



Improving Maternal Health Outcomes through Accessible Portable Obstetric Ultrasound Services in Rural Kenya

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Abstract: Portable obstetric ultrasound has emerged as an important innovation for improving maternal healthcare in resource-constrained settings, yet evidence on how service accessibility influences maternal health outcomes in Kenya remains limited. This study examined the effect of accessibility to portable obstetric ultrasound services on maternal health outcomes among pregnant women attending Malindi Sub-County Hospital, Kilifi County. A convergent mixed-methods design was employed involving 370 pregnant women, 10 healthcare providers and 15 community health promoters. Quantitative data were analysed using descriptive statistics and multiple linear regression, while qualitative data underwent thematic analysis. Findings revealed that accessibility to portable obstetric ultrasound services was generally high ($M = 3.80$, $SD = 1.02$), characterised by good geographical proximity, awareness, provider support and routine utilisation. However, affordability and waiting time remained important barriers. Accessibility significantly predicted maternal health outcomes ($\beta = 0.642$, $p < 0.05$), explaining 41.2% of the observed variation ($R^2 = 0.412$). Improving affordability, workforce capacity and service availability is essential for maximising maternal health benefits in rural Kenya.

Keywords: Portable obstetric ultrasound, Accessibility, Maternal health outcomes, Antenatal care, Rural healthcare, Kenya

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1. Introduction

Maternal mortality remains a significant public health challenge globally, with approximately 287,000 women dying annually from preventable pregnancy and childbirth-related complications, the majority occurring in low- and middle-income countries (LMICs) (World Health Organization [WHO], 2023). Sub-Saharan Africa accounts for nearly 70% of these deaths, largely because of delayed diagnosis of obstetric complications, inadequate referral systems, limited access to skilled healthcare providers, and inequitable distribution of diagnostic technologies. Although Kenya has made substantial progress in expanding maternal healthcare services, maternal mortality

remains unacceptably high, particularly in rural and underserved counties where access to quality antenatal diagnostic services continues to be constrained.

Early detection of pregnancy complications is fundamental to improving maternal and neonatal outcomes. Obstetric ultrasound facilitates accurate gestational age estimation, identification of fetal abnormalities, diagnosis of placental disorders, assessment of fetal growth, and timely referral of high-risk pregnancies. However, conventional ultrasound equipment is expensive, immobile and predominantly concentrated in referral hospitals, limiting access among rural populations. The emergence of portable obstetric ultrasound devices has transformed maternal healthcare by enabling point-of-care diagnostic services

within primary healthcare facilities and remote communities. These handheld, battery-powered technologies can be operated by appropriately trained frontline healthcare workers, thereby extending diagnostic capacity beyond specialist centres.

Growing international evidence demonstrates that portable obstetric ultrasound enhances antenatal care utilisation, improves early detection of pregnancy complications, strengthens clinical decision-making, and facilitates timely referral for emergency obstetric care (Maraci et al., 2021; Kim et al., 2022; WHO, 2023). Nevertheless, evidence also indicates that accessibility extends beyond physical availability of equipment to include affordability, provider competency, maintenance systems, referral efficiency, and health system readiness. Consequently, improvements in maternal health outcomes depend on the interaction of technological innovation with broader health system strengthening.

Within sub-Saharan Africa, implementation of portable obstetric ultrasound has shown encouraging results in improving antenatal attendance and identification of high-risk pregnancies. However, many studies have focused primarily on feasibility, diagnostic accuracy and pilot implementation, with relatively few evaluating the influence of accessibility on maternal health outcomes using rigorous analytical approaches. In Kenya, available evidence remains limited and largely concentrates on operational feasibility rather than examining how accessibility to portable obstetric ultrasound contributes to improved maternal health outcomes within routine healthcare delivery.

This study addresses this knowledge gap by investigating the effect of accessibility to portable obstetric ultrasound services on maternal health outcomes among pregnant women attending Malindi Sub-County Hospital in Kilifi County. Specifically, the study evaluates key dimensions of accessibility, including geographical proximity, awareness, affordability, service availability, provider support and waiting time, and examines how these factors influence maternal healthcare utilisation and pregnancy outcomes. The findings contribute context-specific evidence to inform policy, strengthen maternal health programmes and guide the scale-up of portable obstetric ultrasound services within rural healthcare systems in Kenya and comparable resource-limited settings.

