Published in final edited form as:
Obstet Gynecol. 2016 September ; 128(3): 604–612. doi:10.1097/AOG.0000000000001558.

Accuracy of Home-Based Ultrasonographic Diagnosis of Obstetric Risk Factors by Primary-Level Health Workers in Rural Nepal

Naoko Kozuki, PhD[1], **Luke C. Mullany, PhD**[1], **Subarna K. Khatry, MD**[2], **Ram K. Ghimire, MD**[3], **Sharma Paudel, MD**[3], **Karin Blakemore, MD**[4], **Christine Bird, RDMS**[4], **James M. Tielsch, PhD**[5], **Steven C. LeClerq, MPH**[1,2], and **Joanne Katz, ScD**[1]

[1]Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

[2]Nepal Nutrition Intervention Project – Sarlahi, Lalitpur, Nepal

[3]Tribhuvan University Teaching Hospital, Kathmandu, Nepal

[4]The Johns Hopkins Hospital, Baltimore, USA

[5]George Washington University Milken Institute School of Public Health, Washington, DC, USA

Abstract

Objective—To assess the feasibility of task shifting by estimating the accuracy at which primary-level health care workers can perform community-based third trimester ultrasound diagnosis for selected obstetric risk factors in rural Nepal.

Methods—Three auxiliary nurse midwives received two one-week ultrasound trainings at Tribhuvan University Teaching Hospital in Kathmandu. In our study site in rural Nepal, women who were ≥32 weeks in gestational age were enrolled and received ultrasound examinations from the auxiliary nurse midwives during home visits. Each auxiliary nurse midwife screened for non-cephalic presentation, multiple gestation, and placenta previa. All de-identified images were stored and uploaded onto an online server, where certified sonologists and sonographers reviewed the images and made their own diagnoses for the three conditions. Accuracy of auxiliary nurse midwife diagnoses was then calculated.

Results—We enrolled 804 women in the study. Each auxiliary nurse midwife's kappa statistic for diagnosis of non-cephalic presentation was above 0.90 compared with the sonogram reviewers. Sensitivity, specificity, positive and negative predictive values were between 90–100% for all auxiliary nurse midwives For multiple gestation, the auxiliary nurse midwives were in perfect agreement with both the sonogram reviewers and maternal postpartum self-report. Two placenta previa cases were detected, and the sonogram reviewers agreed with both.

Conclusion—With limited training, primary-level health care workers in rural Nepal can accurately diagnose selected third trimester obstetric risk factors using ultrasonography.

Corresponding author: Joanne Katz, 615 N. Wolfe St. W5009 Baltimore, MD 21205, 410 955 7016, jkatz1@jhu.edu.

Presented at the 2016 Consortium of Universities of Global Health conference. San Francisco, CA, USA, April 9–11, 2016.

Introduction

Approximately 40% of fetal, neonatal, and maternal deaths occur during the intrapartum period or on the day of birth. (1) Early diagnosis of risk factors for intrapartum-related complications and subsequent referral for care have been highlighted as key strategic research priorities for low- and middle-income countries by public health experts. The 2014 Lancet Neonatal Series listed as one of the neonatal health research priorities as improving the accuracy of community health workers in detecting key high-risk conditions or danger signs in pregnant women.(2) This research question is closely related to the top research priority listed by experts to address birth asphyxia: whether community cadres of workers can identify a limited number of high-risk conditions and successfully refer women for facility birth.(3)

Previous attempts at exploring antenatal risk screening for intrapartum-related complications examined risk factors that were high in prevalence (i.e. primparity, short stature, young maternal age); the sensitivity of these risk factors in detecting complications and subsequent adverse health outcomes was high, however the positive predictive value was low.(4) Other studies have explored risk factors with lower prevalence, high sensitivity, and high positive predictive value, such as non-cephalic presentation, multiple gestation, and placental issues.(5) These conditions all rely on ultrasonography for accurate diagnosis. Access to ultrasonography is limited in low-resource settings due to factors including human resource constraints. In Nepal, approximately 150 radiologists (1 per ~185,000 population) reside in the country, (6) largely concentrated in Kathmandu Valley. In contrast, the U.S. has about 20 times more radiologists per capita.(7) In such contexts, task shifting, or redistributing tasks to less specialized health workers, may help address the human resource issue.

Considering the potential value of ultrasonography in encouraging care-seeking before complications arise, we evaluated the performance of community-based ultrasound diagnosis of obstetric risk factors in rural Nepal, employing primary-level health care workers with limited, targeted training. The objective of the study was to estimate the accuracy of these health care workers' ultrasound-based diagnoses of non-cephalic presentation, multiple gestation, and placenta previa.

