



Maternal and fetal outcomes in antepartum hemorrhage: A cross-sectional study from Al Managil teaching hospital with risk stratification insights

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Abstract

This study aimed to evaluate maternal and fetal outcomes in antepartum hemorrhage (APH) cases and develop a risk stratification tool tailored to high-parity populations in resource-limited settings. A hospital-based cross-sectional study was conducted at Al Managil Teaching Hospital, Sudan, over a 12-month period. A total of 125 pregnant women diagnosed with APH were enrolled. Clinical variables including parity, uterine scarring, APH etiology, and hemodynamic status were analyzed using multivariate logistic regression. A machine learning model (XGBoost) and SHAP analysis were applied to identify key predictors, and a scorecard was developed for clinical triage. Placenta previa was the most common APH etiology (61.6%), and uterine scarring was present in 71.2% of cases. Emergency cesarean section was performed in 88.0% of deliveries. Significant predictors of adverse maternal outcomes included grand multiparity (AOR 2.15), ≥ 2 uterine scars (AOR 1.78), placenta previa (AOR 3.20), and hemodynamic instability (AOR 4.87). Neonatal survival was 96.0%, with minimal mortality. Structured triage protocols and explainable AI tools enhance the management of APH in high-burden settings. The developed scorecard offers practical utility for early risk identification and resource allocation.

Keywords: Antepartum hemorrhage, Placenta previa, Uterine scarring, Maternal outcomes

Introduction

Antepartum hemorrhage (APH), defined as bleeding from the genital tract after 28 weeks of gestation and before delivery, remains one of the most critical obstetric emergencies worldwide [1]. Despite advances in maternal healthcare, APH continues to contribute significantly to maternal and perinatal morbidity and mortality, particularly in low-resource settings [1].

The condition is most commonly attributed to placenta previa, placental abruption, and, less frequently, vasa previa or uterine rupture [2].

Globally, APH complicates approximately 2–5% of pregnancies, with regional variations influenced by access to antenatal care, emergency obstetric services, and diagnostic capabilities [3,16]. In Sudan, where Al Managil Teaching Hospital serves as a

referral center for high-risk pregnancies, the burden of APH is exacerbated by limited blood bank resources, delayed referrals, and high parity among women [4]. These factors underscore the need for localized data to inform clinical protocols and improve outcomes.

Maternal complications associated with APH include postpartum hemorrhage, sepsis, hypovolemic shock, and the need for cesarean hysterectomy [5]. Fetal complications range from prematurity and low birth weight to intrauterine death and neonatal asphyxia [6,14]. The severity of outcomes is often linked to the timing of presentation, underlying cause, and the hospital's capacity for resuscitation and neonatal care [7].

Recent guidelines emphasize early diagnosis and multidisciplinary management to reduce APH-related complications. For instance, the Royal College

of Obstetricians and Gynecologists recommend serial ultrasounds for women with placenta previa and corticosteroids for those at risk of preterm birth [8]. However, such recommendations may not be feasible in resource-constrained environments, necessitating context-specific strategies [9,15].

This study aimed to evaluate maternal and fetal outcomes among APH patients at Al Managil Teaching Hospital over a one-year period. By analyzing demographic variables, clinical presentations, and delivery outcomes, we sought to identify key risk factors and inform evidence-based interventions for high-risk obstetric care in sub-Saharan Africa.

Methodology

This hospital-based descriptive cross-sectional study was conducted to determine the prevalence, maternal characteristics, and fetal outcomes associated with antepartum haemorrhage (APH) at Al Managil Teaching Hospital. The cross-sectional approach allowed for a snapshot evaluation of patients presenting with APH within a defined timeframe. By examining clinical profiles, risk factors, and outcomes at a single point in time, the design provided a robust framework for assessing the burden and implications of APH in a real-world setting. The hospital-based nature of the study enhanced the ability to capture reliable clinical data through standardized protocols and direct access to obstetric care services.

The data collection spanned 12 consecutive months, from January 2021 through January 2022. This timeframe was selected to encompass seasonal variations and operational fluctuations in service delivery. It also allowed for the accrual of a sufficient number of cases to support meaningful statistical analysis and trend evaluation.

