrasound diagnosis of abdominal aortic aneurysm (AAA) as a cause for abdominal pain may allow for rapid identification of surgical candidates and save resources for further diagnostic workup once a diagnosis has been reached. Prior studies of ultrasound for diagnosis of AAA have shown high rates of sensitivity and specificity.

The emergency medicine literature suggests clinicians performing bedside ultrasound can attain a high sensitivity and specificity for detection of cholecystitis compared with formal ultrasound radiology. Ultrasound can also be used to diagnose liver abscesses with a sensitivity of 86%, to guide aspiration/percutaneous drainage and to follow resolution during treatment.

While evaluation of appendicitis in the developed world relies heavily on computed tomography and surgical consultation, in resource-limited settings the diagnosis is often made by generalist clinicians based on history and physical exam alone. In a meta-analysis comparing ultrasound and CT (pooling 9,356 children and 4,341 adults), ultrasound demonstrated a sensitivity and specificity of 88% and 94% in children and 83% and 93%, respectively, in adults.[23] It is important to note that the diagnosis of appendicitis cannot be excluded unless a normal appendix is visualized.

ULTRASOUND GUIDED PROCEDURES

Given the prevalence of tuberculosis-related pleural effusions and ascites in hospitalized patients in LMICs, ultrasound guidance for these procedures may improve safety and success. A study evaluating ultrasound-guided thoracentesis in 605 patients demonstrated a decreased

risk of pneumothorax with a rate of 2.5% compared with previously quoted rates of 4-30%.[24] A study evaluating ultrasound-guided paracentesis demonstrated success in 95% of patients who had ultrasound compared with 61% of patients who did not receive ultrasound. Ultrasound was able to identify if patients had inadequate fluid for the procedure and provided an alternative diagnosis in two patients with abdominal swelling: a large cystic mass in one and ventral hernia in another.

Ultrasound-guided nerve blocks can be used to provide regional anesthesia in complex laceration repairs, orthopedic fracture/dislocation reductions and operative procedures. Ultrasound-guided nerve blocks improve success rates and reduce the number of needle passes, dosage of local anesthesia and complication rates.[25]

GATEWAY TO FUTURE IMPLICATIONS

The previous research has clearly shown that the introduction of bedside ultrasound can have a significant impact on clinical management in resource-limited settings, and that providers in these settings can be rapidly trained to use ultrasound for basic diagnostic and procedural indications, many questions still remain for future investigation. In particular, various training models for emergency ultrasound in resource-limited settings should be directly compared through controlled studies to determine the most effective and least time- and cost-intensive methods for training general providers in these settings. In addition, more research is needed to determine whether remote review of ultrasound images can aid in the upkeep of ultrasound skills by local practitioners while also providing quality assurance for images obtained in resource-limited settings.

Finally, there are several areas where ultrasound may prove useful for particular indications in LMICs that have not been well studied in high-income countries, either because the disease process is not prevalent or better diagnostic tests are already available.

CONCLUSION

Bedside ultrasonography performed by Clinicians is emerging as a useful diagnostic tool for healthcare providers in resource-limited settings. Much of the research to date supports the use of this technology to guide management plans and procedures; however, comprehensive, long-term studies have not been performed. As further research emerges to evaluate the impact of ultrasound in resource-limited settings it will be possible to draw conclusions about the long-term sustainability of ultrasound programs in the developing world, target populations who may benefit most from ultrasound services, and further expand the indications for its use.

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