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Diagnostic and predictive value of Doppler ultrasound for evaluation of complications in preterm infants

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ABSTRACT

Objective: To evaluate the diagnostic and predictive utility of Doppler ultrasound in identifying complications and outcomes in preterm infants.

Study Design: A cross-sectional study conducted at Sheikh Zayed Hospital, Rahim Yar Khan, involving 100–120 preterm infants selected through a convenient sampling method. Doppler ultrasound was used within 72 hours of symptom onset to assess cerebral hemodynamics.

Methods: Key variables included gestational age, birth weight, and complications such as patent ductus arteriosus, periventricular leukomalacia, and intraventricular hemorrhage. Doppler findings, including resistive index (RI) and cerebral perfusion, were analyzed. Statistical methods included correlation and regression analyses to determine relationships between Doppler findings and clinical outcomes.

Results: Patent ductus arteriosus (30%) was the most common, followed by intraventricular hemorrhage (25%). Increased RI was observed in 40% of participants, reduced cerebral perfusion in 20%, and normal Doppler flow in 40%. Increased RI significantly predicted mortality (OR =


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4.2, $p < 0.01$), while reduced perfusion was associated with neurodevelopmental delays (OR = 3.8, $p < 0.01$). Normal Doppler flow correlated with favorable outcomes in 60% of cases.

Conclusion: It is concluded that Doppler ultrasound is a critical tool for early identification and prediction of complications in preterm infants. Its non-invasive nature and real-time data capability make it essential for neonatal care. Future studies should validate findings in diverse populations and explore integration with other diagnostic tools to enhance predictive accuracy.

KEYWORDS: Doppler ultrasound, preterm infants, resistive index, cerebral perfusion, neonatal complications, neurodevelopmental outcomes.

INTRODUCTION

Premature birth presents a significant challenge to neonatal medicine, as preterm infants are at high risk for various cerebral abnormalities that can result in both immediate and long-term neurodevelopmental complications. The prevalence of neurological impairment in preterm infants has been a subject of extensive research, with a particular focus on understanding the mechanisms of cerebral injury and finding effective diagnostic tools to monitor cerebral development in these vulnerable patients. Doppler ultrasound, a non-invasive and highly versatile imaging modality, has emerged as a crucial diagnostic tool for identifying abnormalities in cerebral blood flow that may predict adverse neurodevelopmental outcomes. This paper explores the diagnostic and predictive value of Doppler ultrasound in detecting cerebral abnormalities in preterm infants, focusing on its correlation with long-term neurodevelopmental outcomes.

The phenomenon of preterm birth—defined as childbirth occurring before 37 weeks of gestation—has become an increasingly significant public health concern worldwide. Advances in neonatal intensive care have dramatically improved the survival rates of preterm infants. However, these advancements have also highlighted the long-term developmental challenges these infants often face. Preterm birth disrupts crucial stages of neurodevelopment, exposing infants to a range of physical, cognitive, and socioemotional risks. Consequently, understanding the correlation between preterm birth and neurodevelopmental outcomes has become a vital area of research, with significant implications for clinical practices, early intervention strategies, and long-term care planning [1].

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Preterm infants, particularly those born before 32 weeks of gestation or with a birth weight below 1500 grams, are susceptible to numerous health complications. Due to their underdeveloped organ systems, preterm infants experience higher rates of respiratory distress syndrome, intraventricular hemorrhage, periventricular leukomalacia, and sepsis, among other conditions. These health challenges require specialized medical attention in the neonatal intensive care unit (NICU) and, while many infants survive, the impact on brain development can be profound and lasting. The fetal brain undergoes rapid development during the last trimester of pregnancy, a period when the cortex grows in complexity, myelination accelerates, and neural circuits critical for cognitive, sensory, and motor functions are established. Preterm birth interrupts these developmental processes, leaving the infant's brain vulnerable to injury from external factors such as hypoxia, fluctuating blood pressure, and mechanical ventilation. These external stressors can result in structural and functional brain alterations, which may influence neurodevelopmental trajectories and predispose preterm infants to cognitive and motor impairments in later life. Research has consistently shown that preterm birth is associated with a spectrum of neurodevelopmental outcomes, ranging from mild delays to severe disabilities. Neurodevelopmental outcomes are typically assessed in several key domains: cognitive, motor, behavioral, and sensory functions. For extremely preterm infants (born at less than 28 weeks of gestation), studies indicate that between 25-50% experience some form of neurodevelopmental impairment by early childhood. These impairments may persist into adolescence and adulthood, affecting academic performance, employment opportunities, and quality of life.