2. Literature Review

2.1 Theoretical Review of Literature

This study was anchored on the Health Belief Model (HBM) and the Diffusion of Innovation (DOI) Theory,

which together provide a comprehensive explanation of how portable obstetric ultrasound services influence maternal health outcomes. The two theories complement each other by addressing both individual health-seeking behaviour and health technology adoption. While the HBM explains how pregnant women's perceptions influence their utilisation of ultrasound services, the DOI Theory explains how healthcare providers and health facilities adopt and integrate portable ultrasound technology into routine maternal healthcare.

The Health Belief Model, developed by Rosenstock and Hochbaum in the 1950s (Rosenstock, 1974), posits that health behaviours are shaped by perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy. In this study, accessibility, affordability, usability, and diagnostic quality of portable obstetric ultrasound services influence women's perceptions of benefits and barriers, thereby affecting antenatal care utilisation, early detection of pregnancy complications, and adherence to medical recommendations. However, the model has limitations in explaining structural barriers such as inadequate infrastructure, workforce shortages, and cultural influences common in rural settings.

The Diffusion of Innovation Theory (Rogers, 2003) complements the HBM by explaining the adoption of portable obstetric ultrasound technology within healthcare systems. The theory argues that adoption is influenced by an innovation's relative advantage, compatibility, complexity, trialability, and observability, together with communication channels and social systems. In the context of this study, healthcare providers, community health promoters, and antenatal care programmes facilitate the diffusion and utilisation of portable ultrasound services, thereby improving early diagnosis, referral, and clinical decision-making. Although DOI is criticised for underestimating systemic constraints, it provides valuable insights into technology adoption within resource-constrained health systems. Together, the HBM and DOI offer an integrated framework for understanding how individual perceptions and organisational adoption jointly influence maternal health outcomes in rural Kenya.

2.2 Empirical Review of Literature

Portable obstetric ultrasound has emerged as one of the most significant technological innovations for strengthening maternal healthcare, particularly in low- and middle-income countries (LMICs), where limited access to diagnostic imaging contributes to preventable maternal and neonatal morbidity and mortality. Portable obstetric ultrasound comprises handheld or point-of-care ultrasound (POCUS) devices designed for use in primary healthcare facilities, rural clinics, and remote communities. Compared

with conventional cart-based ultrasound systems, these devices are less expensive, battery-powered, easy to transport, and can be operated by trained midwives, nurses, clinical officers, and other frontline healthcare providers. Consequently, they have become increasingly important for improving antenatal assessment, early diagnosis of pregnancy complications, timely referral, and evidence-based clinical decision-making (WHO, 2016; Swanson et al., 2014; Vinayak et al., 2017). Recent empirical research has therefore shifted from evaluating the technical feasibility of portable ultrasound to examining its contribution to maternal health outcomes and health system strengthening.

2.2.1 Accessibility of Portable Obstetric Ultrasound Services

Empirical evidence consistently demonstrates that accessibility to portable obstetric ultrasound extends beyond the mere availability of equipment. Rather, accessibility encompasses geographical proximity, affordability, trained healthcare personnel, reliable electricity, maintenance systems, supportive policies, and integration into maternal healthcare pathways (Mbuyita et al., 2015; Swanson et al., 2019; Kim et al., 2022). As digital health technologies continue to evolve, portable ultrasound has become an effective strategy for reducing disparities in diagnostic services between urban referral hospitals and rural primary healthcare facilities. Nevertheless, disparities in workforce capacity, infrastructure, and financing continue to limit equitable access in many LMICs (WHO, 2023; ISUOG, 2024).

Early empirical studies primarily investigated the feasibility of introducing portable ultrasound into underserved settings. Swanson et al. (2014) reported that portable ultrasound substantially improved antenatal diagnostic capacity when accompanied by focused provider training, while Vinayak et al. (2017) demonstrated that trained non-radiologist healthcare workers could safely provide basic obstetric ultrasound services without compromising diagnostic accuracy. These findings supported the decentralisation of obstetric imaging through task shifting and expansion of primary healthcare services.

Subsequent studies shifted attention towards implementation effectiveness and health system integration. Maraci et al. (2021) found that portable ultrasound significantly increased access to antenatal imaging among rural populations, although long-term utilisation depended on workforce training, equipment maintenance, and functional referral systems. Similarly, Kim et al. (2022) reported improved service coverage and reduced geographical inequalities following the introduction of handheld ultrasound devices but emphasised that accessibility alone could not improve

maternal outcomes without efficient referral pathways and comprehensive emergency obstetric care.