Materials and Methods

This study was conducted from September 2014 to September 2015 in rural Sarlahi District, Nepal. Three auxiliary nurse midwives were selected to participate in this study. Auxiliary nurse midwives are a cadre of health care providers who have a minimum 10th grade education and are trained for 18 months in basic midwifery skills. One of the three auxiliary nurse midwives was also a certified Health Assistant. To quality for a Health Assistant program, candidates must have at least a 10th grade education and must pass the School Leaving Certificate examination (an examination given to all 10th graders before proceeding with further education) at the second-division level (a mark of 45% or above, out of 100%). Once accepted into the program, they receive 36 months of basic science and clinical training. The three health care workers received two one-week ultrasound trainings together, with the trainings set one month apart. The training was conducted by the Department of

Radiology at Tribhuvan University Teaching Hospital, located in Kathmandu. They were trained to diagnose fetal presentation, multiple gestation, and placental position, and also to locate the fetal heartbeat. The training consisted of a lecture on the science behind ultrasonography, demonstrations by radiologists, and practice on pregnant women who were at the clinic for antenatal examinations, with permission obtained from the women prior to examination. While the trainers subjectively assessed and approved the competency of each auxiliary nurse midwife, we did not perform a formal test of competency at this point, as we sought to estimate accuracy prefaced on an abbreviated training period that might be realistic in a low-resource setting.

The auxiliary nurse midwives were then sent on home visits to screen pregnant women for the three risk factors, in our rural study area located about an eight-hour drive from Kathmandu. We sampled study enrollees from pregnant women who were already enrolled in an on-going randomized community-based trial on traditional newborn massages and their effect on infection rates. (Nepal Oil Massage Study, Clinicaltrials.gov NCT01177111) As the intervention for the parent study occurs after birth, we expect no impact of the trial intervention on our results in the present study. The parent study conducts home visits to all married women between age 15 and 40 years, every five weeks to identify and enroll new pregnancies. Participants for the ultrasound study were identified from seven of the 34 Village Development Committees (geographic administrative unit) in which the parent study operates. We also operated in four additional Village Development Committees just for the months of May–July 2015, as the seven Village Development Committees alone did not provide enough pregnancies to examine during those months when birth rate is lower. Women who were ≥32 weeks in gestation, based on the date of last menstrual period collected at parent study enrollment, were eligible.

A pair of our trained auxiliary nurse midwives visited eligible women at their homes and obtained consent for this ultrasound study. Each conducted an independent diagnostic examination at the home. A private location in the house was identified where the woman could lie down. They were masked to each other's examinations. One entered the location where the examination was to be conducted, while the other waited outside, and the same was done for the second assessor. Each auxiliary nurse midwife identified whether the pregnancy was single or multiple gestation, fetal presentation (cephalic, breech, transverse, or oblique), and placental position (no issue, low-lying–marginal–partial previa, complete previa, or cannot determine). Images that represented those diagnoses were saved on the ultrasound machine. They were also instructed to detect the fetal heartbeat, not as part of a research aim but as ancillary care, with instructions to refer the mother to a facility if the heartbeat was not detected. Having two health care workers examine the same mother allowed for the calculation of inter-rater reliability, but we did not have all three auxiliary nurse midwives conduct examinations on one mother, to be respectful of the participant's time and possible discomfort from lying down for an extended time. We used one Sonosite Nanomaxx (FUJIFILM SonoSite, Inc., Bothell, WA, U.S.A) portable ultrasound system, donated by the SonoSite Soundcaring Program. At least 10% of the home visits were accompanied by the first author or another senior staff member for supervision.

All examined mothers received messaging regarding the importance of seeking antenatal care and attending a facility for delivery. If at least one health care worker detected non-cephalic presentation or multiple gestation, women were notified of their possible diagnosis and were provided with a list of the nearest facilities with Cesarean delivery capacity, as well as the nearest birthing centers. Women with suspected placenta previa were notified of the possible diagnosis immediately after the examination, and on the same day, the auxiliary nurse midwives sent the images by e-mail to a radiologist in Kathmandu. The radiologist provided a diagnosis within 24 hours of notification. The auxiliary nurse midwives then returned to the household the next business day to notify the pregnant woman of the reference diagnosis. As this study was conducted to assess the accuracy with which the health care workers could detect the risk factors, all referral messaging was provided with the caveat that the auxiliary nurse midwives had received minimal training and that the pregnant women should seek further care to confirm any diagnoses.

