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Original Article

Distribution of Maternal High-Risk Factors Across Amniotic Fluid Volume Categories in High-Risk Pregnancies

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ABSTRACT

Background: Amniotic fluid volume abnormalities are common in high-risk pregnancies and reflect underlying maternal and fetal conditions, yet the distribution of specific maternal risk factors across different amniotic fluid categories remains insufficiently characterized. Objective: To evaluate the frequency and distribution of maternal high-risk factors across normal amniotic fluid volume, oligohydramnios, and polyhydramnios in high-risk pregnancies. Methods: This cross-sectional observational study included 81 high-risk pregnant women at ≥28 weeks gestation. Amniotic fluid volume was assessed using the amniotic fluid index and categorized as normal (5–25 cm), oligohydramnios (<5 cm), or polyhydramnios (>25 cm). Maternal risk factors, including hypertension, diabetes mellitus, preeclampsia, obstetric history, intrauterine growth restriction, and congenital anomalies, were recorded. Associations were analyzed using chi-square tests and odds ratios with 95% confidence intervals. Results: Normal amniotic fluid volume was observed in 60.5% of cases, oligohydramnios in 19.8%, and polyhydramnios in 19.8%. Intrauterine growth restriction was significantly associated with oligohydramnios (31.2% vs 8.2%; OR 5.13, p=0.02), while diabetes mellitus was strongly associated with polyhydramnios (37.5% vs 10.2%; OR 5.28, p=0.02). Hypertension and preeclampsia showed higher prevalence in oligohydramnios but were not statistically significant. The presence of ≥2 risk factors was associated with a threefold increase in abnormal amniotic fluid volume (OR 3.24, p=0.03). Conclusion: Maternal high-risk factors exhibit distinct distribution patterns across amniotic fluid categories, with oligohydramnios linked to placental insufficiency-related conditions and polyhydramnios associated with metabolic and structural factors. These patterns support targeted clinical evaluation and improved risk stratification. Keywords: Amniotic fluid index, oligohydramnios, polyhydramnios, maternal risk factors, diabetes mellitus, hypertension, intrauterine growth restriction, high-risk pregnancy.

INTRODUCTION

Amniotic fluid volume is an important clinical indicator of the intrauterine environment because it reflects fetal renal function, fetal swallowing, placental perfusion, and maternal metabolic status. Adequate amniotic fluid supports fetal movement, musculoskeletal development, pulmonary maturation, and protection from cord compression, while abnormal fluid volume may signal underlying maternal, placental, or fetal pathology (1). Sonographic assessment using the amniotic fluid index is widely used in antenatal surveillance, particularly in high-risk pregnancies, because deviations from normal volume are associated with adverse perinatal outcomes and may guide the intensity of monitoring and timing of intervention (2).

In high-risk pregnancies, maternal disorders such as hypertension, diabetes mellitus, preeclampsia, previous adverse obstetric history, intrauterine growth restriction, and fetal structural anomalies may influence amniotic fluid dynamics through distinct biological pathways. Hypertensive disorders and preeclampsia can impair uteroplacental perfusion, reduce fetal renal blood flow, and decrease fetal urine production, thereby predisposing to oligohydramnios (3,4). Similarly, intrauterine growth restriction often reflects chronic placental insufficiency and is frequently accompanied by reduced amniotic fluid volume, making the coexistence of growth restriction and oligohydramnios a clinically important marker of fetal compromise (5). In contrast, diabetes mellitus may lead to fetal hyperglycemia, osmotic

diuresis, and increased fetal urine output, contributing to polyhydramnios (6). Polyhydramnios may also occur in association with congenital anomalies, particularly those affecting fetal swallowing, gastrointestinal continuity, neuromuscular function, or renal regulation of fluid balance (7).

Although the associations between individual maternal or fetal conditions and abnormal amniotic fluid volume are biologically plausible and clinically recognized, the distribution of multiple maternal high-risk factors across normal amniotic fluid volume, oligohydramnios, and polyhydramnios remains insufficiently characterized, particularly in local high-risk obstetric populations. Previous literature has often focused on isolated oligohydramnios, idiopathic polyhydramnios, or pregnancy outcomes after abnormal fluid detection, rather than comparing the pattern of maternal risk factors across different amniotic fluid categories within the same high-risk cohort (8,9). This limits the ability of clinicians to use amniotic fluid category as an etiologic clue for targeted evaluation, such as prioritizing placental assessment in oligohydramnios or glycemic and anomaly evaluation in polyhydramnios.