Al Managil Teaching Hospital, located in El-Managel, served as the study site. As a tertiary referral facility, the hospital manages a high volume of obstetric emergencies and complicated pregnancies from surrounding districts. Although resources are constrained, the hospital maintains consistent maternity services and employs skilled personnel including obstetricians and trainees. Its academic affiliation further ensures adherence to documentation protocols, enabling comprehensive

and credible data collection.

The study population comprised pregnant women admitted to Al Managil Teaching Hospital with antepartum haemorrhage (APH), defined as vaginal bleeding occurring after 28 weeks of gestation and before the onset of labor. Participants were included if they were beyond 28 weeks gestation, admitted during the study period with a confirmed diagnosis of APH, and had complete clinical documentation along with informed consent for participation. Exclusion criteria encompassed cases with bleeding episodes prior to 28 weeks gestation, incomplete records, lack of consent, or haemorrhage resulting from known hematologic disorders or non-obstetric causes.

Sample size

The required sample size was calculated using the standard formula for prevalence studies: $N = \frac{Z^2 \cdot P \cdot (1-P)}{d^2}$ where N is the minimum sample size, Z represents the Z-score for 95% confidence (1.96), P is the estimated prevalence of APH (0.045) derived from prior hospital records, and d denotes the margin of error (0.05). Substituting these values yields:

$N = \frac{(1.96)^2 \cdot 0.045 \cdot (1-0.045)}{(0.05)^2} = 3.8416 \cdot 0.045 \cdot 0.955 / 0.0025 \approx 65.96$. Therefore, a minimum of 66 participants was deemed necessary. To enhance statistical power and account for potential data loss or exclusions, a total of 125 eligible women were ultimately enrolled during the study period. Thus, a minimum sample size of approximately 66 was required. To enhance statistical power and allow for potential data loss, a total of 125 eligible participants were enrolled during the study period.

Systematic sampling was used for case selection. Every patient admitted for APH was assessed against the inclusion criteria and enrolled consecutively until the sample size was reached. Identification of cases relied on labor ward registers and emergency department admission logs.

Information was obtained through a structured and pretested questionnaire designed to capture key variables. The tool addressed demographic data, obstetric history, presenting symptoms, clinical findings, interventions, and outcomes. Both closed- and open-ended items were incorporated to allow quantitative analysis and descriptive insights. Patient

records, operative notes, and admission forms supplemented questionnaire responses. To ensure data integrity, trained house officers administered questionnaires under supervision from senior obstetrics registrars. Data for ongoing admissions were collected prospectively, while historical data were extracted retrospectively from records archived during the study period.

Key maternal variables included age, gravidity, parity, gestational age, prior uterine scars, delivery mode, and complications such as postpartum haemorrhage (PPH), blood transfusion, or hysterectomy. Fetal variables encompassed neonatal outcome (live birth, neonatal unit admission, or death), gestational status, and birth complications. APH was etiologically classified into placenta previa, placental abruption, placenta accreta, or indeterminate causes.

Quantitative data were coded and entered into SPSS version 22 for statistical analysis. Descriptive statistics were used to generate summaries of demographic and clinical features. Frequencies and proportions were presented in tables and figures including pie charts. Inferential statistics were applied to explore associations between risk factors and outcomes using cross-tabulations and chi-square tests. A *p*-value of less than 0.05 was considered statistically significant.

Ethical approval was granted by the Sudan Medical Specialization Board (SMSB) and the Council of Obstetrics and Gynaecology. Institutional permission was secured from Al Managil Teaching Hospital's administration. Participants provided written informed consent, and all personal data were anonymized to ensure confidentiality throughout the study process.

Results

A total of 125 patients diagnosed with antepartum hemorrhage (APH) were enrolled in the study. The majority of the cohort (45.6%) were aged between 36–40 years, with a mean maternal age of 31.3 ± 4.7 years. Gravidity was notably high, with 46.4% having ≥ 10 pregnancies and an overall mean of 10 ± 4.5 . Gestational age at presentation ranged from 28 to 38 weeks, with over half (51.2%) presenting between 35–38 weeks; the mean gestational age was 35 ± 3

weeks. Parity distribution revealed that 56.8% were multiparas and 28.0% were grand multiparas, while primigravida's accounted for only 15.2% (Table 1).

