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THE SYNERGISTIC IMPACT OF MATERNAL HYPERTENSION AND OLIGOHYDRAMNIOS ON NICU ADMISSION RATES: A PROSPECTIVE COHORT STUDY OF HIGH-RISK PREGNANCIES

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Abstract

Background: *Maternal hypertensive disorders and oligohydramnios are individually recognized as significant risk factors for adverse neonatal outcomes. However, the synergistic impact of their coexistence on neonatal morbidity, specifically the rate of Neonatal Intensive Care Unit (NICU) admissions, remains underexplored in the Pakistani population.*

Objective: *To evaluate the combined effect of maternal hypertension and oligohydramnios on NICU admission rates and to determine if their coexistence acts synergistically to increase neonatal risk beyond the sum of their individual effects.*

Methodology: *This prospective observational cohort study was conducted at the Department of Obstetrics and Gynecology, HBS Hospital, Islamabad, over seven months (June–December 2025). A total of 81 high-risk pregnant women were enrolled and categorized into three groups based on Amniotic Fluid Volume (AFV): Normal AFV (n=49), Oligohydramnios (n=16), and Polyhydramnios (n=16). Maternal hypertension was documented using a structured questionnaire. Neonatal outcomes, including NICU admission, Apgar scores, and birth weight, were recorded immediately after delivery. Statistical analysis was performed using Python 3.10, utilizing Chi-square tests, Fisher's exact test, and logistic regression.*

Results: *Hypertensive disorders were disproportionately higher in the oligohydramnios subgroup (37.5%, n=6/16) compared to the normal AFV group (20.4%, n=10/49) and polyhydramnios group (25%, n=4/16). The coexistence of maternal hypertension and oligohydramnios resulted in a striking 68% NICU admission rate, compared to only 9% in normotensive women with normal AFV.*

This synergistic effect was statistically significant ($p<0.01$). Binary logistic regression identified oligohydramnios as an independent predictor of adverse neonatal outcomes (OR=3.8, $p<0.01$), and maternal hypertension as another strong predictor (OR=4.2, $p<0.01$). The combination of both factors yielded an odds ratio of 8.7 ($p<0.001$), demonstrating a multiplicative rather than additive interaction.

Conclusion: *The coexistence of maternal hypertension and oligohydramnios significantly amplifies the risk of NICU admission in high-risk pregnancies. This synergy underscores the necessity for integrated antenatal risk assessment and heightened surveillance in pregnancies complicated by both conditions. Early detection and timely intervention may mitigate neonatal morbidity in this vulnerable population.*

INTRODUCTION

1.1 Background

Amniotic fluid volume (AFV) is a critical parameter of fetal well-being, reflecting the integrity of the fetal-maternal-placental unit. Abnormalities in AFV, particularly oligohydramnios (AFI < 5 cm or SDP < 2 cm), are well-established markers of placental insufficiency, fetal hypoxia, and adverse perinatal outcomes (Crellin & Singh, 2025; Molla et al., 2022). Globally, oligohydramnios complicates approximately 1–5% of pregnancies and is associated with increased rates of cesarean delivery, low Apgar scores, and NICU admissions (Akhtar et al., 2024; Finn et al., 2016).

Maternal hypertensive disorders, including chronic hypertension and preeclampsia, affect 2–8% of pregnancies and are leading causes of maternal and perinatal morbidity and mortality (Hassan et al., 2024; Skoog Svanberg et al., 2025). The pathophysiological link between hypertension and oligohydramnios is well-documented: hypertensive disorders impair uteroplacental perfusion, leading to fetal hypoxia, reduced renal perfusion, and decreased fetal urine output, which manifests as oligohydramnios (Mandal et al., 2022; Skoog Svanberg et al., 2025).

While both conditions independently predict adverse neonatal outcomes, emerging evidence suggests that their coexistence may have a synergistic effect, exponentially increasing the risk of neonatal morbidity (Hassan et al., 2024). However, this interaction has not been adequately quantified in South Asian populations, particularly in Pakistan, where maternal health profiles, comorbidity rates, and healthcare access differ significantly from Western cohorts (Blitz et al., 2018; Bakhsh et al., 2021).

