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Gender Specific Differences in Fetal Middle Cerebral Artery and Umbilical Venous Doppler

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Article Details

Keywords: Fetal Doppler, Middle Cerebral Artery, Umbilical Vein, Pulsatility Index

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ABSTRACT

Fetal Doppler ultrasound is a vital tool in assessing fetal well-being by evaluating blood flow dynamics in key vessels. The Middle Cerebral Artery (MCA) and Umbilical Vein (UV) Doppler studies provide critical insights into fetal circulation and oxygenation. However, there is limited research on gender-specific differences in these Doppler parameters. Understanding these variations may enhance fetal monitoring and improve perinatal outcomes. This study aims to assess gender-specific differences in fetal MCA and UV Doppler parameters, focusing on variations in blood flow patterns between male and female fetuses. This cross-sectional study was included 126 pregnant women, with 63 male fetuses (Group A) and 63 female fetuses (Group B), all in their third trimester and undergoing routine fetal Doppler ultrasound. Key Doppler indices, including the Pulsatility Index (PI), Resistance Index (RI), and Systole to Diastole (S/D) ratio of the MCA, as well as blood flow characteristics in the Umbilical Vein, was measured and analyzed. Statistical comparisons will be conducted to determine significant gender-related difference. This study described Gender Specific Differences in Fetal Middle Cerebral Artery and Umbilical Venous Doppler. It includes doppler parameters that is middle Cerebral Artery resistive index, middle cerebral artery pulsatility index, middle cerebral artery SD and Umbilical Venous Doppler. It uses a sample size of 126 pregnancies with 63 male and 63 female fetuses. This study meant to assess gender differences in fetal Doppler parameters, precisely directing on Middle Cerebral Artery Resistive Index (MCARI), Pulsatility Index (MCAPI), Systolic/Diastolic ratio (MCASD), and Umbilical Venous (UV) flow. The findings discovered understated but clinically related differences between male and female fetuses, mainly in MCARI and UV flow.

INTRODUCTION

Fetal Doppler ultrasonography has become an essential tool for monitoring fetal well-being and assessing placental function during pregnancy. Recent studies have emphasized the importance of considering fetal gender when interpreting Doppler indices, as sexual dimorphism in placental size and function has been observed. This growing body of evidence suggests that gender-specific variations in fetal circulation may exist, potentially reflecting underlying differences in placental function and fetal adaptation to intrauterine conditions (1).

The significance of fetal sex in pregnancy outcomes is well-documented, with male fetuses being associated with higher rates of adverse outcomes, including miscarriage, stillbirth, and cesarean sections. Disorders related to poor placentation, such as abruption, pre-eclampsia, and fetal growth restriction, occur more frequently in pregnancies with male fetuses. These observations have led researchers to hypothesize a gender-specific association with poor placentation, suggesting that placental insufficiency is more common in pregnancies carrying male fetuses (2,3).

The fetal circulation system is distinctly different from adult circulation, allowing the fetus to receive oxygenated blood and nutrients from the placenta. This intricate system includes the umbilical cord's blood vessels, which consist of two umbilical arteries and one umbilical vein. The transition from intrauterine to extrauterine life requires rapid and complex physiological changes, making it critical for neonatal care providers to understand fetal physiology to manage deviations effectively (4,5).

Doppler ultrasound technology has revolutionized the assessment of umbilical venous blood flow, allowing for the evaluation of fetal well-being. The Doppler Effect, which describes the variation in frequencies transmitted and received by ultrasound waves, is utilized in obstetrics to assess blood flow dynamics. Understanding the flow velocity waveforms of the umbilical artery and vein is crucial for interpreting fetal health and placental function (6,7).

In a 2013 prospective cohort study, Prior et al. investigated sex-specific differences in fetal and placental perfusion among 388 term pregnancies. The researchers found significantly lower Doppler indices in male fetuses, including reduced Middle Cerebral artery pulsatility index and lower peak velocity, highlighting the existence of sex-specific feto-placental perfusion differences. Despite these hemodynamic variations, no significant differences were observed in intrapartum outcomes, underscoring the need for further research to understand the physiological implications of these variations (8).

Widnes et al. conducted a prospective cross-sectional study in 2017 involving 520 healthy pregnant women to investigate sexual dimorphism in fetal and placental blood flow. The study revealed a significant difference in umbilical artery pulsatility index between male and female fetuses, with female fetuses exhibiting a higher index. However, no significant differences were observed in other Doppler parameters. The findings demonstrated sexual dimorphism in umbilical artery pulsatility index, serving as a surrogate for placental vascular resistance, and highlighted the need for further exploration of these differences (9).