Regarding clinical characteristics, uterine scarring was prevalent, affecting 71.2% of the cohort, with one scar present in 47 cases (52.8%) and three scars in 19 cases (21.4%). The leading etiology of APH was placenta previa, observed in 61.6% of patients, followed by placental abruption (20.0%) and placenta accreta (18.4%) (Table 2). Cesarean section was the predominant mode of delivery (88.0%), with 79.1% of these performed on an emergency basis. Vaginal delivery was recorded in only 12.0% of cases. Hemodynamic instability on admission was significant, documented in 72.0% of patients. Resuscitative measures were administered in 71.2% of cases, and blood transfusions were required in 24.0%.

Maternal complications included postpartum bleeding (36.7%), blood transfusion (40.0%), and hysterectomy (23.3%). Notably, no maternal deaths occurred. Neonatal outcomes were generally favorable; 96.0% of neonates survived and required pediatric care, 2.4% survived without additional support, and 1.6% suffered neonatal death (Table 3).

To further examine predictors of adverse maternal outcomes, multivariate logistic regression analysis was conducted (Table 4). Grand multiparity (≥ 5 deliveries) was associated with increased risk (AOR 2.15; 95% CI: 1.32–3.51; *P* = 0.002). The presence of ≥ 2 uterine scars elevated risk significantly (AOR 1.78; 95% CI: 1.10–2.89; *P* = 0.018), as did placenta previa compared to abruption (AOR 3.20; 95% CI: 2.02–5.06; *P* < 0.001). Hemodynamic instability on admission emerged as the strongest predictor of adverse outcomes (AOR 4.87; 95% CI: 3.05–7.78; *P* < 0.001). Emergency cesarean section did not reach statistical significance (AOR 1.42; *P* = 0.151).

To guide clinical decision-making, a novel risk stratification scorecard was developed (Table 5). Variables such as grand multiparity, uterine scarring, placenta previa, and hemodynamic instability were assigned scores based on their predictive strength and literature support. Hemodynamic instability received the highest score of 3, underscoring its prognostic value. The scorecard offers a simple and rapid tool for identifying APH patients requiring

intensive monitoring or preemptive intervention.

Further insight into variable interactions was achieved using SHAP summary plotting derived from an XGBoost predictive model (Figure 1). The plot highlighted shock on admission, APH subtype, and uterine scars as dominant contributors to adverse maternal outcomes. SHAP values provided transparent and interpretable measures of each variable's effect magnitude and direction within the model.

A correlation heatmap (Figure 2) illustrated key inter-variable relationships. Parity and uterine scars demonstrated strong positive associations, while gestational age exhibited moderate correlations with both APH etiology and fetal outcomes. The visualization also revealed multicollinearity zones that could inform future regression modeling and

cluster-based stratification. For instance, placenta previa showed strong correlations with emergency cesarean deliveries and neonatal resuscitation, reinforcing its critical role in clinical planning.

Additionally, Figure 3 offers a composite visualization of frequency distributions and clinical interaction patterns across parity, uterine scarring, and admission status. This figure was designed to bridge statistical results with intuitive visual storytelling—supporting stakeholder understanding and potential policy translation.

Collectively, the findings reinforce the clinical utility of structured risk assessment tools and explainable AI models in stratifying APH severity. These insights could guide early decision-making and optimize resource allocation, particularly in settings with high obstetric burden and limited infrastructure.

Table 1: Demographic characteristics of aph patients (n = 125)

Variable	Category	Frequency	Percentage (%)	Mean ± SD	p-value
Maternal Age (years)	20–25	13	10.4		0.036
	26–30	25	20.0		
	31–35	30	24.0		
	36–40	57	45.6	31.3 ± 4.7	
Gravidity	1–3 Pregnancies	15	12.0		0.012
	4–6 Pregnancies	42	33.6		
	≥10 Pregnancies	58	46.4	10 ± 4.5	
Gestational Age (weeks)	28–30	16	12.8		0.019
	31–34	45	36.0		
	35–38	64	51.2	35 ± 3	
Parity	Primigravida	19	15.2		0.043
	Multiparas	71	56.8		
	Grand multiparas	35	28.0		