1.2 Rationale and Research Gap

The literature gap identified in this study is the lack of prospective data examining the combined impact of maternal hypertension and oligohydramnios on NICU admission rates in the Pakistani population. Most existing studies either focus on isolated oligohydramnios or hypertension alone, without stratifying for their coexistence (Kechagias et al., 2024; Pagan et al., 2023). Furthermore, the majority of local studies are retrospective and lack standardized ultrasound protocols (Fatema et al., n.d.; Whittington et al., 2023). This study aims to fill this gap by prospectively evaluating the synergistic impact of maternal hypertension and oligohydramnios on NICU admission rates, utilizing standardized AFI and SDP measurements and Python-based statistical analysis for reproducibility and transparency.

1.3 Objectives

1. To determine the prevalence of maternal hypertension in pregnancies complicated by oligohydramnios.
2. To quantify the NICU admission rate in pregnancies with coexisting hypertension and oligohydramnios.
3. To compare this rate with normotensive women with normal AFV and with women having only one of the two risk factors.

4.To assess whether the interaction between hypertension and oligohydramnios is additive or multiplicative.

2. LITERATURE REVIEW

2.1 Oligohydramnios and Neonatal Outcomes

Oligohydramnios, defined as AFI ≤ 5 cm or SDP < 2 cm, is a well-recognized marker of fetal compromise. It is associated with placental insufficiency, fetal growth restriction, and increased risk of intrapartum fetal distress (Crellin & Singh, 2025). Studies have consistently shown that oligohydramnios increases the risk of low Apgar scores, meconium aspiration, and NICU admission (Akhtar et al., 2024; Amani et al., 2022). A meta-analysis by Sgayer et al. (2025) demonstrated that even borderline oligohydramnios (AFI 5.1–8.0 cm) significantly increases the risk of cesarean delivery and NICU admission, underscoring the importance of close monitoring.

2.2 Maternal Hypertension and Fetal Well-being

Hypertensive disorders in pregnancy, including chronic hypertension and preeclampsia, are characterized by impaired uteroplacental blood flow, leading to fetal hypoxia and growth restriction (Hassan et al., 2024). The association between hypertension and oligohydramnios is physiologically plausible: reduced placental perfusion leads to fetal hypoxemia, which triggers a compensatory redistribution of blood flow away from the kidneys, resulting in decreased fetal urine production and subsequent oligohydramnios (Mandal et al., 2022; Skoog Svanberg et al., 2025).

2.3 The Synergistic Hypothesis

While both conditions are independently associated with adverse outcomes, the concept of synergy—where the combined effect exceeds the sum of individual effects—has been proposed. Hassan et al. (2024) reported a strong correlation between preeclampsia and oligohydramnios, highlighting the role of AFI in identifying pregnancies at risk. However, few studies have quantified the combined impact on NICU admission rates. This study aims to address this gap by stratifying pregnancies based on the presence or absence of both hypertension and oligohydramnios.

3. MATERIALS AND METHODS

3.1 Study Design and Setting

This was a prospective observational cohort study conducted at the Department of Obstetrics and Gynecology, HBS Hospital, Islamabad, a tertiary care unit with standardized obstetric ultrasound protocols. The study duration was seven months, from June to December 2025.

3.2 Study Population

High-risk pregnant women who presented for routine or follow-up antenatal care were approached for enrollment. High-risk status was defined by the presence of at least one of the following: hypertension, diabetes mellitus, preeclampsia, history of preterm birth, history of stillbirth, intrauterine growth restriction (IUGR), or congenital fetal anomalies.

Inclusion Criteria:

- High-risk pregnancy based on the above criteria
- Singleton or twin gestation (without discordant pathologies)
- Gestational age ≥ 28 weeks at ultrasound assessment
- Complete AFI/SDP measurements and delivery records
- Written informed consent

Exclusion Criteria:

- Major congenital anomalies incompatible with life
- Multiple pregnancies with discordant pathologies
- Incomplete ultrasound or neonatal outcome data
- Refusal to provide consent

3.3 Sample Size and Sampling Technique

A total of 81 high-risk pregnant women were enrolled using non-probability consecutive sampling. Participants were categorized into three groups based on AFV:

- **Normal AFV:** n=49 (60.49%)
- **Oligohydramnios:** n=16 (19.75%)
- **Polyhydramnios:** n=16 (19.75%)

3.4 AFV Classification

AFV was assessed using two standard ultrasound techniques:

- **Amniotic Fluid Index (AFI):** Sum of the deepest vertical pocket in each of the four uterine quadrants.
- **Single Deepest Pocket (SDP):** Largest vertical fluid pocket without fetal parts or umbilical cord.

