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POINT-OF-CARE ULTRASOUND (POCUS) FOR OBSTETRIC EMERGENCIES IN DISTRICT HOSPITALS OF KHYBER PAKHTUNKHWA

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Abstract

Background: *Obstetric emergencies contribute significantly to maternal mortality in resource-limited settings like Pakistan. Point-of-care ultrasound (POCUS) offers potential for rapid diagnosis, but its implementation and impact in district hospitals of Khyber Pakhtunkhwa remain unevaluated.*

Methods: *A prospective multicenter study was conducted across six district hospitals from June 2023 to May 2024. Healthcare providers (n=24) received structured POCUS training. Pregnant women (n=1,155) presenting with obstetric emergencies underwent POCUS followed by radiology ultrasound. Primary outcomes included diagnostic accuracy, time-to-diagnosis, and impact on clinical management.*

Results: *POCUS demonstrated high diagnostic accuracy for ectopic pregnancy (sensitivity 94.0%, specificity 99.6%), placental abruption (sensitivity 92.1%, specificity 98.3%), and placenta previa (sensitivity 96.8%, specificity 99.4%). Median time-to-diagnosis decreased from 4.8 hours to 0.3 hours ($p<0.001$). POCUS findings changed clinical management in 38.2% of cases, including timely surgical intervention in 12.3% and avoidance of unnecessary transfers in 15.6%. Inter-observer agreement with radiologists was excellent ($\kappa=0.91$). Maternal complications decreased from 8.9% to 3.2% ($p<0.001$).*

Conclusions: *POCUS significantly improves diagnosis and management of obstetric emergencies in district hospitals. Its implementation reduces diagnostic delays, optimizes referrals, and improves patient outcomes. Integration of POCUS into emergency obstetric care protocols in resource-limited settings is recommended.*

INTRODUCTION

Maternal mortality remains a critical public health challenge and a key indicator of health system performance globally [1]. Despite significant progress, approximately 800 women die every day from preventable causes related to pregnancy and childbirth, with 95% of these deaths occurring in low and middle-income countries (LMICs) [2]. Pakistan bears a disproportionate burden of maternal mortality, with an estimated maternal mortality ratio (MMR) of 186 deaths per 100,000 live births, and the situation is particularly concerning in resource-limited regions like Khyber Pakhtunkhwa (KP) [3, 4]. A substantial proportion of these deaths are attributable to obstetric emergencies such as postpartum

hemorrhage (PPH), ectopic pregnancy, retained products of conception, and obstetric shock, which require immediate diagnosis and intervention to prevent fatal outcomes [5, 6].

In district hospitals across KP, which serve as first-level referral centers for primary healthcare facilities, the diagnostic capacity for obstetric emergencies remains limited [7, 8]. The current standard of care often relies on clinical examination alone, which has poor sensitivity for many life-threatening conditions like ectopic pregnancy or placental abnormalities [9, 10]. While conventional ultrasonography is established as a vital tool in obstetrics, its availability in district hospitals is frequently hampered by the high cost of equipment, lack of trained sonographers, and poor maintenance services [11, 12]. This diagnostic gap contributes significantly to delays in appropriate management, leading to adverse maternal and perinatal outcomes [13, 14].

Point-of-care ultrasound (POCUS) has emerged as a potential solution to bridge this diagnostic gap in resource-limited settings [15, 16]. Defined as ultrasound performed and interpreted by the clinician at the bedside, POCUS can provide immediate diagnostic information to guide management decisions [17, 18]. Several studies have demonstrated the feasibility of training non-radiologist healthcare providers in obstetric POCUS, with significant improvements in diagnostic accuracy and management of obstetric emergencies [19, 20]. However, most evidence comes from controlled research settings or tertiary care facilities, with limited data on its implementation and impact at the district hospital level in Pakistan [21, 22].

The potential benefits of POCUS in obstetric emergencies are substantial. It can rapidly identify causes of hemorrhage, confirm fetal viability in threatened abortion, diagnose ectopic pregnancy, and identify placental pathologies [23, 24]. When integrated into clinical algorithms, POCUS has been shown to reduce time-to-diagnosis and improve appropriate triage and management decisions [25, 26]. However, questions remain about the sustainability, accuracy, and clinical impact of POCUS when implemented by healthcare providers with varying levels of ultrasound experience in real-world district hospital settings with their unique constraints [27, 28].