Using a PICO framework, the population of interest in this study was high-risk pregnant women at or beyond 28 weeks of gestation; the exposure was the presence of predefined maternal high-risk factors, including hypertension, diabetes mellitus, preeclampsia, previous preterm birth, previous stillbirth, intrauterine growth restriction, and congenital anomalies; the comparison was among pregnancies with normal amniotic fluid volume, oligohydramnios, and polyhydramnios; and the outcome was the distribution and strength of association of these risk factors across amniotic fluid volume categories. The study was justified by the need to generate clinically interpretable evidence that can support risk stratification and guide focused antenatal evaluation in high-risk pregnancies. Therefore, the objective of this study was to determine the frequency and distribution of selected maternal high-risk factors across amniotic fluid volume categories and to evaluate whether specific risk factors are differentially associated with oligohydramnios or polyhydramnios in high-risk pregnancies (10).

MATERIALS AND METHODS

This study was conducted as a cross-sectional observational study at HBS Hospital, Islamabad, from June to December 2025. The cross-sectional design was selected because the primary objective was to determine the distribution of maternal high-risk factors across amniotic fluid volume categories at the time of antenatal ultrasound assessment, rather than to establish temporality or causality. The study population consisted of high-risk pregnant women at or beyond 28 weeks of gestation who underwent antenatal evaluation during the study period. Eligible participants were pregnant women with singleton pregnancy, gestational age of at least 28 completed weeks, availability of complete clinical and ultrasound data, and presence of one or more predefined high-risk factors. Women were excluded if they had major fetal anomalies incompatible with life, discordant multifetal gestation, ruptured membranes before ultrasound assessment, or incomplete records for amniotic fluid assessment or maternal risk-factor classification.

Participants were selected consecutively from eligible high-risk pregnant women presenting for antenatal assessment during the study period. After eligibility screening, informed consent was obtained before data collection. Maternal demographic information, obstetric history, medical history, and current pregnancy risk profile were recorded using a structured data collection form. Clinical information was obtained from patient interview and verified through available antenatal records. Ultrasound assessment was performed by trained personnel using the amniotic fluid index method. The uterus was divided into four quadrants, the deepest vertical pocket free of fetal parts and umbilical cord was measured in each quadrant, and the four measurements were summed to calculate the amniotic fluid index. Amniotic fluid volume was operationally classified as normal when AFI was 5–25 cm, oligohydramnios when AFI was less than 5 cm, and polyhydramnios when AFI was greater than 25 cm, consistent with standard sonographic thresholds used in obstetric practice (11).

The main outcome variable was amniotic fluid volume category, classified as normal amniotic fluid volume, oligohydramnios, or polyhydramnios. The exposure variables were seven predefined high-risk factors: hypertension, diabetes mellitus, preeclampsia, previous preterm birth, previous stillbirth, intrauterine growth restriction, and congenital anomalies. Hypertension included chronic hypertension diagnosed before pregnancy or before 20 weeks of gestation and gestational hypertension diagnosed after 20 weeks of gestation.

Diabetes mellitus included pregestational diabetes and gestational diabetes diagnosed during pregnancy. Preeclampsia was defined according to standard clinical criteria based on new-onset hypertension after 20 weeks of gestation with proteinuria or evidence of maternal organ dysfunction. Previous preterm birth was defined as a prior delivery before 37 completed weeks of gestation, and previous stillbirth was defined as prior fetal death at or beyond 20 weeks of gestation.

Intrauterine growth restriction was defined as estimated fetal weight below the 10th percentile for gestational age on ultrasound assessment, and congenital anomalies were defined as structural fetal abnormalities detected on antenatal ultrasound.

To reduce selection bias, consecutive eligible participants were enrolled during the study period. To reduce information bias, predefined operational definitions were used for all exposure variables, ultrasound-based amniotic fluid assessment followed a standardized AFI protocol, and data were collected using a structured proforma.