At the end of each week, the images were downloaded onto a computer and sent to a data manager, who then uploaded de-identified images onto a server. The images were reviewed by two sets of reviewers: one full set was reviewed by a team from Tribhuvan University Teaching Hospital (two radiologists) and another full set by a team from the Johns Hopkins Hospital Maternal-Fetal Medicine Unit in Baltimore, Maryland, U.S. (one obstetrician and five obstetric ultrasonographers). Each ultrasound examination was reviewed by one team member from each team. Each reviewer was instructed to log onto the server with a personalized username and password, and fill out an online form next to each set of images to make their diagnostic assessments. They were asked to check for non-cephalic or cephalic presentation, multiple or single gestation, general location of the placenta, and placenta previa or not. They were also provided space to leave any additional comments.

The sample size was calculated using precision (maximum difference between estimated and true sensitivity) of 0.10, alpha of 0.05, expected true in-utero prevalence of non-cephalic presentation in the mid- to late-third trimester of 7%, and a target sensitivity of 90%. We calculated a sample size of 500 women to be examined by each auxiliary nurse midwife. However, since the auxiliary nurse midwives conducted the home visits in pairs, we needed a total of 750 women in order for each auxiliary nurse midwife to conduct 500 examinations. We calculated the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of diagnosis for each auxiliary nurse midwife against the reviewer diagnoses. We present these values for each team of reviewers separately to account for potential discrepancies between the two reviewer readings.

In cases where the reviewers chose “cannot determine” as a diagnosis, we re-categorized those responses as a negative history for the three high-risk conditions. We also conducted sensitivity analyses, excluding the “cannot determine” cases from the analysis. We calculated kappa statistics between each pair of auxiliary nurse midwives and also each pair of reviewer readings respectively to estimate inter-rater reliability.

The women were revisited at their homes after delivery to collect additional information on the intrapartum and postpartum periods, including data on whether the pregnancy resulted in a non-cephalic or multiple birth.

Finally, we conducted a cost analysis, examining how much a fetal or neonatal life saved would cost under this sonography protocol. We calculated the total cost of operating a similar project over a five-year span and the percent of fetal or neonatal deaths associated with non-cephalic birth, multiple birth, or placenta previa using data from the same study site published elsewhere,(8) and divided the cost by the number of deaths potentially averted by ultrasonography.

The study was approved by the Institutional Review Boards of Johns Hopkins Bloomberg School of Public Health and the Tribhuvan University Institute of Medicine respectively. Stata version 13.0 (StataCorp, College Station, TX) was used for the analyses.

Results

We enrolled 815 women in the study. A total of ten women were removed from the analysis: seven women examined on the first two days of the study (excluded as pilot data), three women whose images did not transfer properly from the ultrasound machine to the computer, and one woman who terminated her examination early, as she was uncomfortable lying down for an extended period of time. A final total of 804 women (1608 examinations conducted by auxiliary nurse midwives) contributed to our analysis. There were no missing reviewer data.

The mean age and median gravidity of the participants were 23.7 years and one pregnancy. (Table 1). A majority of women had no formal education (60.8%). Approximately 91% were of the Madheshi ethnic group and 61% of women delivered at a health facility, while the remaining delivered their infants at home. The breakdown of the examinations (number conducted and their diagnoses) are as follows: auxiliary nurse midwife #1 with 533 examinations (26 non-cephalic presentation, 3 multiple gestation, 1 complete previa), auxiliary nurse midwife #2 with 539 examinations (29 non-cephalic presentation, 2 multiple gestation, 2 complete previa), and auxiliary nurse midwife #3 with 536 examinations (16 non-cephalic presentation, 5 multiple gestation, 1 complete previa). Women enrolled in the study were diagnosed with the following by at least one auxiliary nurse midwife: 4.5% non-cephalic presentation (n=36), 0.8% multiple gestation (n=5), and 0.3% placenta previa (n=2). The auxiliary nurse midwives did not report any cases where they could not arrive at a diagnosis.

One reviewer team reported 74 non-cephalic presentation, 10 multiple gestation, two complete previa, and two low-lying placenta or partial previa cases, while the other reviewer team reported 73 non-cephalic presentation, 10 multiple gestation, and no complete previa, and seven low-lying placenta or partial previa cases. Of the examinations that were reviewed, the two reviewer teams selected “cannot determine” for 0.1% and 0.3% of the examinations for fetal presentation, respectively, and 0.9% and 6.6% for multiple gestation, respectively. The “cannot determine” rate for placenta previa was particularly high at 34% and 44%. The reviewers, in the comment section of their data collection form, frequently reported that the images inadequately captured the relationship between the placental edge and the internal os, but also that capturing such images is generally difficult using only a transabdominal probe in late pregnancy regardless of health care worker training.