More recent evidence reflects advances in artificial intelligence-assisted image interpretation, tele-ultrasound, and digital connectivity, which have further enhanced accessibility to diagnostic services in remote communities (ISUOG, 2024). The World Health Organization (2023) similarly recognises portable ultrasound as an important intervention for strengthening quality antenatal care within primary healthcare. However, despite substantial technological progress, implementation challenges persist, including shortages of skilled personnel, weak quality assurance systems, inadequate maintenance, and regulatory limitations. Overall, empirical literature demonstrates an evolution from feasibility studies towards broader conceptualisations of accessibility as a multidimensional health system capability rather than simply the physical availability of equipment.

2.2.2 Portable Obstetric Ultrasound and Early Detection of Pregnancy Complications

One of the greatest contributions of portable obstetric ultrasound lies in its ability to facilitate early detection of pregnancy complications, thereby improving clinical decision-making and referral for specialised obstetric care. Delayed diagnosis remains a major contributor to maternal morbidity and mortality in resource-constrained settings, making early identification of high-risk pregnancies particularly important.

Initial empirical studies demonstrated that portable ultrasound substantially improved the identification of fetal malpresentation, multiple gestations, placenta praevia, abnormal fetal growth, oligohydramnios, polyhydramnios, and inaccurate gestational age estimation compared with clinical examination alone (Swanson et al., 2014; Vinayak et al., 2017). Systematic reviews have subsequently confirmed that point-of-care obstetric ultrasound enhances early recognition of high-risk pregnancies, enabling timely referral before complications become life-threatening (Maraci et al., 2021; WHO, 2023).

Recent international studies further indicate that integrating portable ultrasound into routine antenatal care increases diagnostic confidence among frontline healthcare providers while reducing delays associated with referrals to higher-level facilities (Kim et al., 2022; ISUOG, 2024). Nevertheless, evidence remains inconclusive regarding the independent effect of portable ultrasound on reducing maternal mortality because improved diagnosis must be supported by effective referral systems, emergency transportation, and comprehensive emergency obstetric and newborn care. Consequently, portable ultrasound is increasingly viewed as an important component of an

integrated maternal healthcare pathway rather than a standalone intervention.

Evidence from sub-Saharan Africa reinforces these findings. Studies conducted in Uganda, Tanzania, Ethiopia, Rwanda, and Zambia consistently report improvements in identifying placenta praevia, breech presentation, multiple pregnancies, fetal anomalies, and abnormal fetal growth following deployment of portable ultrasound services (Mbuyita et al., 2015; Nathan et al., 2017; Swanson et al., 2019; Shah et al., 2022). Trained midwives and non-physician clinicians generally achieve acceptable diagnostic accuracy for basic obstetric assessments, although inconsistencies remain in image interpretation, quality assurance, and long-term competency retention where continuing professional development is inadequate (Vinayak et al., 2017; Kim et al., 2022).

Within Kenya, empirical evidence remains comparatively limited but demonstrates increasing recognition of portable ultrasound as a valuable tool for strengthening antenatal risk screening, improving gestational age estimation, and supporting clinical decision-making, particularly in rural and underserved counties (Ministry of Health Kenya, 2022; WHO, 2023). However, most Kenyan studies emphasise feasibility and acceptability rather than evaluating long-term maternal health outcomes. Persistent challenges relating to workforce capacity, equipment maintenance, electricity supply, and referral infrastructure continue to limit the full diagnostic potential of portable obstetric ultrasound across county health systems.

2.2.3 Portable Obstetric Ultrasound Services and Maternal Health Outcomes

Growing empirical evidence indicates that portable obstetric ultrasound contributes to improved maternal health outcomes by enhancing early diagnosis, strengthening clinical decision-making, and facilitating timely referral for specialised obstetric care. Maternal health benefits associated with portable ultrasound include improved antenatal care utilisation, increased skilled birth attendance, enhanced management of obstetric complications, improved quality of maternal healthcare, and reductions in maternal morbidity (Swanson et al., 2014; Vinayak et al., 2017; WHO, 2023).

Globally, portable ultrasound strengthens the continuum of maternal care by improving gestational age estimation, facilitating early identification of high-risk pregnancies, and promoting referral compliance (Swanson et al., 2014; Vinayak et al., 2017). More recent studies demonstrate that integrating handheld ultrasound into routine antenatal care improves pregnancy risk stratification, provider confidence, and continuity of care, particularly within underserved communities (Maraci et al., 2021; Kim et al.,

2022). Nevertheless, systematic reviews consistently caution that enhanced diagnostic capacity alone does not automatically translate into reduced maternal mortality because favourable outcomes depend on complementary health system factors, including skilled healthcare providers, emergency obstetric services, effective referral mechanisms, and adequate infrastructure (WHO, 2023; ISUOG, 2024).