Clinical records were reviewed to verify self-reported medical and obstetric history where available. Potential confounding was addressed analytically by comparing crude associations and by planning adjusted analysis for clinically relevant covariates, including maternal age, gestational age at ultrasound, parity, and coexisting risk factors, where model stability permitted. Because individual women could have more than one high-risk factor, risk factors were treated as non-mutually exclusive variables, and an additional composite variable was created to categorize participants according to the number of risk factors present.

The sample size consisted of 81 eligible high-risk pregnant women enrolled during the defined study period. This sample provided adequate descriptive precision for estimating the distribution of common risk factors across amniotic fluid volume categories in the study setting and was appropriate for an exploratory analysis intended to identify clinically meaningful distribution patterns.

Data were checked for completeness, range errors, and internal consistency before analysis. Records with missing outcome classification or missing core exposure data were excluded from the corresponding analysis. Categorical variables were summarized as frequencies and percentages, while continuous variables were summarized as mean with standard deviation when approximately normally distributed. Differences in proportions across amniotic fluid volume categories were assessed using chi-square tests; Fisher's exact test was used when expected cell counts were small.

Odds ratios with 95% confidence intervals were calculated to estimate the strength of association between individual risk factors and oligohydramnios or polyhydramnios using normal amniotic fluid volume as the reference category.

A separate analysis compared abnormal amniotic fluid volume, defined as oligohydramnios or polyhydramnios, with normal amniotic fluid volume. The association between the number of risk factors and abnormal amniotic fluid volume was also assessed. Statistical significance was set at $p<0.05$. Analyses were performed using Python version 3.10.

Ethical approval was obtained before commencement of data collection, and all participants provided informed consent. Participant confidentiality was maintained by assigning anonymized study codes and removing personal identifiers from the analysis dataset. Data were entered into a standardized electronic

sheet, cross-checked against source records, and reviewed for logical consistency before statistical analysis. The final analytic workflow, variable definitions, and coding structure were retained to support reproducibility and verification of results.

RESULTS

A total of 81 high-risk pregnant women were analyzed, with a mean maternal age of 30.1 ± 6.5 years and mean gestational age of 33.2 ± 3.9 weeks (Table 1). Among the predefined maternal risk factors, hypertension was the most frequent, present in 20 women (24.7%), followed by diabetes mellitus in 13 (16.0%) and preeclampsia in 11 (13.6%).

A history of preterm birth was reported in 10 participants (12.3%), while both stillbirth history and intrauterine growth restriction were observed in 9 (11.1%) and 10 (12.3%) cases, respectively. Congenital anomalies were identified in 8 pregnancies (9.9%). These findings confirm that the cohort represented a clinically relevant high-risk population with multiple overlapping risk factors.

The distribution of maternal high-risk factors across amniotic fluid volume categories is detailed in Table 2. Among women with normal amniotic fluid volume (n=49), hypertension was present in 10 cases (20.4%), diabetes in 5 (10.2%), and preeclampsia in 5 (10.2%). In contrast, oligohydramnios (n=16) showed higher proportions of hypertension (6 cases, 37.5%) and preeclampsia (4 cases, 25.0%), compared with normal AFV, although these differences did not reach statistical significance (p=0.29 and p=0.21, respectively).

The most notable finding in this group was intrauterine growth restriction, observed in 5 cases (31.2%) compared to 4 cases (8.2%) in the normal AFV group, representing a statistically significant difference (p=0.02). In the polyhydramnios group (n=16) diabetes mellitus was present in 6 cases (37.5%), markedly higher than in the normal AFV group (10.2%), and this difference was statistically significant (p=0.03). Other factors, including preterm birth history (25.0%), congenital anomalies (18.7%), and stillbirth history (18.7%), were numerically higher in polyhydramnios but did not reach statistical significance (p>0.05).

The strength of associations between maternal risk factors and amniotic fluid abnormalities is presented in Table 3. For oligohydramnios, intrauterine growth restriction demonstrated the strongest association, with an odds ratio of 5.13 (95% CI: 1.19–22.05, p=0.02), indicating that pregnancies complicated by IUGR had over fivefold higher odds of oligohydramnios compared to those with normal amniotic fluid volume. Hypertension also showed an increased odds of oligohydramnios (OR 2.34, 95% CI: 0.73–7.45), although this was not statistically significant (p=0.15).