Therefore, this study aims to evaluate the implementation and impact of a structured POCUS program for obstetric emergencies in district hospitals of Khyber Pakhtunkhwa, Pakistan. Specifically, we will assess the diagnostic accuracy of POCUS performed by trained clinical providers compared to radiologist-performed ultrasound, its impact on clinical decision-making, and the feasibility of its integration into routine emergency obstetric care. The findings will provide crucial evidence for policymakers and healthcare administrators regarding the scalability of POCUS as a tool to improve maternal health outcomes in resource-limited settings.

Methods

Study Design and Setting

A prospective, multicenter implementation study was conducted over a 12-month period from June 2023 to May 2024. The study was implemented across six district headquarters (DHQ) hospitals in Khyber Pakhtunkhwa province, Pakistan, selected through stratified random sampling to represent diverse geographical and healthcare delivery contexts. These facilities serve as primary referral centers for basic health units and rural health centers, handling approximately 300-500 deliveries per month each. The study protocol received ethical approval from the Khyber Pakhtunkhwa Health Research Ethics Board and institutional review boards of all participating hospitals.

Study Participants

The study included two participant groups: healthcare providers and patients. For provider training, we enrolled medical officers and gynecology residents (n=24) working in emergency obstetric units who had no prior formal ultrasound training. Patient participants were pregnant women presenting with obstetric emergencies including abdominal pain, vaginal bleeding, or suspected pregnancy complications

during the study period. Exclusion criteria included hemodynamic instability requiring immediate intervention and patients under 18 years of age. Written informed consent was obtained from all patient participants and healthcare providers involved in the training component.

Intervention: POCUS Training Program

A structured POCUS training program was implemented consisting of three components. First, a 5-day intensive hands-on workshop covered basic ultrasound physics, knobology, and focused assessment protocols for obstetric emergencies including: fetal viability and gestational age estimation, placental localization, identification of free fluid in Morison's pouch and pouch of Douglas, and basic cardiac assessment. Second, a 3-month supervised clinical practicum where trainees performed scans under expert supervision until competency was achieved (minimum 50 supervised scans). Third, monthly quality assurance sessions with review of stored images and clinical cases. Training was conducted by certified ultrasound trainers from the Pakistan Society of Ultrasound in Clinical Medicine.

Study Instruments and Data Collection

Portable ultrasound machines (Butterfly iQ+ and Sonosite Edge II) were deployed at each study site. Data collection included: (1) POCUS findings recorded by trainees using standardized data collection forms, (2) clinical management decisions pre- and post-POCUS, (3) time-to-diagnosis from presentation to definitive imaging diagnosis, and (4) patient outcomes including maternal complications and perinatal outcomes. All patients underwent confirmatory radiology department ultrasound within 24 hours when possible. Data were collected by trained research assistants using structured questionnaires and entered into a secure electronic database.

Outcome Measures

Primary outcomes included: (1) diagnostic accuracy of POCUS compared to radiology department ultrasound (sensitivity, specificity, PPV, NPV), (2) change in clinical management after POCUS, and (3) time-to-diagnosis for obstetric emergencies. Secondary outcomes included: (1) provider competency scores using the Objective Structured Assessment of Ultrasound Skills (OSAUS) tool, (2) patient satisfaction scores, and (3) cost-effectiveness analysis of POCUS implementation.

Sample Size Calculation and Statistical Analysis

Sample size was calculated based on detecting a 20% improvement in diagnostic accuracy with 80% power and alpha of 0.05, requiring 350 patient encounters. Data analysis was performed using STATA version 17.0. Diagnostic accuracy measures were calculated with 95% confidence intervals. McNemar's test was used for paired proportions. Time-to-diagnosis was analyzed using Kaplan-Meier curves and log-rank tests. Multivariate logistic regression identified factors associated with improved diagnostic accuracy.

Quality Assurance

Quality assurance measures included: (1) random review of 20% of POCUS images by expert radiologists blinded to initial interpretations, (2) periodic competency assessments of providers, and (3) regular maintenance and calibration of ultrasound equipment. A data safety monitoring board reviewed study progress quarterly.

Results

Participant Flow and Characteristics

During the 12-month study period, a total of 432 healthcare providers were assessed for eligibility across the six district hospitals. Of these, 408 were excluded for the following reasons: prior formal ultrasound training (n=215), not meeting minimum clinical experience requirements (n=132), or declined to participate (n=61). Consequently, 24 healthcare providers (12 medical officers and 12 gynecology residents) were enrolled in the POCUS training program. All 24 providers completed the training and were included in the final analysis.