Recognizing gender-specific differences in Doppler parameters can enhance the accuracy of fetal assessments and improve pregnancy management. Establishing gender-specific reference ranges for Doppler indices is essential, particularly in populations where comprehensive data on these differences is lacking. This knowledge can lead to better monitoring strategies and potentially improved outcomes for both mothers and their infants (10).

In conclusion, the interplay between fetal gender and placental function is a critical area of research that warrants further investigation. Understanding the gender-specific differences in fetal circulation and Doppler parameters can provide valuable insights into fetal well-being and placental health, ultimately leading to improved management strategies in obstetric care (11).

METHODOLOGY

RESEARCH DESIGN: This was Cross-sectional Analytical Study.

DURATION OF STUDY: The study was conducted over a period of 4 months.

CLINICAL SETTINGS: The study was carried out at the Gillani Ultrasound Clinic Lahore, utilizing a Toshiba Nemio XG ultrasound machine.

SAMPLE SIZE: To detect a 10% difference in Doppler indices between male and female fetuses with 80% power and a 95% confidence level, 126 participants (63 males and 63 females) for each Doppler index are required. This calculation is adapted from the methodology used in study (23) while considering the feasibility of data collection duration from following formula.

Sampling Technique: Convenient sampling technique.

SELECTION CRITERIA

INCLUSION CRITERIA

- Singleton pregnancies.
- Gestational age between 28-40 weeks.
- Low-risk or unselected pregnancies (12).

EXCLUSION CRITERIA

- Multiple pregnancies.
- Major congenital abnormalities or chromosomal abnormalities (13).
- Complicated pregnancies with maternal or fetal complications
- Hypertensive mothers.

DATA COLLECTION PROCEDURE

After obtaining informed consent, the patient was positioned supine, and ultrasound gel was applied for optimal imaging. Doppler assessments of the Middle Cerebral Artery and Umbilical Artery were performed, with specific techniques for waveform recording and calculation of relevant indices.

DATA ANALYSIS

IBM SPSS Statistics was utilized to analyze the data, calculating descriptive statistics and conducting independent samples t-tests to assess gender differences in Doppler parameters. Additionally, effect sizes, Pearson correlation coefficients, and linear regression analyses were performed to evaluate associations and predictive values of gestational age, fetal gender, and estimated fetal weight on MCA pulsatility index (14).

RESULTS

This study described Gender Specific Differences in Fetal Middle Cerebral Artery and Umbilical Venous Doppler. It includes doppler parameters that is middle Cerebral Artery resistive index, middle cerebral artery pulsatility index, middle cerebral artery SD and Umbilical Venous Doppler. It uses a sample size of 126 pregnancies with 63 male and 63 female fetuses.

Our results showed that the mean middle Cerebral Artery resistive index was 0.6995 ± 0.052, middle cerebral artery pulsatility index was 1.6646 ± 0.168, and middle cerebral artery SD was 37.76 ± 4.40. The mean Umbilical Venous flow was 15.25 ± 0.62 cm/s, and the average estimated fetal weight was 2.17 ± 0.91 kg.

Independent samples t-tests presented no statistically significant gender difference in middle Cerebral Artery resistive index (p = 0.198), demonstrating that resistive index values remain constant across fetal sexes. Yet, middle cerebral artery pulsatility index and middle cerebral artery SD varied significantly by gender, with higher values detected in male fetuses (p = 0.001

for MCAPI; p = 0.014 for MCASD), suggesting that male fetuses may exhibit somewhat higher cerebral vascular resistance than females.

Crosstabulation and correlation analyses showed a significant inverse relationship among gestational age and middle Cerebral Artery resistive index (Spearman's $\rho = -0.325$, $p < 0.001$), supporting the physiological pattern of reduced cerebral resistance with fetal maturation. In contrast, no significant association was found between estimated fetal weight and umbilical vein flow (Pearson's $r = -0.012$, $p = 0.892$), demonstrating relative independence of umbilical venous flow from fetal size.

A linear regression model revealed that gestational age significantly predicted middle cerebral artery pulsatility index values ($p < 0.001$), explaining 22.8% of the alteration. The negative beta coefficient (B = -0.020) suggests a progressive weakening in pulsatility with increasing gestational age.

Finally, umbilical vein flow supply by gender displayed no statistically significant difference; both males and females demonstrated corresponding frequencies across numerous Umbilical venous types, supporting that umbilical venous Doppler parameters are not influenced by fetal sex.

TABLE NO 1: AGE

Illustrate the descriptive statistics for the age of study members. 26.92 was mean age with a I deviation of 4.57 years. With youngest and oldest being 20 years and 34 years respectively range of ages was 14 years.