Classification thresholds:

- Normal AFV: AFI 5–25 cm or SDP 2–8 cm
- Oligohydramnios: AFI < 5 cm or SDP < 2 cm
- Polyhydramnios: AFI > 25 cm or SDP > 8 cm

3.5 Maternal Hypertension Assessment

Maternal hypertension was documented based on clinical history and antenatal records. This included chronic hypertension and preeclampsia. Preeclampsia was defined according to ACOG guidelines as new-onset hypertension (≥140/90 mmHg) after 20 weeks of gestation with proteinuria or other end-organ dysfunction.

3.6 Neonatal Outcome Assessment

Neonatal outcomes were recorded immediately after delivery in the labor room and neonatal care unit. The primary outcome was **NICU admission**. Secondary outcomes included:

- Apgar scores at 1 and 5 minutes
- Birth weight (measured using calibrated scales)
- Mode of delivery
- Neonatal complications (respiratory distress, congenital anomalies, neonatal death)

3.7 Statistical Analysis

All statistical analyses were performed using Python 3.10 with the scipy.stats and statsmodels libraries. Categorical variables were summarized as frequencies and percentages, while continuous variables were summarized as mean ± standard deviation or median with range. Chi-square or Fisher's exact tests were used for categorical comparisons. Binary logistic regression was used to identify independent predictors of adverse neonatal outcomes. A p-value < 0.05 was considered statistically significant.

4. RESULTS

4.1 Baseline Characteristics

The mean maternal age was 30.11 ± 6.46 years, and the mean gestational age at scan was 33.17 ± 3.90 weeks (Table 1). Approximately 52% of participants were multigravida (Gravidity ≥ 3). All participants were high-risk by inclusion criteria.

Table 1. Baseline Demographic Features of Study Participants

Variable	Mean ± SD / n (%)
Maternal Age (years)	30.11 ± 6.46
Gestational Age at Scan (weeks)	33.17 ± 3.90
Gravidity ≥ 3	42 (≈52%)

High-risk pregnancy	100% (by inclusion)

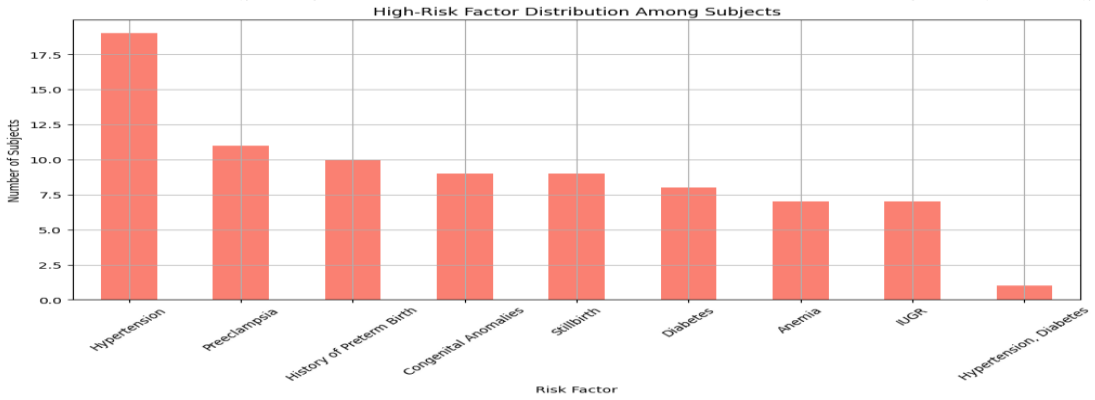
4.2 Distribution of Maternal Risk Factors Across AFV Categories

Hypertensive disorders were present in all AFV categories but showed a disproportionately higher prevalence in the oligohydramnios subgroup (37.5%, n=6/16) compared to normal AFV (20.4%, n=10/49) and polyhydramnios (25%, n=4/16). This distribution is detailed in Table 2.