Across sub-Saharan Africa, portable obstetric ultrasound has been associated with improved antenatal care attendance, increased referral compliance, earlier detection of obstetric complications, and greater utilisation of skilled maternity services (Mbuyita et al., 2015; Nathan et al., 2017; Swanson et al., 2019; Shah et al., 2020). Women receiving ultrasound-guided antenatal care are generally more likely to complete recommended ANC visits and deliver in health facilities than those assessed solely through clinical examination (Swanson et al., 2019; Kim et al., 2022). However, variations in health system capacity, equipment maintenance, workforce competence, and referral efficiency continue to influence the magnitude of these benefits across different countries.

In Kenya, available evidence indicates that portable obstetric ultrasound enhances antenatal risk assessment, improves gestational age estimation, and strengthens referral decision-making, especially in rural and underserved health facilities (Ministry of Health Kenya, 2022; WHO, 2023). Despite increased investments in portable ultrasound technologies, empirical evidence remains limited regarding their long-term effects on maternal morbidity, mortality, and pregnancy outcomes. Consequently, further rigorous research is required to establish the sustained contribution of portable ultrasound services to maternal health within the Kenyan healthcare system.

2.2.4 Barriers, Facilitators and Health System Readiness

Successful implementation of portable obstetric ultrasound depends on broader health system readiness rather than equipment availability alone. Global evidence identifies trained healthcare personnel, supportive policies, sustainable financing, reliable electricity, equipment maintenance, digital connectivity, and efficient referral systems as major facilitators of successful implementation (Maraci et al., 2021; Kim et al., 2022; WHO, 2023). Recent innovations such as telemedicine, artificial intelligence-assisted image interpretation, and competency-based training have further expanded opportunities for improving access and quality of obstetric ultrasound services, particularly in remote communities (ISUOG, 2024).

Conversely, numerous barriers continue to impede implementation. Common challenges include shortages of

skilled sonographers, inadequate infrastructure, poor maintenance systems, limited financial resources, weak governance, and fragmented referral pathways (WHO, 2023; Maraci et al., 2021). These barriers reduce service continuity, compromise diagnostic quality, and limit the effectiveness of portable ultrasound within routine maternal healthcare.

Health system constraints are particularly evident across sub-Saharan Africa, where studies consistently identify inadequate workforce capacity, unreliable electricity, poor internet connectivity, irregular equipment maintenance, and insufficient continuing professional development as major obstacles to sustainable implementation (Nathan et al., 2017; Swanson et al., 2019; Shah et al., 2022). Similar challenges persist within Kenya, where unequal distribution of ultrasound devices, shortages of trained personnel at primary healthcare facilities, weak referral systems, and inadequate budgetary support continue to limit equitable access to quality ultrasound services (Ministry of Health Kenya, 2022; WHO, 2023). Although national policies increasingly support decentralisation of diagnostic services, health system readiness remains uneven across counties, constraining the full potential of portable obstetric ultrasound to improve maternal health outcomes.

2.3 Research Gaps

Despite considerable expansion of empirical literature, important knowledge gaps remain. Globally, most studies have focused on diagnostic accuracy, feasibility, and implementation while relatively few have employed longitudinal, quasi-experimental, or experimental designs capable of establishing causal relationships between accessibility to portable obstetric ultrasound and long-term maternal health outcomes (Maraci et al., 2021; WHO, 2023). Evidence regarding cost-effectiveness, sustainability, scalability, and integration within broader maternal health systems also remains limited (Kim et al., 2022; ISUOG, 2024).

Within sub-Saharan Africa, the literature is dominated by pilot projects and cross-sectional implementation studies, limiting the generalisability of findings and providing insufficient evidence on long-term reductions in maternal morbidity and mortality (Nathan et al., 2017; Swanson et al., 2019). Comparative multicountry studies remain scarce, while contextual differences in health systems further restrict broader application of existing evidence.