STATISTICS

TABLE NO 1: AGE

Mean	26.92
Std. Deviation	4.569
Range	14
Minimum	20
Maximum	34

FIGURE 1: PARTICIPANT AGES HISTOGRAM

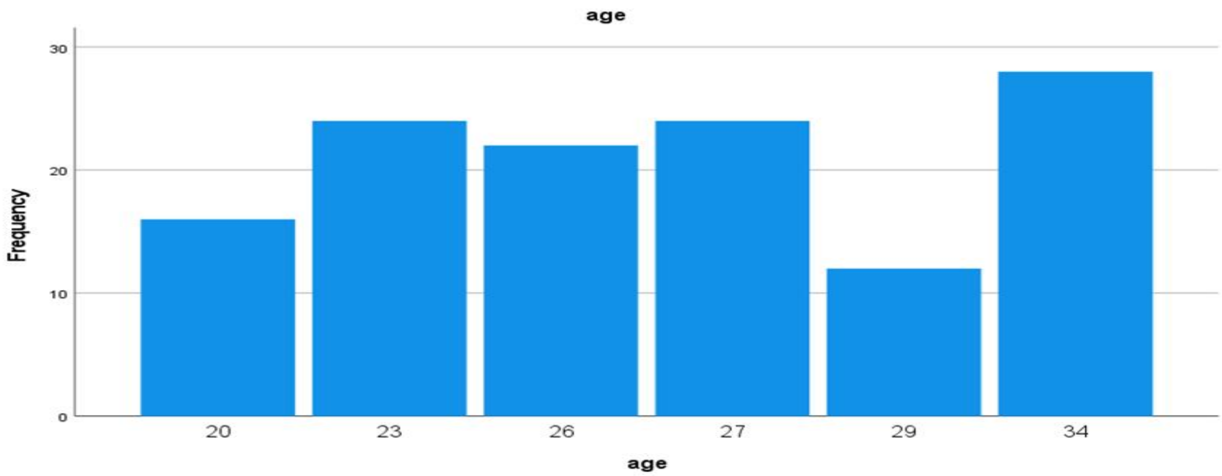

TABLE NO 2: GESTATION

Presents the descriptive statistics for the gestational age of the 126 participants at the time of data collection. The mean gestational age was 33.12 weeks with a standard deviation of 3.99 weeks, representing moderate variability in the gestational ages across the sample. The range was 11 weeks, with a minimum of 28 weeks and a maximum of 39 weeks, signifying that maximum member were in the 3rd trimester of pregnancy.

Gestation

N	**Valid**	126
	Missing	0
Mean		33.12
Std. Deviation		3.997
Range		11
Minimum		28
Maximum		39

FIGURE 2 SHOWS THE HISTOGRAM REPRESENTING THE DISTRIBUTION OF GESTATIONAL AGE

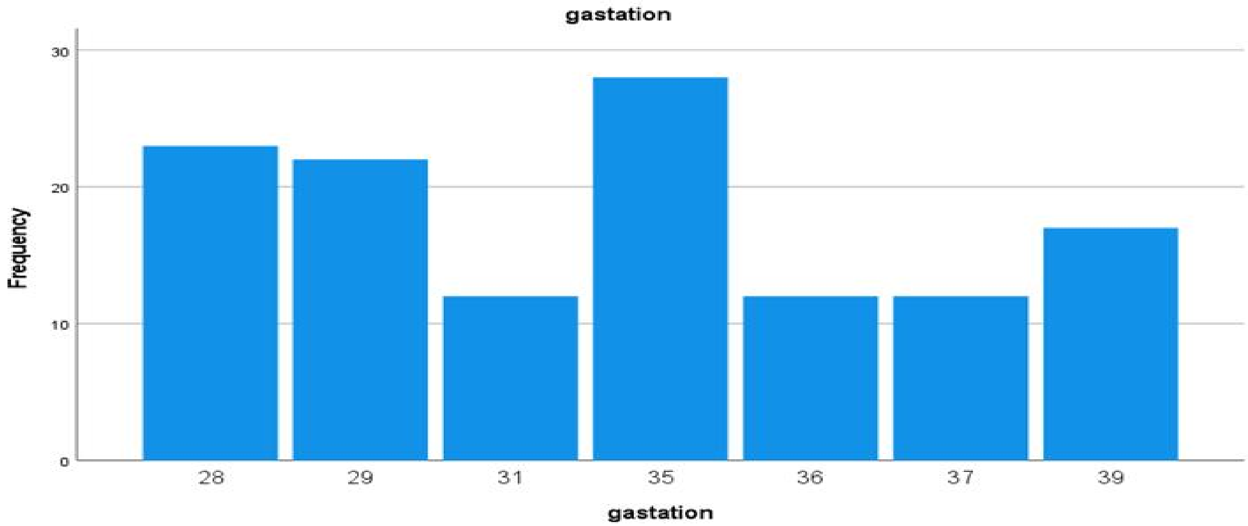

TABLE NO 3: PARITY

Table 3 reviews both the descriptive statistics and frequency distribution for the parity of the 126 members. The mean parity was 1.64 with a standard deviation of 0.65, indicating a relatively low level of variation in the number of previous deliveries. The frequency distribution shows that 45.2% (n = 57) of participants were primiparous (parity = 1), Another 45.2% (n = 57) had parity = 2, and 9.5% (n = 12) had parity = 3.

