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ULTRASONOGRAPHIC COMPARISON OF UMBLICAL ARTERY AND MIDDLE CEREBRAL ARTERY DOPPLER INDICES OF OLIGOHYDROMNIOS AND NORMAL AMNIOTIC FLUID LEVELS IN PREGNANT FEMALES

Original Research

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ABSTRACT

Background: Oligohydramnios, defined by reduced amniotic fluid volume, is a significant indicator of placental insufficiency and fetal compromise. Amniotic fluid plays a critical role in cushioning the fetus, supporting pulmonary development, and facilitating fetal movements. Doppler ultrasound of key fetal vessels, such as the umbilical artery (UA) and middle cerebral artery (MCA), provides valuable insights into fetal hemodynamics in compromised pregnancies. Evaluating these indices can help clinicians identify fetuses at risk and guide timely intervention.

Objective: To compare the Doppler indices of the umbilical artery and middle cerebral artery between pregnant women diagnosed with oligohydramnios and those with normal amniotic fluid levels.

Methods: This cross-sectional observational study was conducted at Jinnah Hospital Lahore and included 73 pregnant women between 18 and 40 years of age. Participants were divided into two groups: oligohydramnios (n=29) and normal amniotic fluid (n=44). Amniotic fluid levels were assessed using the amniotic fluid index (AFI) and single deepest pocket (SDP) methods. Doppler ultrasonography was used to measure peak systolic velocity (PSV), end-diastolic velocity (EDV), pulsatility index (PI), resistance index (RI), and systolic/diastolic (S/D) ratios for both UA and MCA. Statistical analyses were performed using SPSS version 24, with a significance level set at $p<0.05$.

Results: The mean umbilical artery PSV was significantly lower in the oligohydramnios group (34.53 ± 17.60 cm/s) compared to the normal fluid group (52.85 ± 16.39 cm/s). Similarly, the MCA PSV was 36.54 ± 15.05 cm/s in oligohydramnios and 57.66 ± 19.71 cm/s in the normal group. MCA EDV was 10.62 ± 6.44 cm/s in oligohydramnios versus 21.39 ± 11.65 cm/s in controls. Although MCA PI was higher in oligohydramnios (1.40 ± 0.21) compared to normal (1.22 ± 0.35), this was not statistically significant ($p=0.2668$). No significant differences were observed in most RI and PI values.

Conclusion: Oligohydramnios is associated with marked reductions in fetal blood flow velocities, especially in the umbilical and middle cerebral arteries, reflecting compromised fetal circulation. Doppler evaluation of these vessels offers a reliable, non-invasive method to monitor fetal well-being and anticipate adverse outcomes in high-risk pregnancies.

Keywords: Amniotic Fluid Index, Middle Cerebral Artery, Oligohydramnios, Pulsatility Index, Resistive Index, Umbilical Artery, Ultrasonography Doppler.

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INTRODUCTION

Oligohydramnios, a condition marked by decreased amniotic fluid volume, remains a significant clinical concern in obstetric care due to its association with various maternal and fetal complications. Amniotic fluid plays a vital role in fetal development by cushioning the fetus, allowing for unrestricted movement, aiding in lung maturation, and maintaining thermal stability within the uterine environment. Its volume is most commonly assessed using either the Amniotic Fluid Index (AFI), where values between 8 to 24 cm are considered normal, or the Single Deepest Pocket (SDP) method, which considers values between 2 to 8 cm as normal. A diagnosis of oligohydramnios is made when the AFI falls below 5 cm or the SDP measures less than 2 cm (1,2). The primary source of amniotic fluid in the second and third trimesters is fetal urine, which reflects adequate placental perfusion. Any compromise in placental blood flow may reduce fetal renal perfusion and urine output, resulting in reduced amniotic fluid volume (3). Among the critical vascular structures influencing fetal well-being, the umbilical artery and middle cerebral artery (MCA) play central roles. The umbilical artery, arising from the fetal internal iliac arteries, serves to carry deoxygenated blood and waste products from the fetus to the placenta. Its function is frequently assessed via Doppler ultrasound to detect abnormalities such as increased resistance or absent end-diastolic flow, which may be early indicators of placental insufficiency and fetal distress (4,5). Conversely, the MCA is responsible for perfusing the fetal brain and is closely monitored in high-risk pregnancies. Changes in its Doppler indices, especially a reduced pulsatility index (PI), are reflective of fetal adaptive mechanisms such as brain-sparing, a response to chronic hypoxia where blood is preferentially shunted to vital organs like the brain (6).