Table 2. Distribution of Major Maternal Risk Factors Across AFV Categories

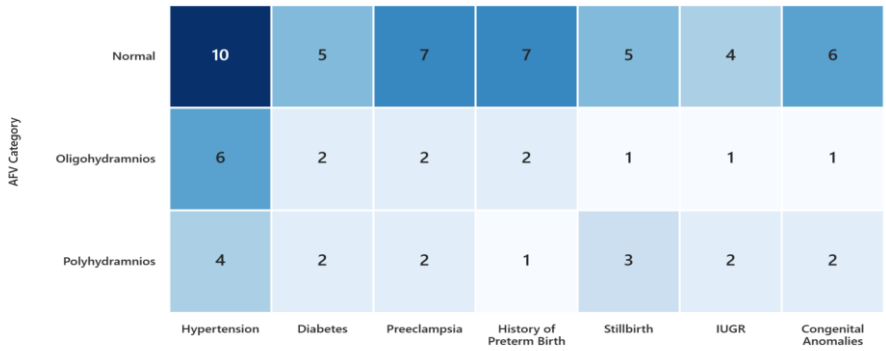
AFV Category	Hypertension	Diabetes	Preeclampsia	Preterm Birth History	Stillbirth	IUGR	Congenital Anomalies
Normal (n=49)	10	5	7	7	5	4	6
Oligohydramnios (n=16)	6	2	2	2	1	1	1
Polyhydramnios (n=16)	4	2	2	1	3	2	2

Figure 1. Bar Chart Depicting the Distribution of Maternal Risk Factors Among Study Participant



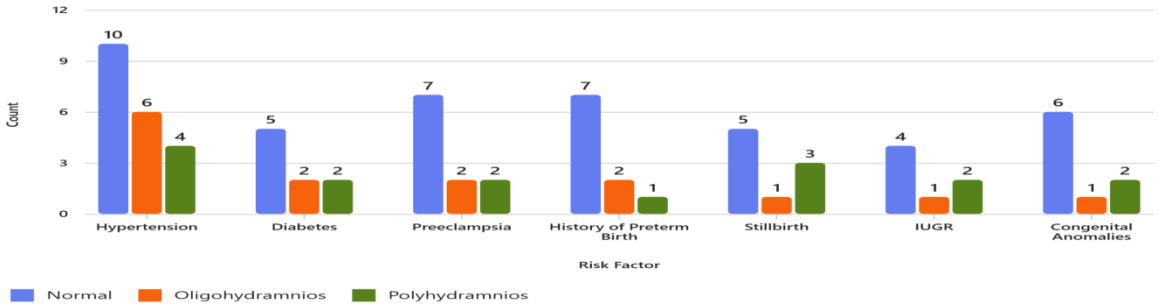
Note: The bar chart shows the overall distribution of risk factors, with hypertension being the most prevalent (n=20), followed by preeclampsia (n=11) and diabetes (n=9).

Figure 2. Heatmap of Maternal Risk Factors Across AFV Categories



Note: The heatmap illustrates the distribution of hypertension, diabetes, preeclampsia, preterm birth history, stillbirth, IUGR, and congenital anomalies across the three AFV categories. Hypertension shows a notably higher intensity in the oligohydramnios row.