Material and Methods:

This study design is cross-sectional. The duration of training was 4 months. Patients referred for Doppler ultrasound due to measuring the gastational age. Written informed consent was obtained from all participants.This study will be conducted at the Shiekh Zaye Hospital (Rahim Yar Khan). The sample size of 100-120 study participants will be included in this study. The convenient sampling technique will follow in this study.The sample collection procedure for evaluating the diagnostic and predictive value of Doppler ultrasound in preterm infants involves a few key steps. Informed consent is obtained from parents, and the infant's medical history is reviewed. The

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ultrasound machine is prepared, and the infant is comfortably positioned. Gel is applied, and the anterior fontanelle is scanned to measure cerebral blood flow, with results recorded and abnormalities noted.

RESULTS

Data were collected from 120 patients, with mean gestational age of 32 ± 3 weeks and a mean birth weight of 1.4 ± 0.3 kg, reflecting the characteristics of a typical preterm cohort. Male infants constituted 60% of the sample, while females accounted for 40%. Respiratory distress was the most prevalent complication, affecting 70% of participants, followed by patent ductus arteriosus (25%) and hypoxic-ischemic encephalopathy (5%). These findings highlight the vulnerability of preterm infants to respiratory and cardiac complications, emphasizing the need for targeted monitoring and interventions.

Table 4.1; Demographics of Study Participants

Characteristic	**Value**
Mean Gestational Age	32 ± 3 weeks
Mean Birth Weight	1.4 ± 0.3 kg
Male	60%
Female	40%
Respiratory Distress Cases	70%
Patent Ductus Arteriosus	25%
Hypoxic-Ischemic Encephalopathy	5%

Patent ductus arteriosus (PDA) was the most prevalent, affecting 30% (33 participants), followed by intraventricular hemorrhage (IVH) in 25% (28 participants). Hypoxic-ischemic encephalopathy (HIE) and periventricular leukomalacia (PVL) were observed in 20% (22 participants) and 15% (17 participants), respectively. Notably, 10% (11 participants) of the infants had no complications, highlighting the variability in clinical outcomes within this vulnerable population. These findings underscore the importance of early diagnosis and tailored management for preterm infants at risk of multiple complications.

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Table 4.2; Prevalence of Complications

Complication	Percentage (%)	Number of Participants (n)
Patent ductus arteriosus (PDA)	30%	33
Periventricular leukomalacia (PVL)	15%	17
Intraventricular hemorrhage (IVH)	25%	28
Hypoxic-ischemic encephalopathy (HIE)	20%	22
No complications	10%	11

Doppler ultrasound findings revealed that 40% (44 participants) of preterm infants exhibited an increased resistive index (RI), indicating potential complications associated with cerebral vascular resistance. Reduced cerebral perfusion was observed in 20% (22 participants), highlighting impaired blood flow regulation as a significant concern. Interestingly, 40% (44 participants) demonstrated normal Doppler flow, correlating with better clinical outcomes.

Table 4.3; Doppler Ultrasound Findings

Doppler Finding	Percentage (%)	Number of Participants (n)
Increased resistive index (RI)	40%	44
Reduced cerebral perfusion	20%	22
Normal Doppler flow	40%	44

The timing of Doppler ultrasound assessments showed that 60% (66 participants) of scans were performed within the first 24 hours of symptom onset, aligning with recommendations for early

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diagnosis in preterm infants. The remaining 40% (44 participants) underwent Doppler evaluations between 24 and 72 hours.

Table 4.4; Timing of Doppler Use

Timing	**Percentage (%)**	**Number of Participants (n)**
Within 24 hours	60%	66
24–72 hours	40%	44

The study outcomes revealed that 15% (17 participants) of the preterm infants experienced mortality, underscoring the severity of complications in this population. Neurodevelopmental delays were observed in 25% (28 participants), reflecting challenges in long-term developmental trajectories. Encouragingly, 60% (66 participants) achieved normal developmental outcomes, highlighting the potential for favorable prognoses with timely diagnosis and effective management.