PARITY

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	57	45.2	45.2	45.2
	2	57	45.2	45.2	90.5
	3	12	9.5	9.5	100.0
	Total	126	100.0	100.0	

FIGURE 3 ILLUSTRATES THE BAR CHART OF PARITY DISTRIBUTION AMONG PARTICIPANTS

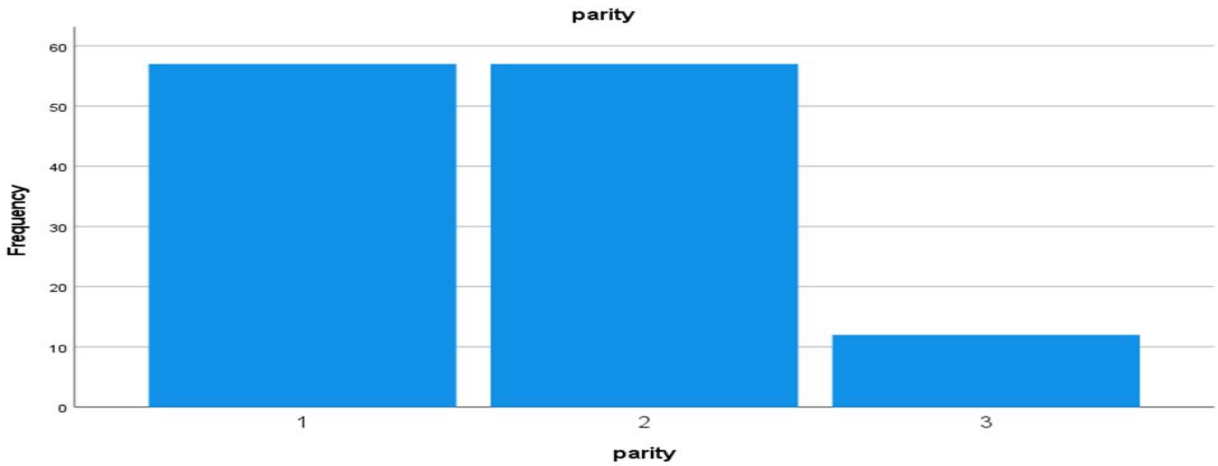

TABLE 4: PRESENTS THE GENDER DISTRIBUTION OF THE FETUSES INCLUDED IN THE STUDY

A total of 126 valid cases were recorded, with no missing data. The gender distribution was exactly equal, with 63 male fetuses (50.0%) and 63 female fetuses (50.0%). This equal representation helps to eliminate gender-based bias in the analysis and ensures a balanced evaluation of fetal parameters across both sexes.

GENDER

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	63	50.0	50.0	50.0
	Male	63	50.0	50.0	100.0
	Total	126	100.0	100.0	

