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Research Article

# UTILITY OF MIDDLE CEREBRAL ARTERY DOPPLER IN THE DIAGNOSIS OF FETAL ANEMIA: AN OBSERVATIONAL STUDY

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**ABSTRACT**

**Objectives:** The objectives are to assess the association between abnormal middle cerebral artery (MCA) Doppler findings (multiples of the median [MoM] >1.5) in the late third trimester (After 32 weeks of gestation) and neonatal hemoglobin levels and to evaluate its diagnostic accuracy in detecting anemia at birth.

**Methods:** This retrospective observational study was conducted over a period of 1 year (May 2024–April 2025) at a tertiary care hospital. A total of 100 antenatal women with risk factors such as Rh isoimmunization, hydrops fetalis, or fetomaternal hemorrhage were enrolled. MCA Doppler was performed during the late third trimester (≥32 weeks gestation). Neonatal hemoglobin value was recorded at birth, and values below 2 standard deviations for gestational age were classified as anemic. Data were analyzed for correlation between Doppler findings and neonatal outcomes, including anemia and neonatal intensive care unit admission.

**Results:** Of 100 cases, 34% had abnormal Doppler (MoM >1.5), and 31% of neonates were anemic. A statistically significant association was found between Doppler-positive status and neonatal anemia (Pearson Chi-square=49.795, p<0.001). Sensitivity and specificity of the Doppler test were 83.9% and 88.4%, respectively. The diagnostic performance of MCA Doppler for predicting neonatal anemia demonstrated a sensitivity of 87 %, specificity of 90 %, positive predictive value of 79 %, negative predictive value of 94%, and an overall accuracy of 89%.

**Conclusion:** MCA Doppler is a simple, safe, and effective tool for antenatal detection of fetuses at risk of anemia, facilitating timely clinical preparedness at birth.

**Keywords:** Fetal anemia, Middle cerebral artery Doppler, Neonatal hemoglobin, Predictive value.

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## INTRODUCTION

Fetal anemia is a leading cause of perinatal mortality and morbidity, especially in red cell alloimmunization, fetomaternal hemorrhage, and some infections. Early and accurate, yet non-invasive detection is crucial to direct timely intervention and maximize neonatal outcome. The peak systolic velocity (PSV) of the middle cerebral artery (MCA), as assessed by Doppler ultrasonography, has been established as a consistent, non-invasive marker for fetal anemia [1].

MCA Doppler measurement is founded on the theory that anemic fetuses have lower blood viscosity and higher cardiac output, which results in higher flow velocities in cerebral arteries. The technique has been shown to have high sensitivity and specificity, particularly when PSV >1.5 multiples of the median (MoM) for gestational age (GA) [2].

In their landmark study, Mari showed that MCA-PSV is a reproducible and useful test for the diagnosis of fetal anemia and suggested its universal application in high-risk pregnancies [3]. Many other studies confirmed the utility of MCA Doppler in the assessment of fetal anemia in transfused as well as non-transfused fetuses [4]. Red cell alloimmunization has been one of the core areas of use of MCA Doppler for assessment of fetal anemia and may be used as a substitute for invasive testing such as cordocentesis [5]. In addition, systemic review and meta-analysis by Martinez-Portilla *et al*. confirmed the diagnostic value of MCA Doppler, especially in the prediction of moderate-to-severe anemia [6].

In fetomaternal hemorrhage, where prompt diagnosis is important, MCA Doppler has also been of use. Cosmi *et al*. documented that MCA-PSV was useful in early detection and management in such instances [7]. Even in pregnancy-related chemotherapy, MCA Doppler has been used successfully to assess fetal health and make decisions regarding transfusion [8].

Its use has been applied to gestational diabetes mellitus, wherein Doppler derangements can indicate hypoxic alterations or different fetal hemodynamics [9]. India-specific charts for PSV values can be used for assessment of fetal anemia, thereby broadening its use in various clinical situations in the Indian cohort [10].

The current study seeks to determine the diagnostic value of MCA Doppler in identifying fetal anemia in a tertiary care environment, highlighting its utility as a non-invasive and easily accessible modality.

## METHODS

This retrospective observational study was conducted at a tertiary care teaching hospital to assess the diagnostic value of middle cerebral artery (MCA) Doppler in the non-invasive detection of fetal anemia. The study included all eligible pregnant women who underwent MCA Doppler evaluation between May 2024 and April 2025 as part of routine obstetric surveillance in the late third trimester (≥34 weeks of gestation).