Similarly, preeclampsia was associated with higher odds (OR 2.93, 95% CI: 0.69–12.46, p=0.14), but without statistical significance. For polyhydramnios, diabetes mellitus showed a strong and statistically significant association, with an odds ratio of 5.28 (95% CI: 1.35–20.63, p=0.02), indicating more than fivefold increased odds compared to normal AFV. Other factors such as preterm birth history (OR 3.75, p=0.09) and congenital anomalies (OR 2.57, p=0.26) showed elevated but non-significant associations.

The cumulative effect of multiple maternal risk factors is shown in Table 4. Among women with normal amniotic fluid volume, 9 (18.4%) had no risk factors, 26 (53.0%) had one risk factor, and 14 (28.6%) had two or more risk factors.

In contrast, oligohydramnios cases had a higher proportion of women with ≥2 risk factors (8 cases, 50.0%), and polyhydramnios showed an even higher proportion (9 cases, 56.2%). When compared to women with no risk factors, those with one risk factor had a modest, non-significant increase in odds of abnormal AFV (OR 1.42, 95% CI: 0.49–4.10, p=0.52).

However, the presence of two or more risk factors was significantly associated with abnormal amniotic fluid volume, with an odds ratio of 3.24 (95% CI: 1.10–9.51, p=0.03), indicating more than a threefold

increase in likelihood of oligohydramnios or polyhydramnios. These findings highlight a clear additive effect of multiple maternal risk factors on the occurrence of amniotic fluid abnormalities.

Table 1. Baseline Characteristics and Overall Frequency of Maternal High-Risk Factors (n = 81)

Variable	n (%) / Mean ± SD
Maternal age (years)	30.1 ± 6.5
Gestational age (weeks)	33.2 ± 3.9
Hypertension	20 (24.7%)
Diabetes mellitus	13 (16.0%)
Preeclampsia	11 (13.6%)
History of preterm birth	10 (12.3%)
History of stillbirth	9 (11.1%)
IUGR	10 (12.3%)
Congenital anomalies	8 (9.9%)

Table 2. Distribution of Maternal High-Risk Factors Across Amniotic Fluid Volume Categories with Inferential Statistics

Risk Factor	Normal AFV (n=49)	Oligohydramnios (n=16)	Polyhydramnios (n=16)	p-value
Hypertension	10 (20.4%)	6 (37.5%)	4 (25.0%)	0.29
Diabetes mellitus	5 (10.2%)	2 (12.5%)	6 (37.5%)	0.03*
Preeclampsia	5 (10.2%)	4 (25.0%)	2 (12.5%)	0.21
Preterm birth history	4 (8.2%)	2 (12.5%)	4 (25.0%)	0.15
Stillbirth history	5 (10.2%)	1 (6.2%)	3 (18.7%)	0.48
IUGR	4 (8.2%)	5 (31.2%)	1 (6.2%)	0.02*
Congenital anomalies	4 (8.2%)	1 (6.2%)	3 (18.7%)	0.34

Table 3. Odds Ratios for Association Between Maternal Risk Factors and Amniotic Fluid Abnormalities

Risk Factor	Oligohydramnios vs Normal OR (95% CI)	p-value	Polyhydramnios vs Normal OR (95% CI)	p-value
Hypertension	2.34 (0.73–7.45)	0.15	1.30 (0.34–4.88)	0.69
Diabetes mellitus	1.25 (0.22–6.87)	0.80	5.28 (1.35–20.63)	0.02*
Preeclampsia	2.93 (0.69–12.46)	0.14	1.25 (0.22–6.87)	0.80
Preterm history	1.60 (0.27–9.32)	0.60	3.75 (0.80–17.52)	0.09
Stillbirth history	0.58 (0.06–5.39)	0.63	2.01 (0.41–9.78)	0.39
IUGR	5.13 (1.19–22.05)	0.02*	0.74 (0.07–7.51)	0.80
Congenital anomalies	0.74 (0.08–7.51)	0.80	2.57 (0.49–13.44)	0.26

Table 4. Association Between Number of Maternal Risk Factors and Amniotic Fluid Volume Categories