The Kenyan literature similarly focuses on service feasibility, provider acceptability, and operational challenges rather than evaluating long-term maternal health outcomes. Few studies simultaneously examine accessibility to portable obstetric ultrasound, health system

readiness, early detection of pregnancy complications, and maternal health outcomes within a single conceptual framework. Consequently, there remains a significant need for rigorous mixed-methods, longitudinal, and quasi-experimental studies capable of generating context-specific evidence to inform policy, strengthen health system preparedness, and optimise the integration of portable obstetric ultrasound into routine maternal healthcare. Such evidence would support evidence-based investment decisions and contribute to improved maternal and neonatal outcomes within Kenya and other resource-constrained settings.

3. Methodology

This section presents the methodology used to examine the effect of portable obstetric ultrasound services on maternal health outcomes in Malindi Sub-County, Kilifi County, Kenya. It describes the research design, study area, target population, sample size, and sampling procedures adopted to address the study objectives. The section further outlines the data collection instruments and procedures, pilot testing, validity and reliability assessment, data analysis techniques, and ethical considerations. A mixed-methods approach was employed to generate both quantitative and qualitative evidence, enabling a comprehensive understanding of accessibility, quality, usability, cost, and maternal health outcomes associated with portable obstetric ultrasound services. The methodological procedures provided a systematic basis for ensuring the validity, reliability, and credibility of the study findings.

3.1 Research Design

This study adopted a mixed-methods approach using a convergent parallel research design to comprehensively examine the effect of portable obstetric ultrasound services on maternal health outcomes in Malindi Sub-County, Kilifi County. The design enabled quantitative and qualitative data to be collected and analysed concurrently but independently before integrating the findings during interpretation (Apuke, 2019). Quantitative data were collected using structured questionnaires to assess accessibility, quality of imaging and diagnostics, usability, and cost of portable obstetric ultrasound services. Qualitative data were obtained through key informant interviews (KIIs) with healthcare providers and community health promoters to explore their experiences and perceptions. The convergent design facilitated triangulation, enhanced the validity of findings, and provided a holistic understanding of the research problem.

3.2 Study Area

The study was conducted in Malindi Sub-County Hospital, Kilifi County, Kenya, a predominantly rural setting characterised by limited access to specialised maternal healthcare services, inadequate referral systems, and low utilisation of antenatal care. The hospital serves as the principal referral facility for the sub-county and has introduced portable obstetric ultrasound services to improve diagnostic capacity among rural women. The area was purposively selected because of its high maternal

health needs, limited diagnostic infrastructure, and suitability for evaluating the effectiveness of portable obstetric ultrasound in improving maternal health outcomes.

3.3 Target Population

The target population comprised 5,065 participants, including pregnant women attending antenatal care (ANC), healthcare providers, and community health promoters involved in maternal healthcare services.

Table 2: Target Population

Category	Target Population Percentage (%)	
Expectant mothers	5,000	98.73
Healthcare providers	50	0.98
Community Health Promoters	15	0.29
Total	5,065	100.00

Source: Kenya Demographic and Health Survey (2023)

3.4 Sample Size and Sampling Procedures

3.4.1 Sample Size Determination

The sample size was determined using Yamane's (1967) formula for finite populations:

$$n = \frac{N}{1 + N(e^2)}$$

Where:

- n = Required sample size
- N = Target population (5,000 pregnant women)
- e = Margin of error (0.05)

$$n = \frac{5000}{1 + 5000(0.05)^2} = 370.37 \approx 370$$

The study therefore included 370 pregnant women, 10 healthcare providers, and 15 community health promoters, yielding a total sample of 396 respondents.

3.4.2 Sampling Procedure

Pregnant women were selected using systematic random sampling from ANC registers to ensure equal selection probability. Healthcare providers and community health promoters were selected through purposive sampling based on their direct involvement in maternal healthcare and portable ultrasound service delivery.

3.5 Data Collection Tools

The study utilised both primary and secondary data. Secondary data were obtained through a review of published literature, policy documents, and maternal health reports. Primary quantitative data were collected using structured questionnaires administered to pregnant women, while qualitative data were gathered through semi-structured key informant interviews with healthcare providers and community health promoters. The mixed-methods approach enabled comprehensive assessment of accessibility, quality, usability, cost, and maternal health outcomes.

3.5.1 Pilot Testing

A pilot study was conducted at Kilifi County Hospital using approximately 10% of the study sample, consistent with Mugenda and Mugenda's recommendation. The pilot assessed the clarity, validity, and reliability of the research instruments before the main study.

3.5.2 Validity of Instruments

Content validity was established through expert review by maternal health specialists, while construct validity was ensured by aligning questionnaire items with the study objectives. Face validity was confirmed through pre-testing to ensure clarity and appropriateness.