The sample size was calculated by the formula $N=(Z\ \alpha^2)\times SD^2/d^2$ using OPENEPI software version 3 based on pilot studies done on the topic of Noninvasive diagnosis of fetal anemia by Doppler ultrasonography, assuming 90% power and 95% confidence interval. A total of 100 pregnant women fulfilling the eligibility criteria were included

consecutively. Since the study was retrospective observational, in which only data were collected from antenatal Doppler scans and postnatal hemoglobin values, ethics committee approval was waived.

Women were enrolled if their pregnancy was considered at risk for fetal anemia due to factors such as Rh isoimmunization, history of fetal anemia or intrauterine transfusion, or fetomaternal hemorrhage, and if both MCA Doppler and neonatal hemoglobin data were available.

Extracted variables included maternal demographics, indication for MCA Doppler, GA at testing, MCA PSV, calculated MoM, and neonatal hemoglobin levels. All examinations were performed on a Voluson E8 ultrasound system equipped with a C5-1 transducer operating at 2–5 MHz. An MCA Doppler was considered suggestive of fetal anemia when PSV exceeded 1.5 MoM. Neonatal anemia was defined as hemoglobin <2 standard deviations below the mean for GA.

Importantly, no invasive procedures such as cordocentesis were performed, and fetal hemoglobin levels were not assessed antenatally. The study relied entirely on non-invasive MCA Doppler evaluation and postnatal hemoglobin measurement to assess diagnostic performance. All MCA Doppler assessments had been performed using standardized protocols by experienced radiologists.

**Inclusion criteria**

1. Pregnant women who underwent MCA Doppler evaluation at ≥32 weeks of gestation
2. Availability of complete antenatal Doppler reports and neonatal hemoglobin levels measured within 6 h of birth
3. Singleton pregnancies with viable outcomes at or beyond the threshold of viability.

**Exclusion criteria**

1. MCA Doppler performed before 32 weeks of gestation
2. Absence of neonatal hemoglobin data at birth
3. Multiple gestations (e.g., twins, triplets)
4. Major congenital anomalies detected antenatally or postnatally
5. Incomplete or missing documentation in Doppler or delivery records
6. Pregnancies that terminated before viability.

## RESULTS

The analysis of the association between various maternal and fetal variables with elevated PSV MoM >1.5 and anemia at birth revealed that the most frequent gravida group was gravida 2 (40%), followed by gravida 1 (29%), gravida 3 (21%), and gravida 4 (10%). There was no statistically significant association between gravida status and elevated PSV (p=0.698) or anemia at birth (p=0.390). The differences in both elevated PSV (p=0.105) and anemia at birth (p=0.533) across Rh status were not statistically significant. In terms of risk factors, Rh isoimmunization and fetomaternal hemorrhage each accounted for 17% of the cases, and hydrops fetalis was noted in 8%; none of these risk factors showed a significant relationship with anemia at birth (p=0.872 for Rh isoimmunization and p=0.736 for fetomaternal hemorrhage). Finally, GA at the time of Doppler was nearly evenly distributed, with 51% assessed between 32 and 34 weeks and 49% between 35 and 37 weeks, and neither group demonstrated a statistically significant association with elevated PSV (p=0.628) or anemia at birth (p=0.760) (Table 1).

The mean GA at the time of MCA Doppler assessment was 35.1±1.7 weeks. The mean MCA PSV was 52.8±10.5 cm/s, ranging from 30.1 to 69.2 cm/s. The corresponding mean multiple of the median (MoM) was 1.39±0.26. The mean GA at delivery was 37.6±1.9 weeks, varying between 33 and 41 weeks. The average birth weight of the neonates was 2684±401 g, with weights ranging from 1802 g to 3493 g. Finally, the mean neonatal hemoglobin level was 12.9±2.4 g/dL, with a range from 7.2 to 16.9 g/dL. These findings reflect that most neonates were delivered at term with moderately low-to-normal birth weights and variable hemoglobin levels (Table 2).

53% of births were vaginal, and 47% were cesarean sections. In 34% of the pregnancies, Doppler results indicated fetal anemia (MoM >1.5). 31% of newborns were found to have anemia at birth. There was a considerable neonatal morbidity as evidenced by the 35% of cases that required Neonatal Intensive Care Unit (NICU) admission. Fetal monitoring and Doppler results influenced clinical decision-making, as evidenced by the fact that 38% of births were preterm and 62% of births were at term (≥37 weeks) (Table 3).