Table 4.5; Clinical Outcomes

Outcome	**Percentage (%)**	**Number of Participants (n)**
Mortality Rate	15%	17
Neurodevelopmental Delays	25%	28
Normal Developmental Outcomes	60%	66

The study stratified Doppler findings by birth weight categories, revealing distinct trends in pulsatility index (PI), cerebral blood flow velocity (CBFV), and resistive index (RI). Infants with birth weights below 1.0 kg had a mean PI of 1.4 ± 0.2, CBFV of 22 ± 4, and RI of 0.75 ± 0.05, indicating higher vascular resistance and lower blood flow. In the 1.0–1.5 kg category, the mean PI decreased to 1.2 ± 0.3, while CBFV increased to 25 ± 5, and RI reduced to 0.7 ± 0.1, suggesting improved hemodynamics with higher birth weight. Infants weighing more than 1.5 kg showed the

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most favorable Doppler parameters, with a mean PI of 1.1 ± 0.2, CBFV of 28 ± 3, and RI of 0.65 ± 0.05.

Table 4.6; Mean Doppler Values by Birth Weight Category

Birth Weight Category (kg)	PI (Mean ± SD)	CBFV (Mean ± SD)	RI (Mean ± SD)
<1.0	1.4 ± 0.2	22 ± 4	0.75 ± 0.05
1.0 - 1.5	1.2 ± 0.3	25 ± 5	0.7 ± 0.1
>1.5	1.1 ± 0.2	28 ± 3	0.65 ± 0.05

The study revealed gender-based differences in Doppler parameters. Male infants had a mean pulsatility index (PI) of 1.3 ± 0.3, cerebral blood flow velocity (CBFV) of 24 ± 6, and resistive index (RI) of 0.72 ± 0.08, indicating slightly higher vascular resistance compared to females. Female infants demonstrated a lower mean PI of 1.2 ± 0.2, higher CBFV of 26 ± 5, and reduced RI of 0.68 ± 0.07, reflecting more favorable cerebral hemodynamics.

Table 4.7; Comparison of Doppler Findings by Gender

Gender	PI (Mean ± SD)	CBFV (Mean ± SD)	RI (Mean ± SD)
Male	1.3 ± 0.3	24 ± 6	0.72 ± 0.08
Female	1.2 ± 0.2	26 ± 5	0.68 ± 0.07

The regression analysis identified significant predictors of adverse outcomes in preterm infants. A pulsatility index (PI) ≥ 1.5 had a regression coefficient (β\betaβ) of 0.45, with a p-value < 0.01 and a 95% confidence interval of 0.25–0.65, indicating a strong association with complications. Similarly, a cerebral blood flow velocity (CBFV) < 20 cm/s showed a β\betaβ of 0.38 ($p < 0.05$, CI: 0.12–0.58), highlighting the importance of adequate blood flow for positive outcomes. A resistive index (RI) ≥ 0.8 was also significantly predictive, with a β\betaβ of 0.42 ($p < 0.01$, CI: 0.20–0.60), underscoring its role as a critical marker of vascular resistance. These findings reinforce the value of Doppler parameters in stratifying risk and guiding early interventions.

Table 4.8; Statistical Models Predicting Neurodevelopmental Outcomes

Predictor Variable	Regression Coefficient (β)	p-value	Confidence Interval (95%)

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PI ≥ 1.5	0.45	<0.01	0.25 - 0.65
CBFV < 20 cm/s	0.38	<0.05	0.12 - 0.58
RI ≥ 0.8	0.42	<0.01	0.20 - 0.60

The correlation analysis revealed significant relationships between Doppler findings and clinical outcomes. An increased resistive index (RI) showed a strong positive correlation (r=0.65r = 0.65r=0.65, p<0.01p < 0.01p<0.01) with severe complications, highlighting its role as a critical marker of adverse conditions. Reduced cerebral perfusion was moderately correlated with mortality (r=0.55r = 0.55r=0.55, p<0.01p < 0.01p<0.01), emphasizing the importance of adequate blood flow for survival. Conversely, normal Doppler flow was positively associated with favorable outcomes (r=0.40r = 0.40r=0.40, p<0.05p < 0.05p<0.05), demonstrating its predictive value for better prognoses. These findings underscore the diagnostic and prognostic utility of Doppler ultrasound in neonatal care.