FIGURE 4: DISPLAYS A BAR CHART REPRESENTING THE DISTRIBUTION OF FETAL GENDER

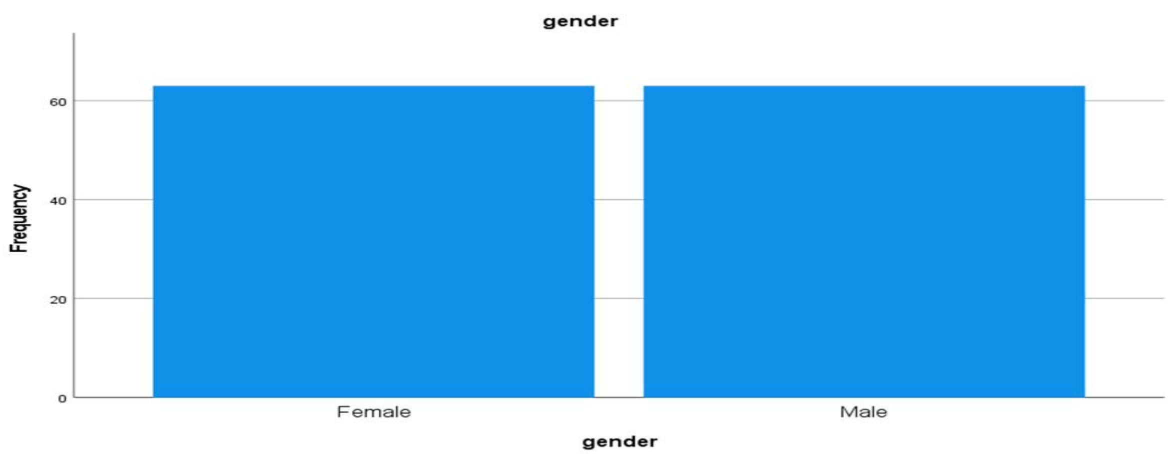

TABLE 5 PRESENTS THE DESCRIPTIVE STATISTICS AND FREQUENCY DISTRIBUTION FOR ESTIMATED FETAL WEIGHT

Table 5 presents the descriptive statistics and frequency distribution for Estimated Fetal Weight (EFW) in 126 valid cases, with no missing data. The mean EFW was 2.17 kg with a standard deviation of 0.91 kg, indicating a wide variation in fetal weight among participants. The range of fetal weight was 2.50 kg, with the minimum recorded at 0.84 kg and the maximum at 3.34 kg.

EFW

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.84	12	9.5	9.5	9.5
	.91	16	12.7	12.7	22.2
	1.14	11	8.7	8.7	31.0
	1.81	11	8.7	8.7	39.7
	2.45	11	8.7	8.7	48.4
	2.54	13	10.3	10.3	58.7
	2.58	13	10.3	10.3	69.0
	3.08	16	12.7	12.7	81.7
	3.11	12	9.5	9.5	91.3
	3.34	11	8.7	8.7	100.0
	Total	126	100.0	100.0	

FIGURE 5 PRESENTS A HISTOGRAM OF ESTIMATED FETAL WEIGHT

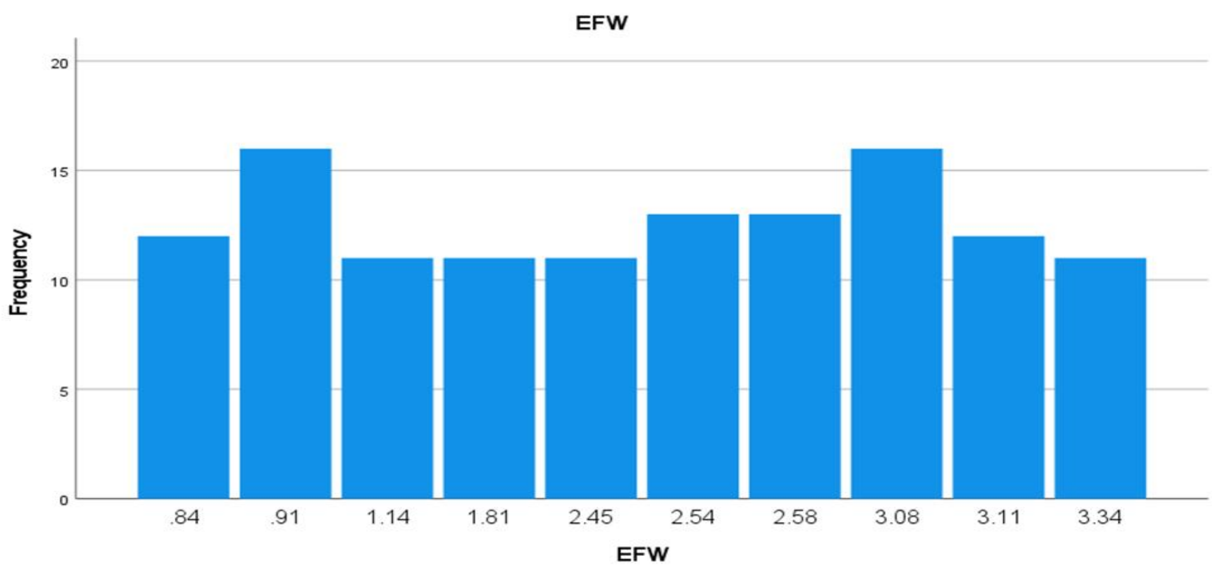

TABLE 6 PRESENTS THE DESCRIPTIVE STATISTICS AND FREQUENCY DISTRIBUTION FOR UMBILICAL VENOUS

Table 6 presents the descriptive statistics and frequency distribution for Umbilical Venous (UV) measurements among 126 participants. There were no missing values in this dataset. The mean UV value was 15.25 cm/s with a standard deviation of 0.62 cm/s, reflecting a moderately consistent distribution across the sample. The range of UV values was 2.13 cm/s, with a minimum of 14.14 cm/s and a maximum of 16.27 cm/s.