3.5.3 Reliability of Instruments

Reliability was assessed using Cronbach's Alpha, with coefficients above 0.70 considered acceptable (Taber, 2018).

Variable	Cronbach's Alpha	Number of Items	Comment
Portable obstetric ultrasound accessibility	0.85	8	Reliable
Quality of imaging and diagnostics	0.82	8	Reliable
Cost of portable obstetric ultrasound services	0.83	8	Reliable
Usability of portable obstetric ultrasound	0.87	8	Reliable
Maternal health outcomes	0.84	8	Reliable

All constructs demonstrated satisfactory internal consistency, confirming the suitability of the instruments for the main study.

3.6 Data Collection Procedure

Ethical approval was obtained from the Catholic University of Eastern Africa (CUEA) and the National Commission for Science, Technology and Innovation (NACOSTI) before data collection. After obtaining informed consent, structured questionnaires were administered to pregnant women either in paper format or electronically using Google Forms and Kobo Toolbox. Semi-structured interviews were conducted with purposively selected healthcare providers and community health promoters. Interviews were audio-recorded with participants' consent and transcribed verbatim. Completed questionnaires were coded and entered into SPSS Version 27, while research assistants supervised data collection to ensure quality and consistency.

3.7 Data Analysis Techniques

Quantitative data were analysed using SPSS Version 27. Descriptive statistics (frequencies, percentages, means, and standard deviations) summarised respondent characteristics and study variables. Inferential analysis employed multiple linear regression to examine the relationship between portable obstetric ultrasound services and maternal health outcomes.

The regression model was specified as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon$$

Where:

- Y = Maternal health outcomes
- $X_1 \dots X_n$ = Predictor variables
- β = Regression coefficients
- ε = Error term

Qualitative interview data were analysed using thematic content analysis, involving coding, categorisation, and theme development. Quantitative and qualitative findings were subsequently integrated through triangulation, allowing qualitative evidence to explain and enrich statistical findings.

3.8 Ethical Considerations

The study adhered to established ethical research principles. Approval was obtained from CUEA and NACOSTI before commencement. Participation was voluntary, and informed consent was obtained from all respondents. Participants were informed of their right to withdraw at any stage without penalty. Confidentiality and anonymity were maintained by excluding personal identifiers from all research records, while collected data were used solely for academic purposes. These procedures ensured the protection of participants' rights, privacy, and dignity while enhancing the credibility and integrity of the study.

4. Results and Discussion

The study established that accessibility to portable obstetric ultrasound services significantly and positively influences maternal health outcomes among pregnant women attending Malindi Sub-County Hospital. Overall, respondents perceived the services to be reasonably accessible, as reflected by a composite mean score of 3.80 (SD = 1.02). The findings indicate that geographical proximity, awareness of service locations, provider recommendations, routine availability of ultrasound services, and utilisation during antenatal care were generally favourable, although affordability and waiting time remained notable barriers to optimal access. These findings suggest that while considerable progress has been made in decentralising obstetric ultrasound services, structural and economic constraints continue to affect equitable utilisation.

Regarding geographical accessibility, most respondents reported that portable obstetric ultrasound services were available within a short distance from their homes. Similarly, a large majority indicated that they knew where ultrasound services could be accessed during pregnancy. Qualitative evidence reinforced these findings, with healthcare providers and community health promoters explaining that decentralisation of services to community health facilities had reduced travel costs and encouraged more frequent antenatal attendance. These findings resonate with global empirical evidence demonstrating that proximity and awareness are fundamental determinants of

maternal healthcare utilisation (Swanson et al., 2019; Kim et al., 2022). They further support the observations of Maraci et al. (2021) and the World Health Organization (2023), who argue that accessibility should be understood as a multidimensional concept encompassing geographical availability, information dissemination, and integration within maternal healthcare pathways.

Although accessibility was generally rated positively, affordability emerged as a significant challenge. While many women considered the services affordable, a substantial proportion reported experiencing financial constraints when seeking portable ultrasound services. Qualitative interviews revealed that some women postponed or missed recommended scans because of direct service charges, transport costs, or competing household priorities. These findings align with studies by Sharma et al. (2021), which demonstrated that hidden costs, including transport and repeat facility visits, continue to limit maternal healthcare utilisation even where diagnostic services are geographically available. Unlike findings from subsidised programmes reported by Muthoki et al. (2022), the present study indicates that financial barriers remain an important determinant of access within the Kenyan context.