For patient participants, 1,250 women presenting with obstetric emergencies were screened during the study period. After applying exclusion criteria (hemodynamic instability requiring immediate

intervention n=45, age <18 years n=12, declined participation n=38), 1,155 patients were included in the final analysis. The mean age of patient participants was 26.4 years (SD=5.8), with a mean gestational age of 24.3 weeks (SD=10.2). The baseline characteristics of the study participants are presented in Table 1.

Table 1
Baseline Characteristics of Healthcare Providers and Patient Participants

Characteristic	Healthcare Providers (n=24)	Patient Participants (n=1,155)
Age, years (Mean, SD)	31.2 (4.5)	26.4 (5.8)
Gender, n (%)		
Male	14 (58.3%)	-
Female	10 (41.7%)	1,155 (100%)
Professional Category, n (%)		
Medical Officer	12 (50.0%)	-
Gynecology Resident	12 (50.0%)	-
Years of Experience (Mean, SD)	4.2 (2.1)	-
Gestational Age, weeks (Mean, SD)	-	24.3 (10.2)
Presenting Complaint, n (%)		
Vaginal Bleeding	-	467 (40.4%)
Abdominal Pain	-	392 (33.9%)
Suspected Preterm Labor	-	296 (25.6%)
Final Diagnosis, n (%)		
Placental Abruption	-	89 (7.7%)
Ectopic Pregnancy	-	67 (5.8%)
Placenta Previa	-	124 (10.7%)
Incomplete Abortion	-	213 (18.4%)
Normal Pregnancy	-	662 (57.3%)

Note: SD = Standard Deviation

Diagnostic Accuracy of POCUS

The diagnostic performance of POCUS compared to radiology department ultrasound for key obstetric emergencies is summarized in Table 2. POCUS demonstrated high overall diagnostic accuracy across all conditions. The sensitivity for

detecting ectopic pregnancy was 94.0% (95% CI: 85.2-97.7) and specificity was 99.6% (95% CI: 99.0-99.9). For placental abruption, sensitivity was 92.1% (95% CI: 84.3-96.2) and specificity was 98.3% (95% CI: 97.2-99.0). The overall diagnostic accuracy of POCUS was 96.8% (95% CI: 95.4-97.8).

Table 2
***Diagnostic Accuracy of POCUS Compared to Radiology Department Ultrasound for Obstetric Emergencies (N=1,155) ***

Diagnostic Measure	Overall (95% CI)	Ectopic Pregnancy (n=67) (95% CI)	Placental Abruption (n=89) (95% CI)	Placenta Previa (n=124) (95% CI)	Fetal Demise (n=45) (95% CI)
Sensitivity, %	94.2 (92.1-95.8)	94.0 (85.2-97.7)	92.1 (84.3-96.2)	96.8 (91.8-98.7)	88.9 (75.4-95.6)
Specificity, %	99.2 (98.5-99.6)	99.6 (99.0-99.9)	98.3 (97.2-99.0)	99.4 (98.7-99.7)	99.8 (99.4-99.9)
Positive Predictive Value, %	93.5 (91.2-95.3)	92.7 (83.8-96.9)	87.5 (79.2-92.8)	95.8 (90.5-98.2)	94.1 (80.9-98.4)
Negative Predictive Value, %	99.3 (98.6-99.6)	99.7 (99.1-99.9)	98.8 (97.8-99.3)	99.6 (98.9-99.8)	99.6 (99.0-99.8)
Positive Likelihood Ratio	117.8 (78.4-176.9)	235.0 (98.5-560.2)	54.2 (34.1-86.1)	161.3 (80.6-322.9)	444.5 (111.1-1777.8)
Negative Likelihood Ratio	0.06 (0.04-0.08)	0.06 (0.03-0.15)	0.08 (0.04-0.16)	0.03 (0.01-0.08)	0.11 (0.05-0.25)
Accuracy, %	96.8 (95.4-97.8)	99.3 (98.6-99.7)	97.6 (96.4-98.4)	99.0 (98.2-99.5)	99.6 (99.0-99.9)

Note: CI = Confidence Interval. All comparisons between POCUS and radiology ultrasound were statistically significant ($p<0.001$ using McNemar's test).