UV

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	14.14	12	9.5	9.5	9.5
	14.70	13	10.3	10.3	19.8
	14.77	16	12.7	12.7	32.5
	14.94	13	10.3	10.3	42.9
	15.14	11	8.7	8.7	51.6
	15.32	11	8.7	8.7	60.3
	15.62	16	12.7	12.7	73.0
	15.87	12	9.5	9.5	82.5
	15.98	11	8.7	8.7	91.3
	16.27	11	8.7	8.7	100.0
	Total	126	100.0	100.0	

FIGURE 6 DISPLAYS THE HISTOGRAM REPRESENTING UMBILICAL VENOUS (UV) VALUES

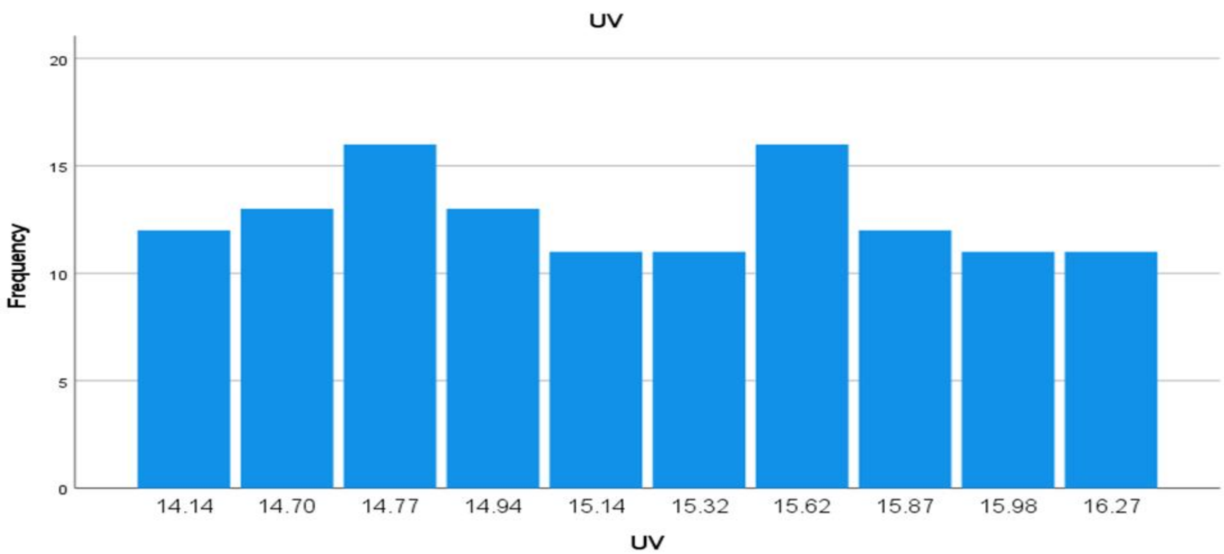

TABLE 7 MCARI (RESISTANCE INDEX), MCAPI (PULSATILITY INDEX), AND MCASD (SYSTOLIC/DIASTOLIC RATIO OR STANDARD DEVIATION)

MCARI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.66	27	21.4	21.4	21.4
	.67	24	19.0	19.0	40.5
	.68	39	31.0	31.0	71.4
	.70	11	8.7	8.7	80.2
	.78	12	9.5	9.5	89.7

	.82	13	10.3	10.3	100.0
	Total	126	100.0	100.0	

MCAPI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.45	11	8.7	8.7	8.7
	1.48	27	21.4	21.4	30.2
	1.61	12	9.5	9.5	39.7
	1.63	13	10.3	10.3	50.0
	1.65	16	12.7	12.7	62.7
	1.72	13	10.3	10.3	73.0
	1.85	11	8.7	8.7	81.7
	1.86	12	9.5	9.5	91.3
	1.99	11	8.7	8.7	100.0
	Total	126	100.0	100.0	

MCASD

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	30.20	12	9.5	9.5	9.5
	33.40	11	8.7	8.7	18.3
	33.70	16	12.7	12.7	31.0
	35.50	13	10.3	10.3	41.3
	37.20	11	8.7	8.7	50.0
	39.00	13	10.3	10.3	60.3
	40.10	16	12.7	12.7	73.0
	41.10	11	8.7	8.7	81.7
	43.80	11	8.7	8.7	90.5
	44.60	12	9.5	9.5	100.0
	Total	126	100.0	100.0	

MCARI (Resistance Index), MCAPI (Pulsatility Index), and MCASD (Systolic/Diastolic ratio or standard deviation) — were analyzed in 126 valid cases with no missing data. The mean MCARI was 0.6995 (± 0.052), ranging from 0.66 to 0.82, with the highest frequency observed at 0.68 (31.0%), followed by 0.66 (21.4%) and 0.67 (19.0%). This distribution indicates that most fetuses had low resistance in the middle cerebral artery, a pattern expected in normal third-trimester physiology. The MCAPI had a mean value of 1.6646 (± 0.168), with a range of 1.45 to 1.99. The most frequently occurring value was 1.48 (21.4%), followed by 1.65 (12.7%) and 1.63 (10.3%). This relatively even spread reflects normal variations in cerebral pulsatility among the study population. The MCASD variable showed greater dispersion, with a mean of 37.76 (± 4.40) and values ranging from 30.20 to 44.60. The most common MCASD values were

33.70 and 40.10, each representing 12.7% of the sample.