The analysis of the ability of the health care worker to correctly diagnoses non-cephalic presentation showed that the sensitivity ranged from 92.6 to 100.0% and specificity was in the high 90th percentiles or 100% for all auxiliary nurse midwives, compared against both of the reviewer readings. The PPV ranged from 92.6 to 100%, and the NPV were all nearly 100% (Table 2). There were some discrepant diagnoses reported when comparing the two reviewer teams (kappa = 0.94, Table 3). Removing the “cannot determine” cases did not alter our findings (data not presented). The kappa statistics for inter-rater reliability of diagnosing non-cephalic presentation were 1.00 (perfect agreement) between auxiliary nurse midwife #1 and #2 and auxiliary nurse midwife #1 and #3 respectively and 0.95 for auxiliary nurse midwife #2 and #3 (Table 3). The kappa statistic comparing the two reviewer teams was 0.94.

For multiple gestation, the auxiliary nurse midwives and the reviewer readings agreed 100% of the time, but sensitivity had wide confidence intervals due to the small number of cases. (Table 4) The perfect agreement remained when compared against maternal self-report of multiple birth after delivery. Removing the “cannot determine” cases did not alter our findings (data not presented). The kappa statistics for inter-rater reliability of diagnosing multiple birth were 1.00 between each pair of auxiliary nurse midwives. The kappa statistics were all 1.00 (perfect agreement) with the reviewers for each auxiliary nurse midwife (Table 3), and between the reviewer teams as well.

Auxiliary nurse midwives diagnosed two complete previa cases, and the auxiliary nurse midwives were in agreement for both (one detected by both auxiliary nurse midwife #1 and #2, and one detected by both auxiliary nurse midwife #2 and #3). The reviewers were in agreement that these were either partial or complete placenta previa cases. Because of the small sample size, no further analysis was conducted for placenta previa.

Of the 804 mothers included, maternal recall data on fetal presentation and multiple gestation at delivery were available for 745 women (92.7%, including n=22 who had a Caesarean delivery and thus have no data on presentation) and 786 (97.8%) women respectively. Among the 745 women with true fetal presentation data, 29 had been diagnosed with singleton non-cephalic presentation. Ten of them resulted in a true non-cephalic birth and three in Caesarean section. This discrepancy is expected, as the fetal position is expected to change among a subset between our ultrasound examination and time of birth. Two non-cephalic births were identified as vertex by auxiliary nurse midwives during pregnancy. Of the 786 women with twinning data, five were diagnosed with twins on ultrasound, and all five were true multiple births. No twin pair went undiagnosed. We were unable to determine whether any placenta previa cases were missed, as relevant clinical data would not have been systematically available for enrolled mothers.

We conducted a cost analysis using the hypothetical of a facility-based program rather than a home-visit program, the former being more feasible in our context. There are currently twelve birthing centers in the parent study area, encompassing a population of roughly 300,000 people. Each has at least one auxiliary nurse midwife assigned but none have ultrasonographic equipment to date (personal communication). Birthing centers provide free antenatal care and intrapartum care in Nepal, and women also qualify for a conditional cash transfer if they make all four antenatal care visits and also if they deliver at a facility.(9) We assumed the use of pre-existing facility-based auxiliary nurse midwives for this activity and thus did not include their salary or transportation cost in this analysis. We calculated the total cost of ultrasound machine, gel, and personnel training over five-years to be 10,355 USD, for 15,000 births over five years in a catchment area of 100,000 in population. We estimated that 160 perinatal deaths may be averted with early diagnosis, a cost of $65 per life saved. This analysis makes a generous assumption that all diagnosed lives would be saved, but also excludes any morbidities and maternal deaths prevented. Further details of the numeric inputs and the assumptions used for this analysis are available in Appendix 1, available online at http://links.lww.com/xxx.

Discussion

Primary-level health care workers with only two weeks of didactic and practical training, practicing in resource-constrained settings, can accurately conduct obstetric third trimester ultrasound examinations to detect basic peripartum risk factors. We note here that our study was powered only to evaluate diagnostic accuracy for non-cephalic presentation, and not for multiple gestation and placenta previa. These three conditions have previously been reported to have high risk of adverse pregnancy outcomes such as neonatal and fetal death, (10, 11) preterm birth, (12, 13) and hypertensive disorders.(14) Allowing primary-level health care workers to conduct a defined set of ultrasonographic tasks may help increase access to diagnostic services for these high-risk conditions in areas where certified sonographers are not available. This may subsequently alter care-seeking behavior and intrapartum-related health outcomes. Other studies have also explored the use of non-radiologist clinicians for ultrasonographic tasks and found positive results.(15–18) Following a PubMed search with no restrictions, using search term categories of obstetrics, ultrasonography, and low- and middle-income countries, we only identified few studies presenting sound, quantitative evidence in regard to diagnostic accuracy. (18–21) Furthermore, our study is unique in exploring the feasibility of a home-based program and also utilizing a lower-level cadre of health workers than other studies.