Multiple maternal-fetal conditions including intrauterine growth restriction (IUGR), preeclampsia, maternal diabetes, hypertensive disorders, and multiple gestations have been linked with the development of oligohydramnios and altered Doppler indices in the umbilical artery and MCA (5). These pathological changes typically manifest as elevated resistance in the umbilical artery and reduced PI in the MCA, reflecting the hemodynamic adaptation of the fetus to a compromised intrauterine environment (6,7). Such Doppler alterations serve as non-invasive markers of fetal hypoxia and correlate with adverse outcomes including IUGR, preterm birth, and increased perinatal morbidity (7). Ultrasonographic Doppler assessment of fetal vessels, particularly the umbilical artery and MCA, has become an indispensable tool in modern obstetrics due to its safety, accessibility, and capacity to provide dynamic, real-time insights into fetal circulation. Unlike invasive diagnostic approaches, Doppler ultrasound offers repeated, risk-free evaluations, enabling early detection of fetal compromise and facilitating timely clinical decision-making. Key indices such as the pulsatility index (PI), resistance index (RI), and systolic/diastolic (S/D) ratio provide quantitative measures to monitor placental and fetal vascular resistance and predict potential complications (8,9). Given its diagnostic precision and clinical utility, Doppler ultrasonography is widely regarded as the gold standard for evaluating pregnancies complicated by oligohydramnios (10). The objective of this study is to assess the diagnostic relevance of umbilical artery and middle cerebral artery Doppler indices in pregnancies complicated by oligohydramnios, and to determine their predictive value in identifying fetal hypoxia and adverse perinatal outcomes.

METHODS

This case-control study was designed to assess the Doppler indices of the umbilical artery and middle cerebral artery among pregnant women with oligohydramnios in comparison to those with normal amniotic fluid levels. The study was conducted at Al Riaz Hospital over a duration of three months, following the approval of the research synopsis. Ethical approval was obtained from the Institutional Review Board (IRB), and informed written consent was taken from all participants prior to data collection, ensuring adherence to ethical standards in human research. A total of 73 participants were enrolled using a non-probability convenience sampling technique. The sample size was calculated using the formula $n = (Z^2 \times P \times (1 - P)) / e^2$, where Z represents the standard normal deviate corresponding to a 95% confidence level (1.96), P is the expected true proportion (0.74), and e is the margin of error (11). The inclusion criteria comprised pregnant women with singleton gestations between 20 and 40 weeks, either diagnosed with oligohydramnios or demonstrating normal amniotic fluid volume. Exclusion criteria included multiple pregnancies, severe maternal conditions such as diabetes mellitus, current use of medications known to alter uteroplacental blood flow, and cases where Doppler visualization of the umbilical and middle cerebral arteries was not feasible.

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Ultrasound examinations were performed using the Toshiba Aplio XG system. Amniotic fluid volume was assessed using standard methods including the Amniotic Fluid Index (AFI) and the Single Deepest Pocket (SDP) approach. Doppler studies were conducted to evaluate the pulsatility index (PI) and resistance index (RI) of both the umbilical artery and middle cerebral artery. All scans were conducted by trained sonographers following standardized protocols to ensure measurement accuracy and reproducibility. Data were entered and analyzed using IBM SPSS Statistics version 24. Descriptive statistics such as means and standard deviations were calculated for continuous variables (e.g., maternal age, gestational age, Doppler indices). Categorical variables (e.g., presence or absence of oligohydramnios) were summarized using frequencies and percentages. To compare categorical variables between groups, the chi-square test was used. For continuous variables, appropriate statistical tests such as the independent *t*-test or the Mann–Whitney *U* test were applied based on data distribution assessed through normality testing (12,13). Odds ratios with 95% confidence intervals were calculated to estimate the strength of association between Doppler findings and oligohydramnios. Statistical significance was defined as a *p*-value less than 0.05. Additionally, pie charts were used to represent the distribution of categorical variables.