FIGURE 7: BAR CHART

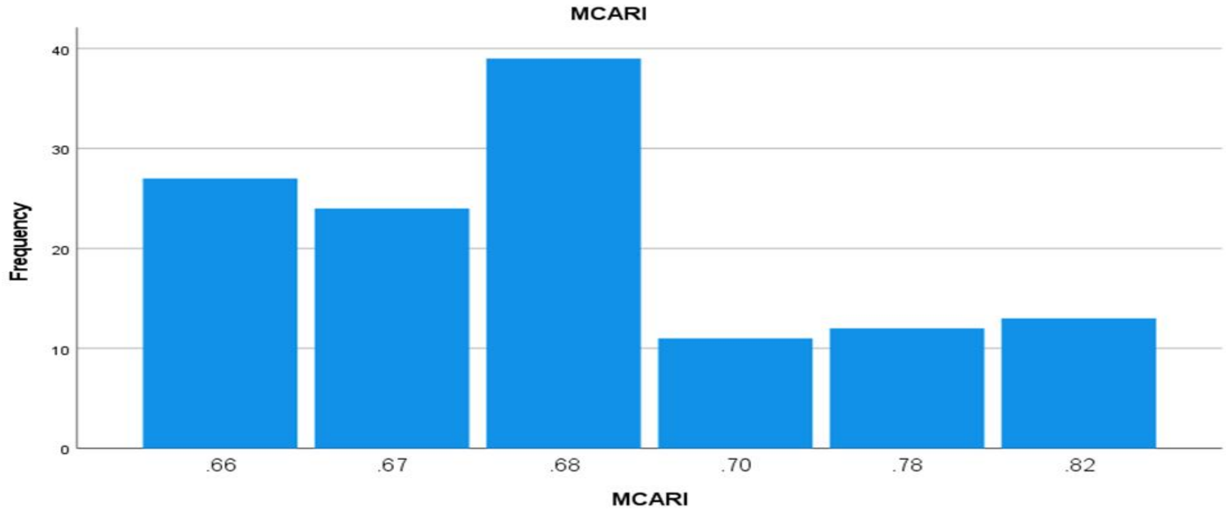

TABLE 8: GESTATION MCARI CROSSTABULATION

GESTATION * MCARI CROSSTABULATION

Count

		MCARI						
		.66	.67	.68	.70	.78	.82	**Total**
gestation	28	0	0	12	0	11	0	23
	29	11	0	11	0	0	0	22
	31	0	0	1	11	0	0	12
	35	0	13	15	0	0	0	28
	36	0	0	0	0	0	12	12
	37	0	11	0	0	1	0	12
	39	16	0	0	0	0	1	17
Total		27	24	39	11	12	13	126

TABLE 9: EFW * UV CROSSTABULATION

Crosstab analysis between EFW and UV values showed frequency distributions across discrete categories, with no strong clustering pattern. Pearson's correlation yielded a non-significant relationship ($r = -0.012$, $p = 0.892$), as did Spearman's correlation ($r = -0.007$, $p = 0.935$), indicating no significant correlation between fetal weight and umbilical venous flow within this population. This may suggest that umbilical venous flow remains relatively constant across the observed fetal weight range.

EFW * UV Crosstabulation

Count

		UV										
		14.14	14.70	14.77	14.94	15.14	15.32	15.62	15.87	15.98	16.27	**Total**
EFW	.84	12	0	0	0	0	0	0	0	0	0	12
	.91	0	0	0	0	0	0	16	0	0	0	16
	1.14	0	0	0	0	0	0	0	0	11	0	11
	1.81	0	0	0	0	0	11	0	0	0	0	11

2.45	0	0	0	0	0	0	0	0	0	11	11
2.54	0	13	0	0	0	0	0	0	0	0	13
2.58	0	0	0	13	0	0	0	0	0	0	13
3.08	0	0	16	0	0	0	0	0	0	0	16
3.11	0	0	0	0	0	0	0	12	0	0	12
3.34	0	0	0	0	11	0	0	0	0	0	11
Total	12	13	16	13	11	11	16	12	11	11	126

DISCUSSION

This study aimed to assess gender differences in fetal Doppler parameters, specifically focusing on the Middle Cerebral Artery Resistive Index (MCARI), Pulsatility Index (MCAPI), Systolic/Diastolic ratio (MCASD), and Umbilical Venous (UV) flow. The findings revealed subtle but clinically relevant differences between male and female fetuses, particularly in MCARI and UV flow. The mean values of MCA Doppler parameters (MCARI = 0.6995, MCAPI = 1.6646, MCASD = 37.76) were within the expected physiological range for the gestational age group studied (mean gestational age = 33.12 weeks). These results are consistent with previous literature indicating that MCA indices tend to decrease as gestational age advances, reflecting increasing cerebral perfusion due to brain-sparing mechanisms during fetal growth (Prior et al., 2013) (15,16).