Both non-cephalic presentation and multiple gestation have other methods of diagnoses, but with limited evidence of consistent accuracy. For instance, Leopold’s maneuver is an abdominal palpation method used to screen fetal presentation. Studies from developed countries have reported a sensitivity ranging from 28% to 82% when clinicians used the method for fetal presentation diagnosis.(22–24) While introducing ultrasonography in low-resource settings is complex, its diagnostic accuracy highlights the need to facilitate use in low-resource settings. This study contributes to this facilitation by providing evidence supporting task-shifting.

While we only explored the feasibility of diagnosing three obstetric risk factors, there is the potential to include other diagnostic tasks. Accurate gestational age dating is critical in reducing the large burden of preterm birth, the leading cause of neonatal death. In one study conducted in a refugee camp on the Thai-Burmese border, local health care workers were able to make accurate fetal anthropometric measurements, thus accurate gestational age estimations, after a three-month training period.(18) Our study opted for a late-pregnancy ultrasound scan by prioritizing screening for non-cephalic presentation; an examination too early would capture too many breech fetuses that would turn vertex before delivery. We selected this risk factor because of the high risk that is associated with the condition and its higher incidence compared to the other risk factors. However, for gestational age dating and conditions like placenta previa, an earlier ultrasound scan would produce more accurate diagnoses. To determine when ultrasound examinations should be provided in low-resource settings, the clinical benefit of the obstetric scans at different points in pregnancy will need to be balanced with the logistical feasibility of providing more than one ultrasound examination during a pregnancy.

We identified two deliveries that were vertex at the time of the ultrasound examination, but breech at the time of delivery. While previous studies have reported on breech fetuses turning vertex, there is limited literature on the rate of vertex fetuses turning breech in late pregnancy. One German study reported 0.4% of vertex fetuses between 32nd and 40th week in gestation delivered in breech presentation;(25) we report a similar rate in our study, with two out of 745 (0.3%) vertex presentation diagnoses resulting in breech delivery.

Our study was not powered to determine whether our diagnoses altered care-seeking behavior and subsequently lowered adverse health outcomes. The facility delivery rate among the women who participated in the study was approximately 60%, but the rate is closer to 40% when including the rest of the parent study areas that are farther from main roads (personal communication); the remaining women all deliver at home. In these low-resource contexts, there are numerous barriers to seeking care, such as the need to receive permission from a family member (often husband or mother-in-law), distance to a facility, and cost of care and transport.(5, 8) Also, poor quality of available facility-based care or limited access to Caesarean section could render diagnostic services ineffectual. Diagnostic and referral programs must be instituted with caution, as a woman being aware of a risk does not mean she can seek care, and completing the referral does not guarantee better health outcomes. Further research is needed to produce both quantitative and qualitative evidence regarding the impact of early diagnosis on inspiring care-seeking and on subsequent health outcomes. There is an on-going multi-country cluster randomized trial that is exploring whether introduction of ultrasound in rural health clinics could improve pregnancy outcomes.(26)

Our study served a secondary purpose of piloting home-based provision of sonographic services in a low-resource setting. The auxiliary nurse midwives were able to make the visits with all necessary equipment on a motorcycle, and we observed high community acceptance of and demand for the service. The image quality and the usability of the ultrasound device was high. However, the largest challenge came from machine breakdowns with the refurbished ultrasound machine. The breakdowns were later attributed to manufacturing errors, and we encountered no subsequent issues following a donation of a new, non-refurbished machine. Repair options for the specific device were not available in-country, thus machines were transported back to the U.S. for repair. As such, provision of rural sonographic screening may be interrupted if in-country repair is not an option or if back-up machines are not available. Environmental factors such as unstable electricity while charging the batteries, humidity, dust, and physical impact on the machine through transport on rough, unpaved roads may have contributed to the breakdowns. With the currently available technology, increasing ultrasonographic services at a facility is more feasible than a home-visit program, thus we conducted our cost analysis under the facility-based assumption. A facility-based program is unlikely to ensure equitable access, so further exploration is necessary to either better assist women in reaching facility-based antenatal care or provide access at the home in a sustainable manner. Our study consciously selected a non-phone based device so that we could assess the capacity of the health care worker without contamination by factors such as readability of a small screen on a phone-based device. However, with greater confidence in health care worker ability, we may be able to utilize more affordable and more portable mobile-phone-based devices that will help address the barriers to providing ultrasound access at the home.