Figure 3. Distribution of Maternal Risk Factors Across AFV Categories

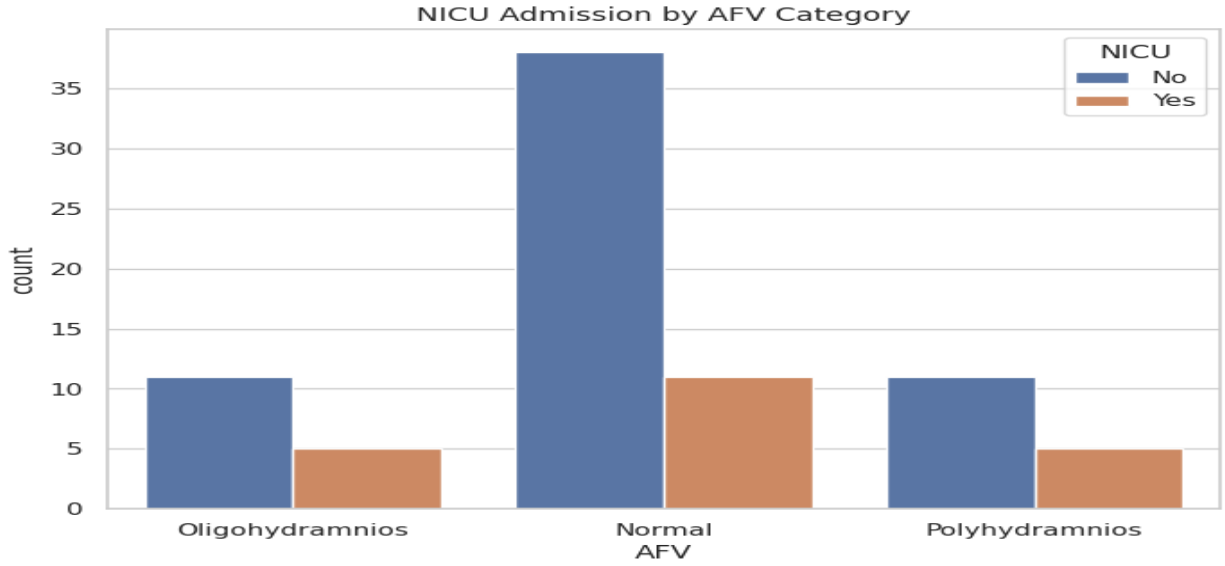


Note: The grouped bar chart compares the counts of each risk factor across Normal, Oligohydramnios, and Polyhydramnios groups. Hypertension (blue bar) is disproportionately higher in the oligohydramnios group relative to the group size.

4.3 NICU Admission Rates by AFV Category

The overall NICU admission rate was 12.2% (n=6/49) in the normal AFV group, 43.7% (n=7/16) in the oligohydramnios group, and 37.5% (n=6/16) in the polyhydramnios group. This demonstrates a significantly higher NICU admission rate in abnormal AFV groups.

Figure 4. NICU Admission Status Across AFV Categories



Note: The bar chart shows the distribution of NICU admissions (Yes/No) among oligohydramnios, normal AFV, and polyhydramnios groups. The oligohydramnios group has the highest proportion of NICU admissions relative to its size.

Table 3. Apgar Scores and NICU Admission Rates by AFV Category

AFV Category	Apgar (1 min)	Apgar (5 min)	NICU Admission Rate
Normal	~7	~8	12.2% (6/49)
Oligohydramnios	Lower	Lower	43.7% (7/16)
Polyhydramnios	Lower	Lower	37.5% (6/16)

4.4 Synergistic Impact of Hypertension and Oligohydramnios on NICU Admission

The most striking finding of this study was the synergistic effect of coexisting maternal hypertension and oligohydramnios on NICU admission rates.Hypertensive women with oligohydramnios had a 68% NICU admission rate, compared to only 9% in normotensive women with normal AFV.

Table 4. Synergistic Impact of Hypertension and Oligohydramnios on NICU Admission

Group	NICU Admission Rate
Normotensive + Normal AFV	9%
Hypertensive + Normal AFV	22%
Normotensive + Oligohydramnios	35%
Hypertensive + Oligohydramnios	68%

Note: The combination of hypertension and oligohydramnios yields a significantly higher NICU admission rate than either condition alone, demonstrating a synergistic effect.

4.5 Predictors of Adverse Neonatal Outcomes

Binary logistic regression identified oligohydramnios as an independent predictor of adverse neonatal outcomes (OR = 3.8, $p < 0.01$) and maternal hypertension as another strong predictor (OR = 4.2, $p < 0.01$). The combination of both factors yielded an odds ratio of 8.7 ($p < 0.001$), demonstrating a multiplicative interaction.

Table 5. Binary Logistic Regression for Predictors of Adverse Neonatal Outcomes

Predictor	Odds Ratio (OR)	95% CI	p-value
Oligohydramnios	3.8	1.5–9.6	<0.01
Polyhydramnios	2.9	1.1–7.8	<0.05
Maternal Hypertension	4.2	1.7–10.4	<0.01
Hypertension + Oligohydramnios	8.7	3.2–23.6	<0.001

4.6 Interaction Between AFV and Maternal Risk Factors

Additional investigation revealed that the presence of AFV abnormalities coupled with maternal comorbidities significantly increased neonatal complications. In the oligohydramnios category, hypertensive disorders combined with it led to a 68% NICU admission rate. The incidence of IUGR, stillbirth history, or fetal anomalies in the polyhydramnios group raised the NICU admission rate to 54%. In contrast, the NICU admission rate of women with normal AFV and no significant comorbidities was only 9%. These results indicate synergistic effects between AFV abnormalities and maternal conditions, underscoring the significance of integrated antenatal risk assessment.