RESULTS

A total of 73 pregnant women were included in the study, with maternal age ranging from 18 to 40 years (mean ± SD: 29.74 ± 6.22 years). The mean amniotic fluid index (AFI) among all participants was 10.39 ± 7.12 cm, spanning from 2.00 to 23.40 cm. Doppler indices showed substantial variability across both groups. The umbilical artery systolic/diastolic ratio (UmA_SD) had a mean of 3.17 ± 0.76, while the resistance index (UmA_RI) and pulsatility index (UmA_PI) averaged 0.70 ± 0.13 and 1.11 ± 0.41, respectively. For the middle cerebral artery (MCA), the systolic/diastolic ratio (MCA_SD), resistance index (MCA_RI), and pulsatility index (MCA_PI) were recorded as 3.49 ± 0.75, 0.69 ± 0.12, and 1.29 ± 0.31, respectively. Among the 29 patients diagnosed with oligohydramnios, the mean UmA_PI was 1.21 ± 0.47 compared to 1.05 ± 0.35 in those without oligohydramnios. Similarly, the mean MCA_PI was elevated in the oligohydramnios group (1.40 ± 0.21) versus the non-oligohydramnios group (1.22 ± 0.35). MCA_RI was also higher in the oligohydramnios group (0.71 ± 0.10) than in the control group (0.68 ± 0.13). Although these values suggested elevated cerebral and umbilical resistance in oligohydramnios, the differences were not statistically significant.

In terms of flow velocities, a more pronounced disparity was observed. The mean peak systolic velocity (PSV) in the umbilical artery was significantly lower in the oligohydramnios group (34.53 ± 17.61 cm/s) compared to 52.85 ± 16.39 cm/s in the control group. A similar trend was noted for the end-diastolic velocity (EDV), which was 9.88 ± 5.58 cm/s in oligohydramnios versus 17.14 ± 7.46 cm/s in the normal fluid group. MCA flow velocities followed the same pattern: MCA_PSV was 36.54 ± 15.05 cm/s in oligohydramnios versus 57.66 ± 19.71 cm/s in the control group, and MCA_EDV was 10.62 ± 6.44 cm/s in the oligohydramnios group versus 21.39 ± 11.65 cm/s in those with normal fluid levels. These differences were statistically significant and indicated reduced fetal perfusion in cases with low amniotic fluid. The comparison of UmA_SD values between groups revealed minimal differences, with a mean of 3.06 ± 0.78 in the oligohydramnios group and 3.24 ± 0.74 in the control group, suggesting comparable systolic-diastolic ratios. Visual distribution of data also supported these findings, with the oligohydramnios group showing a slightly narrower range and fewer outliers, indicating more consistent but compromised vascular flow. Statistical testing using independent sample *t*-tests was performed to determine the significance of differences in Doppler indices between oligohydramnios and non-oligohydramnios groups. The results indicated that none of the mean differences in pulsatility or resistance indices reached statistical significance. Specifically, the *p*-value for UmA_PI was 0.7311, UmA_RI was 0.3646, and UmA_SD was 0.1756. Similarly, the MCA indices also did not yield statistically significant differences, with *p*-values of 0.2668 for MCA_PI, 0.0614 for MCA_RI, and 0.7535 for MCA_SD. Although some trends were observed—such as elevated MCA_PI and UmA_PI in the oligohydramnios group—these differences did not meet the threshold for statistical significance ($p<0.05$).