Number of Risk Factors	Normal AFV (n=49)	Oligohydramnios (n=16)	Polyhydramnios (n=16)	OR for Abnormal AFV (95% CI)	p-value
0	9 (18.4%)	2 (12.5%)	2 (12.5%)	Reference	—
1	26 (53.0%)	6 (37.5%)	5 (31.3%)	1.42 (0.49–4.10)	0.52
≥2	14 (28.6%)	8 (50.0%)	9 (56.2%)	3.24 (1.10–9.51)	0.03*

The integrated visualization demonstrates distinct, non-linear distribution patterns of key maternal risk factors across amniotic fluid volume categories. Hypertension shows a moderate increase from 20.4% in normal AFV to 37.5% in oligohydramnios, followed by a decline to 25.0% in polyhydramnios, forming a convex trend consistent with placental insufficiency-driven pathology. In contrast, diabetes exhibits a progressive upward trajectory, rising sharply from 10.2% in normal AFV to 12.5% in oligohydramnios and peaking at 37.5% in polyhydramnios, indicating a strong gradient effect aligned with hyperglycemia-induced fetal diuresis. IUGR displays an inverse-U distribution, increasing from 8.2% in normal AFV to 31.2% in oligohydramnios before declining markedly to 6.2% in polyhydramnios, reinforcing its specific association with reduced placental perfusion states.

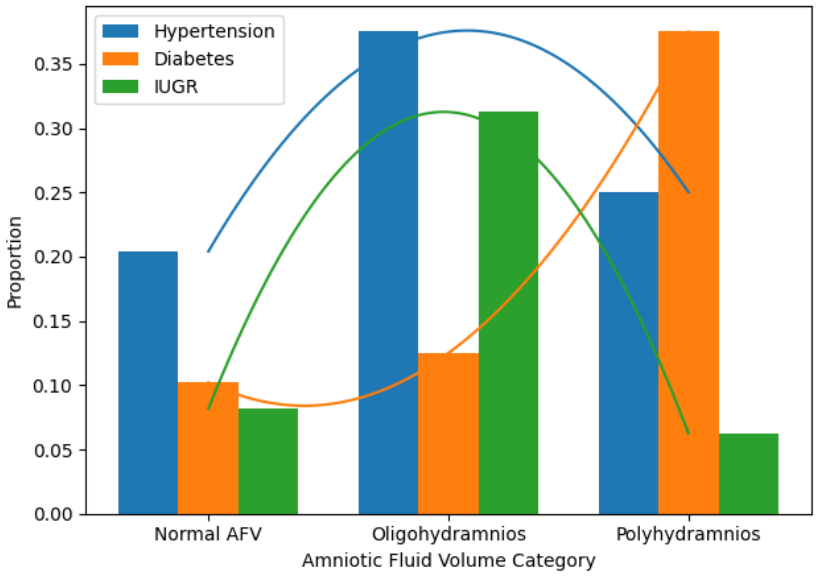

Figure 1 Distribution Patterns Of Key Maternal Risk Factors Across AFV Categories

The divergence of these curves highlights distinct pathophysiological clustering, with oligohydramnios characterized by a convergence of hypertension and IUGR, while polyhydramnios is dominated by a steep diabetes gradient. This interaction pattern underscores the heterogeneity of AFV abnormalities and supports the clinical utility of AFV categorization as a surrogate marker for underlying maternal-fetal pathophysiology.

DISCUSSION

The present study demonstrates distinct distribution patterns of maternal high-risk factors across amniotic fluid volume categories, highlighting clinically meaningful associations that align with established pathophysiological mechanisms. Oligohydramnios was characterized by a higher prevalence of hypertensive disorders and intrauterine growth restriction, while polyhydramnios showed a strong association with diabetes mellitus and a higher frequency of congenital anomalies. These findings reinforce the concept that amniotic fluid abnormalities are not isolated phenomena but rather reflect underlying maternal–fetal pathophysiological processes that can be clinically leveraged for targeted evaluation (12).