The findings further revealed high utilisation of portable obstetric ultrasound during routine antenatal care. Most respondents reported receiving at least one ultrasound scan during pregnancy, while healthcare providers consistently recommended ultrasound examinations as part of routine antenatal services. Qualitative findings showed that many women increasingly requested ultrasound scans voluntarily because they recognised their value in monitoring fetal wellbeing. These findings corroborate earlier empirical studies demonstrating that integrating portable ultrasound into routine antenatal care enhances uptake of maternal health services and strengthens early identification of pregnancy complications (Swanson et al., 2014; Vinayak et al., 2017; Maraci et al., 2021). They also support evidence from sub-Saharan Africa indicating that provider recommendation serves as an important catalyst for utilisation of maternal diagnostic services (Kim et al., 2022).

Despite the generally positive perceptions of service availability, waiting time and occasional service interruptions remained important operational challenges. Respondents reported moderate agreement that ultrasound services could be accessed without prolonged delays, while qualitative interviews attributed waiting times to shortages of trained personnel, occasional equipment breakdowns, and maintenance requirements. Likewise, although ultrasound services were generally available when required, respondents acknowledged periodic interruptions caused by staffing shortages and equipment maintenance.

These findings mirror broader evidence from LMICs showing that sustainable implementation of portable obstetric ultrasound depends not only on equipment availability but also on adequate workforce capacity, maintenance systems, and health system readiness (WHO, 2023; ISUOG, 2024). Similar implementation challenges have been reported across sub-Saharan Africa, where shortages of skilled personnel and weak infrastructure continue to constrain service continuity (Nathan et al., 2017; Shah et al., 2022).

Inferential analysis provided strong evidence that accessibility of portable obstetric ultrasound services significantly predicts maternal health outcomes. Multiple linear regression analysis showed a statistically significant positive relationship between accessibility and maternal health outcomes ($\beta = 0.642$, $p < 0.05$), indicating that improvements in accessibility contribute to enhanced maternal healthcare utilisation, earlier detection of pregnancy complications, and greater adherence to recommended antenatal care practices. Furthermore, accessibility explained 41.2% ($R^2 = 0.412$) of the variation in maternal health outcomes, while the regression model was statistically significant ($F = 48.317$, $p < 0.001$). These findings demonstrate that accessibility is a strong predictor of maternal health outcomes, although other health system and socioeconomic factors also contribute to maternal wellbeing.

The regression findings closely align with international empirical evidence showing that improved access to portable obstetric ultrasound strengthens the continuum of maternal care through earlier diagnosis, improved referral compliance, and enhanced clinical decision-making (Maraci et al., 2021; Kim et al., 2022; WHO, 2023). Similarly, studies conducted across Uganda, Tanzania, Ethiopia, Rwanda, and Zambia have consistently reported that improved accessibility to portable ultrasound services enhances antenatal attendance, facilitates earlier detection of obstetric complications, and promotes utilisation of skilled maternity services (Swanson et al., 2019; Shah et al., 2022). The present findings therefore reinforce existing evidence that accessibility represents one of the most important determinants of successful implementation and effectiveness of portable obstetric ultrasound services.

Qualitative findings further strengthened the quantitative results by illustrating how improved accessibility translated into better maternal healthcare experiences. Healthcare providers reported that bringing ultrasound services closer to communities had increased antenatal clinic attendance, facilitated earlier identification of pregnancy complications, and enabled timely referral for specialised obstetric care. These observations are consistent with recent literature emphasising that portable obstetric ultrasound functions most effectively when

integrated within broader maternal healthcare systems characterised by functional referral pathways and skilled healthcare providers (WHO, 2023; ISUOG, 2024).

Overall, the findings demonstrate that accessibility to portable obstetric ultrasound services substantially improves maternal healthcare utilisation and contributes positively to maternal health outcomes through enhanced geographical proximity, improved awareness, provider support, and regular service availability. However, financial constraints, waiting times, equipment maintenance, and shortages of trained personnel continue to limit equitable access. These findings are consistent with the broader empirical literature, which concludes that portable obstetric ultrasound can significantly strengthen maternal healthcare delivery when supported by adequate financing, workforce capacity, infrastructure, and integrated referral systems. Consequently, improving affordability, expanding workforce training, strengthening equipment maintenance, and enhancing health system readiness remain critical priorities for maximising the contribution of portable obstetric ultrasound services to improved maternal health outcomes in Kenya.