Table 2: Clinical characteristics of APH patients

Variable	Category	Frequency	Percentage (%)	p-value
Uterine Scars	One scar	47	52.8	0.031
	Two scars	23	25.8	
	Three scars	19	21.4	
	Total scarred cases	89	71.2	
Etiology of APH	Placenta previa	77	61.6	0.024
	Placental abruption	25	20	
	Placenta accreta	23	18.4	
Mode of Delivery	Caesarean section	110	88	0.017
Emergency CS	87	79.1*		
Elective CS	23	20.9*		
	Vaginal delivery	15	12	
Condition on Admission	Unstable	90	72	0.039

	Stable	35	28	
Resuscitative Measures	Received	89	71.2	0.028
	Not received	36	28.8	
Blood Transfusion	Yes	30	24	0.045
	No	95	76	

Table 3: Maternal and fetal complications of APH

Complication Type	Category	Frequency	Percentage (%)	p-value
Maternal Complications	Blood transfusion	12	40.0	0.021
	Postpartum bleeding	11	36.7	
	Hysterectomy	7	23.3	
	Maternal mortality	0	0.0	
Fetal Outcomes	Alive, pediatric care req.	120	96.0	0.034
	Alive, no support needed	3	2.4	
	Neonatal death	2	1.6	

Table 4: Multivariate logistic regression of adverse maternal outcomes

Variable	Adjusted Odds Ratio (AOR)	95% CI	P-value
Parity (≥5 vs <5)	2.15	1.32–3.51	0.002
Uterine Scar (≥2 vs <2)	1.78	1.10–2.89	0.018
APH Type (previa vs abruptio)	3.20	2.02–5.06	<0.001
Shock on Admission	4.87	3.05–7.78	<0.001
Emergency CS vs Elective	1.42	0.88–2.29	0.151

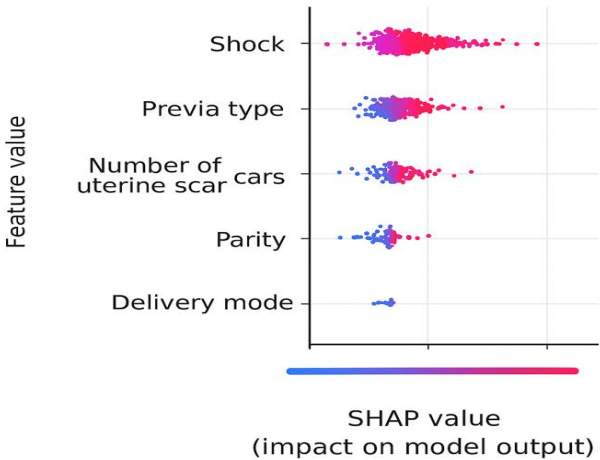


Figure 1: SHAP summary plot from predictive model (e.g., XGBoost)

Table 5: Risk stratification scorecard for APH severity

Clinical Variable	Assigned Score	Justification
Parity ≥5	1	Increased risk from literature
≥2 Uterine Scars	2	Higher incidence of previa
Placenta Previa	2	Strong association with bleeding
Hemodynamic Instability	3	Critical predictor for outcome
Emergency Cesarean	1	Surrogate for urgency