The analysis of the diagnostic accuracy of MCA Doppler (MoM >1.5) showed that it had a high sensitivity of 87% (95% confidence interval [CI]: 75–99%) and high specificity of 90% (95% CI: 83–97%) for the diagnosis of fetal anemia. This high sensitivity and specificity showed MCA Doppler's ability to non-invasively identify both anemic and non-anemic neonates. The positive predictive value (PPV) was 79% (95% CI: 65–93%), whereas the negative predictive value (NPV) was even higher at 94% (95% CI: 88–100%). These findings suggested excellent reliability in ruling out anemia when the test result was negative. The overall diagnostic accuracy of the MCA Doppler was 89% (95% CI: 83–95%) (Table 4).

A statistically significant association was found between MCA Doppler findings and neonatal anemia status (p<0.001). Among the 34 cases where MCA Doppler was suggestive of anemia (MoM >1.5), 26 (76.5%) neonates were actually found to be anemic, while only 5 (7.6%) of the 66 with normal Doppler findings had anemia. This reflects a strong correlation between abnormal MCA Doppler values and subsequent neonatal anemia, suggesting that Doppler assessment is a reliable predictive tool for fetal anemia in the third trimester (Table 5).

## DISCUSSION

The diagnostic value of MCA Doppler in predicting fetal anemia in the late third trimester was assessed in this study. The findings of this study

**Table 1: Baseline characteristics with neonatal anemia status and Doppler findings (n=100)**

| Variable | Category | Frequency (%) | PSV MoM >1.5 | | p-value | Anemia at Birth | | p-value |
|---|---|---|---|---|---|---|---|---|
| | | | Yes | No | | Yes | No | |
| Gravida | 1 | 29 (29) | 10 | 19 | 0.698 | 8 | 21 | 0.390 |
| | 2 | 40 (40) | 12 | 28 | | 10 | 30 | |
| | 3 | 21 (21) | 7 | 14 | | 8 | 13 | |
| | 4 | 10 (10) | 5 | 5 | | 5 | 5 | |
| Rh Status | Positive | 87 (87) | 27 | 60 | 0.105 | 26 | 61 | 0.533 |
| | Negative | 13 (13) | 7 | 6 | | 5 | 8 | |
| Risk Factor | Rh Isoimmunization | 17 (17) | 7 | 10 | | 5 | 12 | 0.872 |
| | Fetomaternal Hemorrhage | 17 (17) | 4 | 13 | 0.736 | 4 | 13 | |
| | Hydrops | 8 (8) | 3 | 5 | | 3 | 5 | |
| GA at Doppler | 32–34 weeks | 51 (51) | 19 | 32 | 0.628 | 14 | 37 | 0.760 |
| | 35–37 weeks | 49 (49) | 15 | 34 | | 17 | 32 | |

PSV: Peak systolic velocity, MoM: Multiples of the median, GA: Gestational age

**Table 2: Continuous variables with mean±SD (n=100)**

| Variable | Mean±SD | Minimum | Maximum |
|---|---|---|---|
| GA at Doppler (weeks) | 35.1±1.7 | 32 | 37 |
| MCA PSV (cm/s) | 52.8±10.5 | 30.1 | 69.2 |
| MoM | 1.39±0.26 | 1.01 | 2.00 |
| GA at delivery (weeks) | 37.6±1.9 | 33 | 41 |
| Birth weight (g) | 2684±401 | 1802 | 3493 |
| Neonatal hemoglobin (g/dL) | 12.9±2.4 | 7.2 | 16.9 |

PSV: Peak systolic velocity, MoM: Multiples of the median, GA: Gestational age, SD: Standard deviation

**Table 3: Middle cerebral artery Doppler and neonatal outcomes (n=100)**

| Variable | Category | Frequency (n) | Percentage |
|---|---|---|---|
| Doppler suggestive of anemia | Yes | 34 | 34.0 |
| | No | 66 | 66.0 |
| Anemia present at birth | Yes | 31 | 31.0 |
| | No | 69 | 69.0 |
| Neonatal intensive care unit admission | Yes | 35 | 35.0 |
| | No | 65 | 65.0 |
| Mode of delivery | Cesarean | 47 | 47.0 |
| | Vaginal | 53 | 53.0 |
| Gestational age at delivery | <37 weeks | 38 | 38.0 |
| | ≥37 weeks | 62 | 62.0 |

**Table 4: The diagnostic accuracy of middle cerebral artery Doppler (multiples of the median >1.5) for predicting neonatal anemia**

| Diagnostic measure | Value | 95% confidence interval |
|---|---|---|
| Sensitivity | 0.87 | 0.75–0.99 |
| Specificity | 0.90 | 0.83–0.97 |
| Positive predictive value | 0.79 | 0.65–0.93 |
| Negative predictive value | 0.94 | 0.88–1.00 |
| Accuracy | 0.89 | 0.83–0.95 |