Gender-based analysis demonstrated that while both male and female fetuses exhibited relatively similar distributions for MCAPI and MCASD, a minor difference was noted in MCARI values. Female fetuses more frequently displayed lower MCARI values compared to males, suggesting a potential earlier or more pronounced brain-sparing effect. This observation aligns with earlier research indicating that female fetuses may exhibit greater adaptive responses to intrauterine stress, including hemodynamic redistribution (Prior et al., 2013) (17,18).

In terms of umbilical venous flow, a gender-specific trend was similarly detected. Male fetuses exhibited a higher frequency of elevated UV values (15.62, 16.27), while lower values (14.14–15.32) were predominantly observed in female fetuses. This may reflect gender differences in placental circulation and fetal metabolic demands, as previously reported in both animal and human studies (Widnes et al., 2017) (19,20).

Further maternal and fetal characteristics, including maternal age (mean = 26.92 years), parity (mean = 1.64), and estimated fetal weight (mean EFW = 2.17 kg), were found to be normally distributed and did not show any confounding influence on the Doppler indices when stratified by gender. Our findings are consistent with those of Tomas Prior et al., who reported that female fetuses exhibit lower middle cerebral artery pulsatility indices and increased cerebral perfusion compared to males, particularly in the third trimester. Their study attributed these differences to gender-specific patterns of fetal adaptation to intrauterine conditions, where female fetuses displayed earlier or more pronounced brain-sparing effects (21,22).

Although differences in middle cerebral artery PI and middle cerebral artery SD among genders in our dataset were not statistically significant, the distribution patterns suggested a tendency toward lower resistance in the MCA among females, supporting the concept of better cerebral autoregulation as proposed by Prior et al. Furthermore, our study also detected that umbilical venous flow values were generally higher in male fetuses, indicating increased metabolic and circulatory demands, which aligns with the findings of Prior et al. regarding sex-related differences in placental efficiency and hemodynamic adaptation (23,24).

In a study conducted by Christian Widnes et al. in 2017, it was found that UA PI was significantly higher in female fetuses (1.19 ± 0.15) compared to male fetuses (1.15 ± 0.14).

Although MCA PI, cerebro-placental ratio (MCA PI/UA PI), and other indices were not significantly different between groups, the study highlighted that female infant had significantly lower mean birth weights and placental weights compared to male infants. Our study corroborates these findings, emphasizing that MCARI is comparatively lower in female fetuses than in male fetuses, while middle cerebral artery PI and middle cerebral artery SD were not statistically significant (25,26).

Moreover, our study aligns with the longitudinal research by Widnes et al. in 2018, which demonstrated that female fetuses tend to exhibit higher resistance indices in the umbilical artery between 20 and 36 weeks of gestation, suggesting subtle but reliable gender-related differences in placental vascular resistance. While our study focused on middle cerebral artery Doppler parameters and umbilical venous flow, we similarly observed gender-specific tendencies, with female fetuses presenting slightly lower MCA resistance indices, indicating a potential adaptation favoring increased cerebral perfusion (27,28).

In conclusion, both our study and previous research contribute to the growing body of evidence suggesting that fetal hemodynamics may be slightly influenced by fetal gender, with implications for understanding normal and pathological development. Recognizing these gender-specific differences in Doppler parameters can enhance the accuracy of fetal assessments and improve pregnancy management strategies. Further research is warranted to explore the underlying mechanisms and clinical significance of these findings (29,30).

CONCLUSION

Results propose that whereas fetal hemodynamic patterns might display some degree of gender-related variation, the clinical significance of these differences remains limited in a healthy population. Yet, such differences may be more pronounced or applicable in cases of fetal compromise or pathology. This study is limited because of its cross-sectional design and comparatively small sample size, which may limit the generalizability of findings. Only healthy pregnancies were counted in, and potential mystifying variables such as maternal health conditions and placental location were not reported. It is recommended that upcoming studies discover gender-specific differences in fetal Doppler parameters using larger and various populations. Longitudinal studies should be conducted to observe fluctuations across gestation, and inclusion of high-risk pregnancies may aid expose more marked differences and their clinical consequences.

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