Table 4.9; Correlation Between Doppler Findings and Clinical Outcomes

Doppler Finding	**Clinical Outcome**	**Correlation Coefficient (r)**	**p-value**
Increased resistive index (RI)	Severe complications	0.65	<0.01
Reduced cerebral perfusion	Mortality	0.55	<0.01
Normal Doppler flow	Normal outcomes	0.40	<0.05

The logistic regression analysis demonstrated the predictive power of key Doppler findings for clinical outcomes. An increased resistive index (RI) was a significant predictor of mortality, with an odds ratio (OR) of 4.2 (95% CI: 2.5–6.8, p<0.01p < 0.01p<0.01), indicating a substantial likelihood of death in affected infants. Reduced cerebral perfusion strongly predicted neurodevelopmental delays, with an OR of 3.8 (95% CI: 2.2–6.1, p<0.01p < 0.01p<0.01), highlighting its impact on developmental outcomes. Conversely, normal Doppler flow was

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associated with a higher probability of normal developmental outcomes, with an OR of 2.5 (95% CI: 1.8–4.2, $p<0.05p < 0.05p<0.05$).

Table 4.10; Predictive Analysis Using Regression

Predictor Variable	Outcome	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
Increased resistive index (RI)	Mortality	4.2	2.5–6.8	<0.01
Reduced cerebral perfusion	Neurodevelopmental delay	3.8	2.2–6.1	<0.01
Normal Doppler flow	Normal developmental outcomes	2.5	1.8–4.2	<0.05

The analysis of complications by gestational age revealed significant differences between infants born at <32 weeks and those born at 32–37 weeks. Among infants born at <32 weeks, patent ductus arteriosus (PDA) was the most prevalent complication, affecting 40% (20 participants), followed by intraventricular hemorrhage (30%, 15 participants) and periventricular leukomalacia (20%, 10 participants). In contrast, infants born at 32–37 weeks had lower complication rates, with PDA observed in 20% (12 participants), intraventricular hemorrhage in 20% (12 participants), and periventricular leukomalacia in only 10% (6 participants).

Table 4.11; Complication Rates by Gestational Age

Gestational Age (Weeks)	Complication	Percentage (%)	Number of Participants (n)

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<32 weeks	Patent ductus arteriosus	40%	20
	Periventricular leukomalacia	20%	10
	Intraventricular hemorrhage	30%	15
32–37 weeks	Patent ductus arteriosus	20%	12
	Periventricular leukomalacia	10%	6
	Intraventricular hemorrhage	20%	12

The analysis of Doppler findings by birth weight demonstrated a clear relationship between lower birth weight and adverse hemodynamic parameters. Among infants weighing <1500g, increased resistive index (RI) was the most common finding, present in 50% (22 participants), followed by reduced cerebral perfusion in 30% (13 participants), and normal Doppler flow in only 20% (9 participants). Conversely, infants weighing ≥1500g showed more favorable Doppler parameters, with increased RI in 30% (20 participants), reduced cerebral perfusion in 10% (7 participants), and normal Doppler flow in 60% (39 participants). These results emphasize the increased risk of vascular and perfusion abnormalities in lower birth weight infants and the importance of using Doppler ultrasound for risk stratification and management.

Table 4.12; Doppler Findings by Birth Weight

Birth Weight (g)	**Doppler Finding**	**Percentage (%)**	**Number of Participants (n)**
<1500g	Increased resistive index (RI)	50%	22

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	Reduced cerebral perfusion	30%	13
	Normal Doppler flow	20%	9
>=1500g	Increased resistive index (RI)	30%	20
	Reduced cerebral perfusion	10%	7
	Normal Doppler flow	60%	39

CONCLUSIONS

It is concluded that Doppler ultrasound is a highly effective and non-invasive diagnostic tool for identifying and predicting complications in preterm infants. The study demonstrated that abnormalities in resistive index (RI) and cerebral perfusion are strongly associated with adverse clinical outcomes, including mortality and neurodevelopmental delays. These findings underscore the importance of incorporating Doppler ultrasound into routine neonatal care protocols, particularly within the critical first 72 hours of symptom onset. Furthermore, Doppler ultrasound's ability to provide real-time, actionable data enhances its utility in guiding timely interventions and improving long-term developmental outcomes. Its portability, cost-effectiveness, and accessibility make it an invaluable tool, especially in resource-limited settings. Despite its limitations, such as a relatively small sample size and limited follow-up duration, the study highlights the significant role Doppler ultrasound can play in stratifying risk and supporting clinical decision-making. Future research should aim to validate these findings in larger, more diverse populations and extend follow-up periods to capture long-term neurodevelopmental impacts. Additionally, integrating Doppler ultrasound with other diagnostic modalities could further enhance its predictive accuracy. Overall, this study reinforces the potential of Doppler ultrasound to transform neonatal care by enabling early diagnosis, improving prognostication, and optimizing outcomes for preterm infants.


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