Impact on Clinical Management and Time-to-Diagnosis

The implementation of POCUS significantly influenced clinical decision-making and reduced diagnostic delays. Table 3 details the specific changes in clinical management following POCUS implementation. The most significant impact was observed in the reduction of unnecessary referrals, with 180 cases (15.6%) avoiding transfer to tertiary care facilities based on negative POCUS findings that were later confirmed by radiology ultrasound.

Table 3
***Impact of POCUS on Clinical Management Decisions and Time-to-Diagnosis (N=1,155) ***

Management Parameter	Pre-POCUS Implementation (n=580*)	Post-POCUS Implementation (n=1,155)	p-value
Time-to-Diagnosis (hours)			
Median (IQR)	4.8 (2.8-7.2)	0.3 (0.2-0.5)	**<0.001**
Mean (SD)	5.1 (2.4)	0.4 (0.3)	**<0.001**
Management Changes, n (%)			
Any Change in Management	89 (15.3%)	441 (38.2%)	**<0.001**
Specific Management Changes			
Surgical Intervention	45 (7.8%)	142 (12.3%)	**0.003**
Medical Management	112 (19.3%)	289 (25.0%)	**0.008**
Referral to Tertiary Care	156 (26.9%)	89 (7.7%)	**<0.001**
Avoided Unnecessary Transfer	67 (11.6%)	180 (15.6%)	**0.023**
Change in Medication	34 (5.9%)	123 (10.6%)	**0.001**
Timing of Intervention			
Immediate Intervention (<1 hour)	78 (13.4%)	345 (29.9%)	**<0.001**
Delayed Intervention (>4 hours)	234 (40.3%)	89 (7.7%)	**<0.001**
Diagnostic Confidence			
High Confidence Diagnosis	267 (46.0%)	978 (84.7%)	**<0.001**
Uncertain Diagnosis	313 (54.0%)	177 (15.3%)	**<0.001**

*Note: *Pre-implementation data collected from hospital records for the 6-month period preceding POCUS implementation. IQR = Interquartile Range; SD = Standard Deviation. p-values from Mann-Whitney U test for time variables and Chi-square tests for categorical variables. *

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Multivariate Analysis of Factors Affecting Diagnostic Accuracy

A multivariate logistic regression analysis was performed to identify factors associated with diagnostic accuracy of POCUS. The model included provider characteristics, training factors, and equipment variables. The results are presented in Table 4.

Table 4

***Multivariate Logistic Regression Analysis of Factors Associated with Diagnostic Accuracy of POCUS (N=1,155 Scans) ***

Factor	Category	Adjusted Odds Ratio (aOR)	95% CI for aOR	p-value
Provider Characteristics				
Professional Category	Gynecology Resident (Ref: Medical Officer)	2.12	1.32-3.41	**0.002**
Years of Experience	>3 years (Ref: ≤3 years)	1.45	0.92-2.28	0.108
Previous Ultrasound Exposure	Any exposure (Ref: None)	1.28	0.81-2.02	0.289
Training Factors				
Number of Supervised Scans	>50 scans (Ref: ≤50 scans)	3.24	1.84-5.71	**<0.001**
OSAUS Competency Score	≥4.0 (Ref: <4.0)	2.87	1.76-4.68	**<0.001**
Time to Competency	≤12 weeks (Ref: >12 weeks)	1.92	1.21-3.05	**0.006**
Equipment and Setting				
Ultrasound Machine Type	High-end portable (Ref: Basic portable)	1.84	1.11-2.94	**0.018**
Hospital Volume	>400 deliveries/month (Ref: ≤400/month)	1.36	0.87-2.13	0.179
Time of Presentation	Regular hours (Ref: After-hours)	1.15	0.74-1.79	0.531
Clinical Factors				
Patient BMI	<30 kg/m² (Ref: ≥30 kg/m²)	1.68	1.07-2.64	**0.024**
Gestational Age	2nd-3rd trimester (Ref: 1st trimester)	1.42	0.91-2.22	0.124
Clinical Urgency	Emergency (Ref: Non-emergency)	0.76	0.49-1.18	0.220

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Note: OSAUS = Objective Structured Assessment of Ultrasound Skills; BMI = Body Mass Index; CI = Confidence Interval. The model was adjusted for all variables listed. Reference categories are indicated by (Ref:).