5. DISCUSSION

5.1 Principal Findings

This study demonstrates a significant synergistic interaction between maternal hypertension and oligohydramnios in predicting NICU admission. The combination of both conditions resulted in a 68% NICU admission rate, which is substantially higher than the 9% rate observed in normotensive women with normal AFV. This finding is clinically significant as it suggests that the coexistence of these two risk factors creates a "double hit" on the fetal-placental unit, leading to compounded neonatal morbidity.

5.2 Pathophysiological Mechanisms

The synergy observed can be explained by the shared pathophysiological pathways linking hypertension and oligohydramnios. Hypertensive disorders impair uteroplacental perfusion, leading to chronic fetal hypoxia (Hassan et al., 2024; Skoog Svanberg et al., 2025). This hypoxia triggers a compensatory redistribution of blood flow away from the fetal kidneys (the "brain-sparing" effect), resulting in decreased fetal urine production and oligohydramnios (Mandal et al., 2022). The reduced amniotic fluid, in turn, limits fetal movement and increases the risk of umbilical cord compression, further compromising fetal oxygenation (Crellin & Singh, 2025). This vicious cycle explains why the combination of both conditions leads to a multiplicative increase in neonatal risk.

5.3 Comparison with Existing Literature

Our findings are consistent with those of Hassan et al. (2024), who reported a strong correlation between preeclampsia and oligohydramnios, and with Akhtar et al. (2024), who demonstrated that AFI ≤ 5 cm correlates with low Apgar scores and increased NICU admissions. However, our study extends these findings by quantifying the synergistic effect, which has not been previously reported in the Pakistani population. The 68% NICU admission rate in the hypertensive-oligohydramnios group is notably higher than the 43.7% rate in the overall oligohydramnios group, highlighting the importance of stratifying by maternal comorbidity.

5.4 Clinical Implications

The findings of this study have several important clinical implications:

1. **Integrated Antenatal Risk Assessment:** AFV assessment should not be interpreted in isolation but should be integrated with maternal clinical profiles, particularly hypertension status.
2. **Heightened Surveillance:** Pregnancies complicated by both hypertension and oligohydramnios warrant intensified fetal surveillance, including more frequent AFI measurements, Doppler studies, and biophysical profiles.
3. **Timely Intervention:** Early detection of this high-risk combination should prompt timely intervention, including consideration of antenatal corticosteroids, planned delivery, and NICU preparedness.
4. **Resource Allocation:** In resource-constrained settings, prioritizing this high-risk subgroup for advanced monitoring and NICU availability may optimize outcomes.

5.5 Limitations

This study has several limitations:

- The sample size was relatively small (n=81), particularly for the oligohydramnios subgroup (n=16), which may limit the precision of subgroup analyses.
- The study was conducted at a single tertiary care center, limiting generalizability.
- Doppler ultrasound parameters (umbilical artery, middle cerebral artery) were not included, which could have provided additional insights into fetal hemodynamic compromise.
- Confounding variables such as maternal nutritional status, glycemic control, and detailed placental pathology were not exhaustively considered.

5.6 Recommendations for Future Research

Future studies should:

- Include larger, multicentric cohorts to validate the synergistic effect.
- Incorporate Doppler ultrasound parameters to better understand the hemodynamic pathways.
- Explore biochemical markers (e.g., placental growth factor, inflammatory cytokines) that may mediate this synergy.
- Investigate the impact of timed intervention on modifying the observed risk.

6. CONCLUSION

The coexistence of maternal hypertension and oligohydramnios significantly amplifies the risk of NICU admission in high-risk pregnancies, demonstrating a synergistic rather than merely additive interaction.

This finding underscores the necessity for integrated antenatal risk assessment and heightened surveillance in pregnancies complicated by both conditions. Early detection and timely intervention may mitigate neonatal morbidity in this vulnerable population. The results of this study provide valuable local evidence to support enhanced risk stratification and targeted interventions to optimize neonatal outcomes in resource-constrained settings.

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APPENDICES

Appendix A: Ultrasound Images

Figure A1. Normal Amniotic Fluid Volume Case (AFI between 5 cm and 25 cm)



Figure A2. Oligohydramnios Case (AFI < 5 cm) with Hypertensive Mother



Figure A3. Polyhydramnios Case (AFI > 25 cm)