Table 1: Descriptive Statistics

N		Range	Minimum	Maximum	Mean	Std. Deviation
AFI	73	21.40	2.00	23.40	10.3877	7.11676
Age	73	22.00	18.00	40.00	29.7397	6.22055
UmA_SD	73	2.88	2.00	4.88	3.1700	.75623
UmA_RI	73	.56	.44	1.00	.7038	.13288
UmA_PI	73	2.39	.51	2.90	1.1136	.40735

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N		Range	Minimum	Maximum	Mean	Std. Deviation
MCA_SD	73	3.09	1.90	4.99	3.4915	.74582
MCA_RI	73	.54	.40	.94	.6903	.12016
MCA_PI	73	1.26	.54	1.80	1.2927	.31457
Valid N (listwise)	**73**					

Table 2: Group Statistics

	Oligohydromnios	N	Mean	Std. Deviation	Std. Error Mean
UmA_SD	Yes	29	3.0586	.78047	.14493
	No	44	3.2434	.73963	.11150
UmA_RI	Yes	29	.6962	.11487	.02133
	No	44	.7089	.14460	.02180
UmA_PI	Yes	29	1.2059	.47455	.08812
	No	44	1.0527	.34881	.05259
MCA_SD	Yes	29	3.4572	.69312	.12871
	No	44	3.5141	.78564	.11844
MCA_RI	Yes	29	.7114	.09508	.01766
	No	44	.6764	.13338	.02011
MCA_PI	Yes	29	1.4041	.21462	.03985
	No	44	1.2193	.34901	.05262
UmA_PSV	Yes	29	34.5345	17.60804	3.26973
	No	44	52.8455	16.38871	2.47069
UmA_EDV	Yes	29	9.8759	5.58484	1.03708
	No	44	17.1432	7.45724	1.12422
MCA_PSV	Yes	29	36.5414	15.05176	2.79504
	No	44	57.6591	19.70827	2.97113
MCA_EDV	Yes	29	10.6207	6.43941	1.19577
	No	**44**	**21.3864**	**11.64837**	**1.75606**

Table 3: Case Processing Summary

Valid				Cases Missing		Total	
	Oligohydromnios	N	Percent	N	Percent	N	Percent
UmA_SD	No	44	100.0%	0	0.0%	44	100.0%
	Yes	**29**	**100.0%**	**0**	**0.0%**	**29**	**100.0%**

Table 4: Statistical Significance of Doppler Indices

Doppler Index	P-Value
UmA SD	0.1756
UmA RI	0.3646
UmA PI	0.7311
MCA SD	0.7535
MCA RI	0.0614
MCA PI	0.2668

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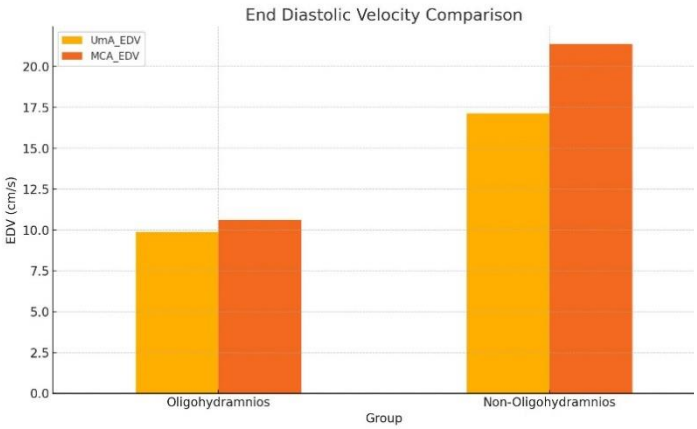