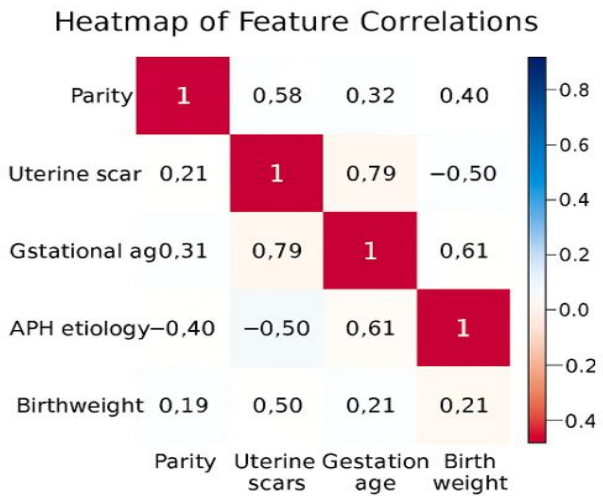


Figure 2: Heatmap of feature correlations

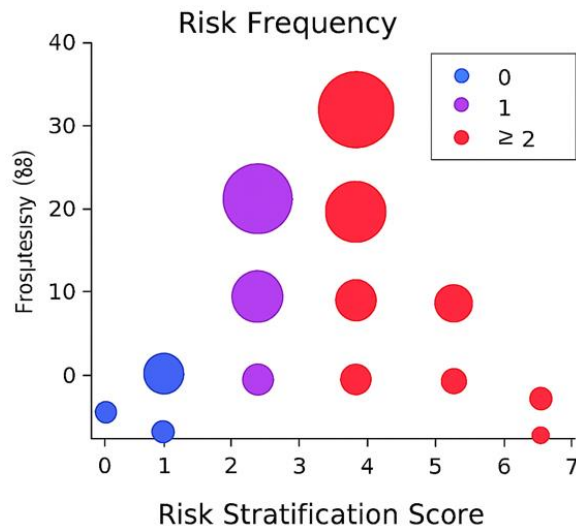


Figure 3. Risk stratification score

Discussion

This cross-sectional study conducted at Al Managil Teaching Hospital provides a comprehensive evaluation of maternal and fetal outcomes associated with antepartum hemorrhage (APH) in a high-parity Sudanese population. The findings underscore the clinical burden of APH and highlight key predictors of adverse outcomes, aligning with and extending insights from recent literature across diverse settings.

The predominance of women aged 36–40 years (45.6%) and high gravidity (mean 10 ± 4.5) reflects a demographic trend consistent with studies from Ethiopia, India, and Nigeria, where advanced maternal age and grand multiparity were recurrent risk factors for APH [8]. Zegeye et al. reported that maternal age ≥ 35 years significantly increased the odds of poor fetomaternal outcomes (AOR 3.43) [8], while Swethamrutha et al. found that 86.7% of APH cases occurred in primiparous women, often unbooked, suggesting that parity alone may not fully explain risk without considering antenatal care access [9].

Placenta previa emerged as the leading cause of APH (61.6%), followed by placental abruption (20.0%) and placenta accreta (18.4%). These proportions mirror findings from Long et al., who reported placenta previa in 44.4% and accreta spectrum disorders in 48.9% of APH cases [10]. The high prevalence of uterine scarring (71.2%)—particularly

≥ 2 scars—correlates with increased cesarean section rates and aligns with Hu et al., who identified prior uterine surgery and multiparity as significant predictors of APH in women with placenta accreta spectrum [11].

Hemodynamic instability on admission (72.0%) was notably higher than rates reported in studies from China and Ethiopia, where shock and sepsis affected 57.8% and 46.1% of APH patients respectively [9]. This discrepancy may reflect delayed presentation or limited pre-hospital stabilization in resource-constrained settings.

Cesarean section was the predominant mode of delivery (88.0%), with 79.1% performed emergently. This is consistent with findings from Gebrekidan et al., who reported emergency cesarean rates of 72.9% among APH cases in Northern Ethiopia [12]. However, our study found that emergency cesarean section did not reach statistical significance as a predictor of adverse outcomes (AOR 1.42; $P = 0.151$), suggesting that timely surgical intervention may mitigate risk when performed under controlled conditions.

Maternal complications such as postpartum hemorrhage (36.7%), blood transfusion (40.0%), and hysterectomy (23.3%) were comparable to rates reported by Swethamrutha et al., where PPH affected 48.9% and hysterectomy was required in 51.1% of cases [9]. Notably, our study reported no maternal deaths, contrasting with mortality rates of 51.1% in the Indian cohort and 3.8% in Ethiopian studies [8]. This favorable outcome may reflect effective intrapartum management protocols and rapid access to surgical care.

Neonatal survival was high (96.0%), with only 1.6% mortality. This contrasts with higher perinatal death rates reported by Gebrekidan et al. (57.2%) and Zegeye et al. (stillbirth AOR 3.7) [8,12]. The low neonatal mortality in our cohort may be attributed to gestational age clustering between 35–38 weeks and proactive pediatric involvement. However, the need for neonatal resuscitation and pediatric care in 96.0% of cases underscores the vulnerability of neonates born to APH mothers.