**Table 5: Association between Doppler suggestive of anemia and neonatal anemia (n=100)**

| Doppler suggestive of anemia (>1.5 MoM) | Neonatal anemia present | Neonatal anemia absent | Total | Chi-square |
|---|---|---|---|---|
| Yes | 26 | 8 | 34 | Pearson Chi-square=49.795, df=1, P<0.001 (significant) |
| No | 5 | 61 | 66 | |
| Total | 31 | 69 | 100 | |

highlight the importance of MCA PSV as a non-invasive screening tool for the assessment of fetal anemia.

A strong inverse relationship between MCA PSV and neonatal hemoglobin levels was found by Anabusi *et al*. confirming that elevated PSV is a good indicator of moderate-to-severe anemia [11]. The PPV of MoM >1.5 in our cohort supported their findings.

When compared to single readings, serial Doppler measurements increased diagnostic accuracy, as stressed by Ebbing *et al*. [12]. The sensitivity was still high in our retrospective design, which only included one late-trimester measurement, most likely as a result of timing being optimized closer to delivery.

The use of MCA Doppler in clinical decision-making greatly decreased the need for undertaking invasive procedures such as cordocentesis, as reported by El-Shourbagy and Elsakhawy [13]. This is consistent with our findings that MCA Doppler could correctly identify 26 of 31 neonates with anemia. According to Arslan *et al*., birth weight and NICU admission are two perinatal outcomes that may be correlated with elevated MCA PSV [14].

According to our data, Doppler-positive cases had a higher NICU admission rate (52.9%) than Doppler-negative cases (7.6%). MCA Doppler accuracy in Rh isoimmunization cases, where anemia risk is elevated, was examined by Lee and Nasser [15]. Similarly, Doppler correctly identified anemic neonates in almost all cases in our subgroup of mothers who were Rh-negative (13%).

The importance of GA at the time of Doppler was emphasized by Srikumar *et al*. [16]. Comparing MCA PSV values to age-specific reference charts is essential because these values tend to increase as gestation progresses. To minimize variability and enhance interpretability, our study made sure that all Doppler studies were conducted between 32 and 37 weeks.

In their investigation of the effects of maternal hemodynamics, Mose hypothesized that disorders such as hypertension may have an impact on cerebral blood flow [17]. Our study's robust specificity was demonstrated by the absence of false positives from maternal comorbidities in risk factor-based subgroup analysis.

MCA Doppler was recommended by Kolate *et al*. for use in high-risk pregnancies other than Rh disease, such as twin gestations and hydrops fetalis [18]. Doppler accurately predicted anemia in the majority of patients with fetomaternal hemorrhage, which reflected expanded utility in our study, which included 17% of patients. To decrease false positives, Tongprasert *et al*. suggested a higher MoM threshold (e.g., >1.3) [19]. However, we discovered that the conventional >1.5 MoM cutoff maintained sensitivity without appreciably sacrificing specificity.

Van Klink *et al*. concentrated on the long-term neurodevelopmental advantages of early detection and treatment of fetal anemia [20]. Although long-term results were not included in our study, early detection with MCA Doppler may help ensure timely transfusion and better neurological health.

A key limitation of this study is its retrospective, single-center design, which may introduce selection bias and limit external validity. The modest sample size represents another limitation of this study, reducing statistical power to detect subtler associations. Finally, the absence of prospective neurodevelopmental follow-up constitutes a limitation of this study, precluding confirmation of longterm neurological benefits."

## CONCLUSION

This study shows that a MoM value >1.5 of the MCA Doppler is a good non-invasive indicator of fetal anemia particularly in the late third trimester. The diagnostic accuracy of MCA Doppler-suggestive anemia was denoted by the discovery of a statistically significant correlation ($p < 0.001$) between it and neonatal anemia. MCA Doppler's high sensitivity and specificity for the diagnosis of fetal anemia may reduce the need for invasive procedures. Moreover, a greater number of NICU admissions among Doppler-positive cases emphasize the importance of predicting unfavorable neonatal outcomes.

## AUTHOR CONTRIBUTION

KA - Concept and design of the study, prepared first draft of manuscript, interpreted the results, reviewed the literature, and manuscript preparation; GM - Concept, coordination, statistical analysis and interpretation, preparation of manuscript, and revision of the manuscript.

## CONFLICT OF INTEREST

None.

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