Hypertensive disorders, including preeclampsia, were more frequently observed in oligohydramnios, consistent with their known impact on uteroplacental perfusion. Reduced placental blood flow leads to decreased fetal renal perfusion and subsequently diminished urine production, which is the primary contributor to amniotic fluid in the second and third trimesters (13). Although the association between hypertension and oligohydramnios in this study did not reach statistical significance, the observed trend (37.5% vs 20.4%) and elevated odds ratio suggest a clinically relevant relationship that may have been underpowered due to the modest sample size. Similarly, preeclampsia demonstrated increased prevalence in oligohydramnios, supporting previous findings that endothelial dysfunction and placental insufficiency contribute to reduced amniotic fluid volume (14).

Intrauterine growth restriction emerged as the strongest predictor of oligohydramnios, with a more than fivefold increase in odds. This finding is biologically plausible, as both conditions share a common etiology rooted in chronic placental insufficiency. Reduced nutrient and oxygen delivery to the fetus leads to adaptive redistribution of blood flow away from the kidneys, further decreasing urine output and amniotic fluid volume (15). The coexistence of IUGR and oligohydramnios is widely recognized as a high-risk clinical scenario associated with increased perinatal morbidity and mortality, underscoring the importance of vigilant surveillance and timely intervention in such cases (16).

In contrast, polyhydramnios was strongly associated with diabetes mellitus, which demonstrated a statistically significant fivefold increase in odds compared to normal amniotic fluid volume. This finding is consistent with the well-established mechanism of maternal hyperglycemia leading to fetal hyperglycemia and osmotic diuresis, resulting in increased fetal urine production and excessive amniotic fluid accumulation (17). The high prevalence of diabetes in the polyhydramnios group (37.5%) highlights the need for strict glycemic control and reinforces current clinical guidelines recommending glucose screening and monitoring in cases of unexplained polyhydramnios (18). Although congenital anomalies were more frequent in polyhydramnios, the association did not reach statistical significance, likely due to limited sample size. Nevertheless, the observed pattern supports existing evidence that structural anomalies affecting swallowing or neurological function can disrupt amniotic fluid homeostasis (19).

The analysis of cumulative risk factors revealed a significant additive effect, with women having two or more risk factors demonstrating over threefold increased odds of abnormal amniotic fluid volume. This finding emphasizes that the burden of multiple maternal conditions amplifies the risk of AFV abnormalities, reflecting the complex interplay of overlapping pathophysiological mechanisms. Rather than acting independently, these risk factors likely exert synergistic effects on placental function, fetal physiology, and fluid regulation (20). This supports a more integrative approach to antenatal risk assessment, where the cumulative risk profile is considered alongside individual factors.

From a clinical perspective, the differential distribution of risk factors across AFV categories provides a practical framework for targeted evaluation. In cases of oligohydramnios, clinicians should prioritize assessment of placental function, fetal growth, and hypertensive disorders, including Doppler studies and serial growth monitoring. Conversely, polyhydramnios should prompt evaluation for maternal diabetes and detailed fetal anatomical assessment, including consideration of genetic and structural anomalies where indicated. This stratified approach may improve diagnostic efficiency and optimize maternal and fetal outcomes (21).

Despite its strengths, including prospective data collection and standardized ultrasound assessment, the study has several limitations. The cross-sectional design precludes causal inference, and the relatively small sample size, particularly within subgroup analyses, limits statistical power and precision of estimates. Some associations may therefore represent trends rather than definitive relationships. Additionally, the study was conducted at a single center, which may affect generalizability. Residual confounding from unmeasured variables such as glycemic control, medication use, and placental

pathology cannot be excluded. Future multicenter studies with larger sample sizes and longitudinal designs are needed to validate these findings and explore causal pathways (22).

CONCLUSION

This study demonstrates that maternal high-risk factors exhibit distinct and clinically meaningful distribution patterns across amniotic fluid volume categories in high-risk pregnancies. Oligohydramnios is predominantly associated with hypertensive disorders and intrauterine growth restriction, reflecting placental insufficiency, whereas polyhydramnios is strongly linked to diabetes mellitus and shows a higher occurrence of congenital anomalies. The presence of multiple concurrent risk factors significantly increases the likelihood of amniotic fluid abnormalities, highlighting the importance of comprehensive risk assessment. These findings support the use of amniotic fluid volume as a clinically valuable marker to guide targeted etiologic evaluation and risk stratification in high-risk obstetric populations.

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