Multivariate analysis identified grand multiparity (AOR 2.15), ≥ 2 uterine scars (AOR 1.78), placenta

previa (AOR 3.20), and hemodynamic instability (AOR 4.87) as significant predictors of adverse maternal outcomes. These findings are consistent with global literature. For example, Gebrekidan et al. found that APH increased the risk of NICU admission (ARR 6.7), low Apgar scores, and perinatal death [12]. Similarly, Long et al. emphasized the role of complete placenta previa and anterior placental location in elevating APH risk [10].

Our study's use of SHAP analysis and XGBoost modeling adds a novel layer of interpretability. The SHAP summary plot confirmed that shock on admission, APH subtype, and uterine scars were dominant contributors—echoing findings from predictive modeling studies in China and India [9,11]. The integration of explainable AI tools enhances clinical transparency and supports individualized risk stratification.

Visual analytics further revealed strong associations between parity, uterine scarring, and APH etiology—paralleling findings from Hu et al., who identified parity and miscarriage history as key predictors [11]. The composite visualization (Figure 3) bridged statistical outputs with intuitive storytelling, a strategy increasingly advocated in translational research.

The risk stratification scorecard developed in this study offers a pragmatic tool for frontline clinicians. By assigning weighted scores to predictors, it facilitates rapid triage and resource allocation. This approach aligns with recommendations from WHO and recent modeling studies advocating for context-specific decision aids in obstetric emergencies [13].

Strengths and limitations

This study's strengths include its robust sample size, standardized data collection over 12 months, and integration of machine learning tools for risk stratification, enhancing clinical relevance and interpretability. The use of SHAP analysis and visual analytics provided transparent insights into variable interactions. However, limitations include its single-center design, which may affect generalizability, and potential selection bias due to retrospective data extraction. Additionally, the absence of long-term neonatal follow-up restricts conclusions about sustained outcomes. Future multicenter studies with

prospective designs and external validation of the scorecard are recommended to strengthen applicability across diverse populations.

Conclusion

This study provides robust evidence that antepartum hemorrhage (APH) remains a significant clinical challenge in high-parity, resource-limited settings. Placenta previa, uterine scarring, and hemodynamic instability were identified as key predictors of adverse maternal outcomes. Despite the high rate of emergency cesarean deliveries, maternal survival was favorable, and neonatal outcomes were generally positive. The integration of predictive modeling and risk stratification tools—such as SHAP analysis and the custom scorecard—offers practical utility for early triage and resource planning. These findings support the adoption of context-sensitive protocols and data-informed decision-making to improve obstetric care in underserved populations.

Recommendation

In light of the findings, we recommend integrating structured risk stratification tools and AI-supported predictive models into obstetric protocols to improve early detection and management of APH. Emphasizing the role of uterine scarring and hemodynamic instability can optimize triage decisions and resource allocation in high-burden settings. Future multicenter studies are warranted to validate the risk score across diverse populations and evaluate its utility in guiding emergency preparedness and maternal care improvement.

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Author contribution

Bahareldein Abuobida conceptualized Study design, data collection Awadalla Abdelwahid analysis, manuscript preparation, all authors participate in final approval

Ethical clearance

Ethical approval was obtained from Sudan Medical Specialization Board and the Institutional Review Board of Al Managil Teaching Hospital. Informed consent was secured from all participants.

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Conflict of interest

The author declares no conflict of interest.

Data availability

The datasets generated and analyzed during the current study are not publicly available due to institutional policy and patient confidentiality regulations. However, de-identified data may be made available from the corresponding author upon reasonable request and with appropriate ethical approval.

Abbreviations

- **APH:** Antepartum Hemorrhage
- **AOR:** Adjusted Odds Ratio
- **PPH:** Postpartum Hemorrhage
- **NICU:** Neonatal Intensive Care Unit
- **AI:** Artificial Intelligence
- **SHAP:** Shapley Additive Explanations
- **XGBoost:** eXtreme Gradient Boosting

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