As shown in Table 4, several factors were significantly associated with higher diagnostic accuracy. Gynecology residents had more than twice the odds of accurate diagnosis compared to medical officers (aOR: 2.12, 95% CI: 1.32-3.41, p=0.002). Training factors were particularly important, with providers performing more than 50 supervised scans having over three times higher odds of accurate diagnosis (aOR: 3.24, 95% CI: 1.84-5.71, p<0.001). Higher OSAUS competency scores (aOR: 2.87, 95% CI: 1.76-4.68, p<0.001) and shorter time to competency (aOR: 1.92, 95% CI: 1.21-3.05, p=0.006) were also significant predictors. Equipment quality significantly influenced accuracy, with high-end portable machines showing better performance (aOR: 1.84, 95% CI: 1.11-2.94, p=0.018). Patient factors such as lower BMI were associated with better diagnostic outcomes (aOR: 1.68, 95% CI: 1.07-2.64, p=0.024).

Discussion

This multicenter implementation study demonstrates that a structured POCUS training program for healthcare providers in district hospitals of Khyber Pakhtunkhwa significantly improved the diagnosis and management of obstetric emergencies. Our findings reveal that trained non-radiologist providers achieved high diagnostic accuracy (94.2% sensitivity, 99.2% specificity) for critical conditions including ectopic pregnancy, placental abruption, and placenta previa. The implementation of POCUS reduced median time-to-diagnosis from 4.8 hours to 0.3 hours and led to significant changes in clinical management in 38.2% of cases. These results have important implications for improving maternal healthcare in resource-limited settings.

The diagnostic accuracy achieved by trained providers in our study compares favorably with previous research in similar settings. Henwood et al. [3] reported sensitivity of 89% for basic obstetric ultrasound following training in Rwanda, while our study demonstrated higher accuracy (94.2%) despite focusing on more complex emergency conditions. This improvement may be attributed to our structured training program which included a 5-day intensive workshop followed by supervised clinical practicum with minimum 50 scans. The excellent inter-observer agreement (κ=0.91) between POCUS operators and radiologists surpasses the substantial agreement (κ=0.67-0.78) reported in previous studies [15, 19], suggesting that standardized training protocols can achieve high consistency even in diverse district hospital settings.

The reduction in time-to-diagnosis from 4.8 hours to 0.3 hours represents a critical advancement in emergency obstetric care. Delays in diagnosis contribute significantly to maternal mortality in resource-limited settings [5, 6], and our findings demonstrate that POCUS can effectively address this challenge. The 15.6% reduction in unnecessary transfers to tertiary care facilities has important implications for healthcare resource utilization, particularly in settings where transportation costs and bed availability are major constraints [27, 28]. These results align with Nathan et al. [26] who reported a 40% reduction in referrals following POCUS implementation in Tanzania, though our study provides more robust multi-center data.

Our multivariate analysis identified several key factors associated with diagnostic accuracy. The significant advantage of gynecology residents over medical officers (aOR: 2.12) underscores the importance of specialty-specific training, consistent with findings by Stachura et al. [16]. The strong association between number of supervised scans and diagnostic accuracy (aOR: 3.24 for >50 scans) supports the WHO recommendation of minimum practice requirements for ultrasound training [1]. However, the feasibility of maintaining such training intensity in routine practice requires further investigation.

The high diagnostic accuracy for ectopic pregnancy (94.0% sensitivity) is particularly noteworthy given that this condition accounts for

significant maternal mortality in Pakistan [4, 6]. Early detection through POCUS can facilitate timely surgical intervention, potentially reducing complications and mortality. Similarly, the 92.1% sensitivity for placental abruption addresses a critical diagnostic challenge where clinical examination alone has poor accuracy [9, 10].

Limitations

Several limitations should be considered when interpreting our findings. First, the study was conducted in district hospitals which may have better resources than more remote facilities, potentially limiting generalizability to primary healthcare centers. Second, the Hawthorne effect may have influenced provider performance during the study period. Third, long-term sustainability of skills remains uncertain without ongoing supervision and quality assurance. Finally, the cost-effectiveness analysis was limited to direct costs and did not capture broader health system impacts.

Conclusion

This study provides strong evidence that POCUS can be effectively implemented in district hospitals of resource-limited settings with high diagnostic accuracy and significant impact on clinical management. The structured training program enabled non-radiologist providers to accurately diagnose obstetric emergencies, reducing diagnostic delays and unnecessary transfers. We recommend that health authorities in similar settings consider integrating POCUS into emergency obstetric care protocols, with particular attention to sustainable training models and quality assurance mechanisms. Future research should focus on long-term skill retention, patient outcomes, and implementation strategies for scaling up POCUS in primary care facilities.

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