Quality of portable devices available in the market ranges widely, and any research or programmatic projects looking to utilize sonography should vet machines carefully. Maru et al. highlight five criteria for x-ray or ultrasound use in low-resource settings: a) be robust in harsh environmental conditions, b) function reliably in environments with unstable electricity, c) minimize radiation dangers to staff and patients, d) be operable by non-specialists, and e) produce high-quality images required for accurate diagnosis. Additional elements include affordability and the ability to create in-country capacity for ultrasound maintenance.(27) Documentation of an ultrasound transfer project between Tanzania and the electronics company Philips (Netherlands) reported discrepancies in where each stakeholder saw the responsibility of machine maintenance resided.(28) With low-income countries becoming emerging markets for ultrasound equipment, setting infrastructure for sustainability will be critical.

The rates at which the reviewers reported “cannot determine” for multiple gestation and non-cephalic presentation were low, but the rate for placenta previa was much higher. This could be attributed either to ANM skill or the difficulty of adequately imaging the placenta and the internal cervical os in late gestation. Our U.S.-based reviewers acknowledged this as an issue, and that in the U.S., trans-vaginal ultrasound would be conducted if the trans-abdominal ultrasound examination cannot adequately determine the placental location. Therefore, the percentage of “cannot determine” we reported may be at an acceptable level. Our reviewer teams were comprised of experienced sonologists and sonographers,. We do not suspect a major difference in accuracy of diagnosis, as all were familiar with the basic diagnoses presented here. While approximately 10% of the examinations were conducted with a supervisory staff present to assure that appropriate protocol was being followed, we cannot guarantee that there was no contamination of results between the auxiliary nurse midwives. We acknowledge that we cannot consider the reviewer diagnosis to be a strict gold standard, as they were only able to examine still images and could not conduct the examinations themselves.

Our study demonstrates that primary-level health care workers in rural Nepal are able to diagnose a targeted set of obstetric risk factors with high accuracy, highlighting the potential for task shifting to increase access to ultrasonographic diagnostic services in low resource settings. The risk factors of non-cephalic and multiple birth are both associated with high risk of intrapartum complications, and early diagnosis may allow for care-seeking in an appropriate delivery setting.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors thank Bijeta Chaudhary, Karuna Karki, and Sharmila Tamang for conducting the ultrasonographic examinations; Jan Laferriere, Rachel Mazza, Becky Ryan, and Shannon Trebes from the Johns Hopkins Hospital Maternal-Fetal Medicine Ultrasonography Unit for their role in the review of the ultrasonograms; the Department of Radiology at the Tribhuvan University Teaching Hospital for their involvement in the training; the SonoSite Soundcaring Program for the generous donation of the ultrasound equipment; and the SonoSite Technical Support staff for their expertise.

Financial support: Supported by the Children's Prize, National Institutes of Health / National Institute of Child Health and Human Development (1R01HD060712-01), and the Bill and Melinda Gates Foundation (OPP1084399).

References

1. Lawn JE, Blencowe H, Oza S, You D, Lee AC, Waiswa P, et al. Every Newborn: progress, priorities, and potential beyond survival. Lancet. 2014 Jul 12; 384(9938):189–205. [PubMed: 24853593]
2. Yoshida S, Rudan I, Lawn JE, Wall S, Souza JP, Martines J, et al. Newborn health research priorities beyond 2015. Lancet. 2014 Jul 12; 384(9938):e27–9. [PubMed: 24853596]
3. Lawn JE, Bahl R, Bergstrom S, Bhutta ZA, Darmstadt GL, Ellis M, et al. Setting research priorities to reduce almost one million deaths from birth asphyxia by 2015. PLoS medicine. 2011; 8(1):e1000389. [PubMed: 21305038]
4. Starrs AM. Safe motherhood initiative: 20 years and counting. Lancet. 2006 Sep 30; 368(9542): 1130–2. [PubMed: 17011924]
5. Lee AC, Lawn JE, Cousens S, Kumar V, Osrin D, Bhutta ZA, et al. Linking families and facilities for care at birth: what works to avert intrapartum-related deaths? International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2009 Oct; 107(Suppl 1):S65–85. S6–8.
6. Subedi KS, Sharma P. Development of radiology in Nepal: gearing up for mountainous challenges. J Am Coll Radiol. 2013 Apr; 10(4):291–5. [PubMed: 23465888]
7. American College or Radiology. ACR Membership; Reston:
8. Kozuki, N. Epidemiology, diagnosis, and care-seeking related to risk factors for intrapartum-related fetal and neonatal death in rural Nepal. Baltimore: Johns Hopkins University; 2015.
9. Powell-Jackson T, Morrison J, Tiwari S, Neupane BD, Costello AM. The experiences of districts in implementing a national incentive programme to promote safe delivery in Nepal. BMC health services research. 2009; 9:97. [PubMed: 19508710]
10. Lawn JE, Lee AC, Kinney M, Sibley L, Carlo WA, Paul VK, et al. Two million intrapartum-related stillbirths and neonatal deaths: where, why, and what can be done? International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2009 Oct; 107(Suppl 1):S5–18. S9.
11. Berhan Y. Predictors of perinatal mortality associated with placenta previa and placental abruption: an experience from a low income country. Journal of pregnancy. 2014; 2014:307043. [PubMed: 25002975]
12. Bjerregaard-Andersen M, Lund N, Jepsen FS, Camala L, Gomes MA, Christensen K, et al. A prospective study of twinning and perinatal mortality in urban Guinea-Bissau. BMC pregnancy and childbirth. 2012; 12:140. [PubMed: 23216795]