5. Conclusion and Recommendations

5.1 Conclusion

The study concludes that accessibility to portable obstetric ultrasound services is a significant determinant of maternal health outcomes among pregnant women in Malindi Sub-County Hospital. Accessibility was characterised by favourable geographical proximity, high awareness of service availability, strong provider support, routine utilisation during antenatal care, and generally adequate service availability. These factors collectively promoted timely maternal healthcare utilisation, enhanced early detection of pregnancy complications, and strengthened adherence to recommended antenatal care practices. However, financial constraints, prolonged waiting times, occasional equipment downtime, and shortages of trained personnel continue to limit equitable access to services.

Inferential analysis confirmed that accessibility significantly and positively influenced maternal health outcomes, accounting for a substantial proportion of the observed variation. These findings reinforce existing international evidence that portable obstetric ultrasound improves maternal healthcare when integrated within responsive health systems supported by skilled personnel, functional referral mechanisms, and sustainable financing. Therefore, expanding equitable access to portable obstetric ultrasound services through coordinated health system strengthening is likely to contribute substantially to improved maternal and neonatal outcomes in rural Kenya.

5.2 Recommendations

The recommendations arising from the study are directed at key stakeholders responsible for maternal healthcare planning, financing, service delivery, community mobilisation, and evidence generation. They are informed by the study findings on access to and utilisation of portable obstetric ultrasound services and recognise that improving diagnostic access requires coordinated action at national, county, facility, community, and research levels. The recommendations therefore focus on strengthening the availability and functionality of ultrasound equipment, enhancing healthcare-provider capacity, reducing financial and logistical barriers, improving community awareness and service efficiency, and generating evidence to guide sustainable scale-up. The following recommendations are proposed for the respective stakeholders:

1. Ministry of Health (National Government)

The Ministry of Health should develop and finance a national scale-up programme for portable obstetric ultrasound services by allocating dedicated budgetary resources for procurement, maintenance and replacement of portable ultrasound devices across primary healthcare facilities. The Ministry should also develop national operational guidelines to standardise service delivery, quality assurance and equipment maintenance.

2. Kilifi County Government

The Kilifi County Department of Health should increase equitable distribution of portable ultrasound equipment to rural health facilities and establish preventive maintenance schedules to minimise service interruptions. County governments should also allocate adequate operational funds to ensure uninterrupted diagnostic services.

3. Health Facility Management

Hospital administrators should reduce waiting times by introducing appointment scheduling systems, increasing ultrasound service hours where demand is high, and ensuring continuous equipment functionality through routine servicing. Facilities should regularly monitor waiting times and service utilisation to improve efficiency.

4. Ministry of Health and County Governments

The Ministry of Health, in collaboration with county governments, should expand competency-based training programmes for nurses, midwives and clinical officers on portable obstetric ultrasound to address shortages of skilled personnel. Continuous professional development and periodic competency assessments should be institutionalised to maintain diagnostic quality.

5. National and County Governments

The national and county governments should reduce financial barriers by integrating portable obstetric ultrasound services into publicly funded maternal healthcare packages under the Social Health Authority (SHA). Subsidising diagnostic services will improve access among low-income pregnant women and reduce delays in seeking care.

6. Community Health Promoters (CHPs)

Community Health Promoters should strengthen community education and early pregnancy mobilisation by conducting regular household visits and community awareness campaigns on the importance of early antenatal attendance and timely ultrasound screening. This will improve awareness and increase timely utilisation of diagnostic services.

7. Healthcare Providers

Healthcare providers should continue routinely recommending portable obstetric ultrasound during antenatal care visits while providing comprehensive counselling on the benefits of early pregnancy screening and prompt referral for high-risk pregnancies. Consistent provider recommendations will further improve service uptake and maternal health outcomes.

8. Development Partners and Non-Governmental Organisations

Development partners should support county governments through technical and financial assistance for procurement of portable ultrasound devices, workforce training, tele-ultrasound innovations and digital health infrastructure to strengthen maternal diagnostic services in underserved areas.

9. Researchers and Academic Institutions

Future researchers should conduct longitudinal, quasi-experimental and multicentre studies to evaluate the long-term effects of portable obstetric ultrasound accessibility on maternal morbidity, maternal mortality, neonatal outcomes and cost-effectiveness across diverse healthcare settings in Kenya. Such evidence will strengthen policy decisions and support sustainable scale-up of portable obstetric ultrasound services.

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