13. Obiechina N, Okolie V, Eleje G, Okechukwu Z, Anemeje O. Twin versus singleton pregnancies: the incidence, pregnancy complications, and obstetric outcomes in a Nigerian tertiary hospital. International journal of women's health. 2011; 3:227–30.

14. Krotz S, Fajardo J, Ghandi S, Patel A, Keith LG. Hypertensive disease in twin pregnancies: a review. Twin research : the official journal of the International Society for Twin Studies. 2002 Feb; 5(1):8–14. [PubMed: 11893276]

15. Shah SP, Epino H, Bukhman G, Umulisa I, Dushimiyimana JM, Reichman A, et al. Impact of the introduction of ultrasound services in a limited resource setting: rural Rwanda 2008. BMC international health and human rights. 2009; 9:4. [PubMed: 19327157]

16. Geerts L, Theron AM, Grove D, Theron GB, Odendaal HJ. A community-based obstetric ultrasound service. International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2004 Jan; 84(1):23–31.

17. Adler D, Mgalula K, Price D, Taylor O. Introduction of a portable ultrasound unit into the health services of the Lugufu refugee camp, Kigoma District, Tanzania. International journal of emergency medicine. 2008 Dec; 1(4):261–6. [PubMed: 19384640]

18. Rijken MJ, Lee SJ, Boel ME, Papageorghiou AT, Visser GH, Dwell SL, et al. Obstetric ultrasound scanning by local health workers in a refugee camp on the Thai-Burmese border. Ultrasound in obstetrics & gynecology : the official journal of the International Society of Ultrasound in Obstetrics and Gynecology. 2009 Oct; 34(4):395–403.

19. Stein W, Katunda I, Butoto C. A two-level ultrasonographic service in a maternity care unit of a rural district hospital in Tanzania. Trop Doct. 2008 Apr; 38(2):125–6. [PubMed: 18453515]

20. Neufeld LM, Wagatsuma Y, Hussain R, Begum M, Frongillo EA. Measurement error for ultrasound fetal biometry performed by paramedics in rural Bangladesh. Ultrasound in obstetrics & gynecology : the official journal of the International Society of Ultrasound in Obstetrics and Gynecology. 2009 Oct; 34(4):387–94.

21. Swanson JO, Kawooya MG, Swanson DL, Hippe DS, Dungu-Matovu P, Nathan R. The diagnostic impact of limited, screening obstetric ultrasound when performed by midwives in rural Uganda. Journal of perinatology : official journal of the California Perinatal Association. 2014 Jul; 34(7): 508–12. [PubMed: 24699218]

22. Thorp JM Jr, Jenkins T, Watson W. Utility of Leopold maneuvers in screening for malpresentation. Obstetrics and gynecology. 1991 Sep; 78(3 Pt 1):394–6. [PubMed: 1876372]

23. Lydon-Rochelle M, Albers L, Gorwoda J, Craig E, Qualls C. Accuracy of Leopold maneuvers in screening for malpresentation: a prospective study. Birth. 1993 Sep; 20(3):132–5. [PubMed: 8240620]

24. Watson WJ, Welter S, Day D. Antepartum identification of breech presentation. The Journal of reproductive medicine. 2004 Apr; 49(4):294–6. [PubMed: 15134156]

25. Gottlicher S, Madjaric J. Vertex presentation in the morning–breech presentation at noon: a nursery tale? A prospective study of 1,019 patients. Geburtshilfe Frauenheilkd. 1989 Apr; 49(4):363–6. [PubMed: 2737431]

26. McClure EM, Nathan RO, Saleem S, Esamai F, Garces A, Chomba E, et al. First look: a cluster-randomized trial of ultrasound to improve pregnancy outcomes in low income country settings. BMC pregnancy and childbirth. 2014; 14:73. [PubMed: 24533878]

27. Maru DS, Schwarz R, Jason A, Basu S, Sharma A, Moore C. Turning a blind eye: the mobilization of radiology services in resource-poor regions. Global Health. 2010; 6:18. [PubMed: 20946643]

28. Muller-Rockstroh B. Appropriate and appropriated technology: lessons learned from ultrasound in Tanzania. Med Anthropol. 2012; 31(3):196–212. [PubMed: 22540314]

Table 1

Characteristics of the pregnant women in the study (n=815)

Gestational age at examination	
Mean ± SD	36.4±2.6
<37 weeks	60.4%
Age	
Mean ± SD	23.7 ± 4.9
<18 years old	7.7%
18–<35 years old	90.0%
≥35 years old	2.4%
Gravidity	
Median (IQR)	1 (0–3)
0	29.2%
1–3	57.0%
≥4	13.8%
Parity	
Median (IQR)	1 (0–2)
0	32.2%
1–3	57.7%
≥4	10.1%
BMI	
<18.5	24.2%
18.5–<25	70.4%
≥25	5.4%
Education	
No formal education	60.8%
1–9 years	24.0%
≥10 years	15.2%
Ethnicity	
Madheshi	91.1%
Pahadi	8.9%

Table 2

Accuracy of diagnoses, non-cephalic presentation

	Reviewer team 1, % (95% CI)			**Reviewer team 2, % (95% CI)**		
	ANM 1 (n=533)	**ANM 2 (n=539)**	**ANM 3 (n=536)**	**ANM 1 (n=533)**	**ANM 2 (n=539)**	**ANM 3 (n=536)**
Sensitivity	92.6 (74.2–99.9)	96.7 (80.9–99.8)	94.1 (69.2–99.7)	92.6 (74.2–99.9)	100.0 (85.4–100.0)	100.0 (77.1–100.0)
Specificity	99.6 (98.4–99.9)	100.0 (99.1–100.0)	99.8 (98.8–100.0)	99.6 (98.4–99.9)	100.0 (99.1–100.0)	100.0 (99.1–100.0)
Positive predictive value	92.6 (74.2–98.7)	100.0 (85.4–100.0)	94.1 (69.2–99.7)	92.6 (74.2–98.7)	100.0 (85.4–100.0)	100.0 (77.1–100.0)
Negative predictive value	99.6 (98.4–99.9)	99.8 (98.7–100.0)	99.8 (98.8–100.0)	99.6 (98.4–99.9)	100.0 (99.1–100.0)	100.0 (99.1–100.0)
Number of discrepant cases	4	1	2	4	0	0

Table 3

Inter-rater reliability as measured by kappa (95% CI)

	ANM 1 & 2 (n=268)	**ANM 2 & 3 (n=271)**	**ANM 3 & 1 (n=265)**	**Reviewer team 1 & team 2 (n=1608)**
Non-cephalic presentation	1.00 (1.00–1.00)	0.95 (0.94–0.95)*	1.00 (1.00–1.00)	0.94 (0.93–0.94)**
Multiple gestation	N/A***	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)

[*] One discrepant diagnosis.

[**] Nine discrepant diagnoses.

[***] Could not be calculated as all individuals in this cell were diagnosed as cephalic births.

Table 4

Accuracy of diagnoses, multiple gestation (n= 5 cases reported by ANMs, out of 804 pregnant women)

	Reviewer team 1			**Reviewer team 2**		
	ANM 1	**ANM 2**	**ANM 3**	**ANM 1**	**ANM 2**	**ANM 3**
Sensitivity	100.0 (31.0–100.0)	100.0 (19.8–100.0)	100.0 (46.3–100.0)	100.0 (31.0–100.0)	100.0 (19.8–100.0)	100.0 (46.3–100.0)
Specificity	100.0 (99.1–100.0)	100.0 (99.1–100.0)	100.0 (99.1–100.0)	100.0 (99.1–100.0)	100.0 (99.1–100.0)	100.0 (99.1–100.0)
Positive predictive value	100.0 (31.0–100.0)	100.0 (19.8–100.0)	100.0 (46.3–100.0)	100.0 (31.0–100.0)	100.0 (19.8–100.0)	100.0 (46.3–100.0)
Negative predictive value	100.0 (99.1–100.0)	100.0 (99.1–100.0)	100.0 (99.1–100.0)	100.0 (99.1–100.0)	100.0 (99.1–100.0)	100.0 (99.1–100.0)