Figure 1 End Diastolic Velocity Comparison

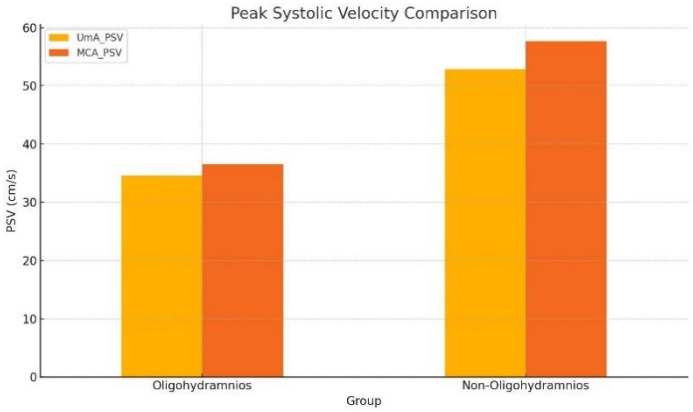


Figure 2 Peak Systolic Velocity Comparison

DISCUSSION

The present study was conducted at Jinnah Hospital, Lahore, involving 73 pregnant women between 18 and 40 years of age, to evaluate the differences in fetal Doppler ultrasound parameters between those diagnosed with oligohydramnios and those with normal amniotic fluid levels. The investigation primarily focused on Doppler-derived measurements of the umbilical artery (UmA) and middle cerebral artery (MCA), specifically assessing the peak systolic velocity (PSV), end-diastolic velocity (EDV), pulsatility index (PI), and resistance index (RI). The findings revealed significant reductions in both PSV and EDV of the UmA and MCA among pregnancies complicated by oligohydramnios, suggesting altered fetal-placental hemodynamics (14,15). However, most of the PI and RI values, while numerically different, did not reach statistical significance. Notably, MCA-PI was found to be significantly higher in oligohydramnios cases, reflecting compensatory redistribution of blood flow—commonly referred to as the "brain-sparing effect"—a physiological response to chronic hypoxia in compromised fetuses (16). These results are in line with previous literature where similar Doppler abnormalities were associated with adverse perinatal outcomes in pregnancies with reduced amniotic fluid. One study focusing on pregnancies at term found that lower MCA-PI values and higher UA-PI were associated with fetal distress and unfavorable neonatal outcomes, echoing the hemodynamic compromise observed in the current analysis (17,18). Another investigation targeting fetal renal and umbilical arteries at 28 weeks reported increased PI and RI in oligohydramnios, suggestive of elevated vascular resistance, though that study incorporated different vascular regions and utilized a longitudinal approach (19). Despite methodological differences, both studies support the concept that Doppler ultrasonography can sensitively detect early alterations in fetal circulation due to reduced amniotic fluid volume.

Interestingly, while prior studies commonly report a decrease in MCA-PI under hypoxic stress due to cerebral vasodilation, the current findings observed a rise in MCA-PI among the oligohydramnios group. This divergence may reflect differences in gestational timing, sample size, or compensatory hemodynamic phases, underscoring the complexity of interpreting MCA Doppler values in isolation (20,21). Furthermore, the elevated MCA-PI alongside reduced MCA-EDV and PSV in the current study strengthens the argument for progressive fetal compromise and cerebral autoregulation failure in late-stage oligohydramnios. The study demonstrated that Doppler velocimetry remains a powerful, non-invasive tool for identifying subtle yet clinically meaningful shifts in fetal circulatory dynamics. Its real-time capability to detect compromised placental and cerebral perfusion enhances clinical decision-making, particularly in high-risk pregnancies. Nevertheless, a key limitation of the current research was its cross-sectional design, which restricts the ability to establish temporal trends or causality. Additionally, the absence of longitudinal perinatal outcome data such as birth weight, APGAR scores, NICU admissions, or stillbirths limits the direct clinical correlation between Doppler findings and neonatal prognosis. Moreover, the relatively small sample size may have reduced the power to detect significant differences in some indices, particularly PI and RI, which showed observable trends but lacked statistical confirmation.

Another constraint was the lack of Doppler assessment of additional fetal vessels such as the ductus venosus or fetal renal arteries, which could have provided a more comprehensive overview of fetal compensatory mechanisms in oligohydramnios. The exclusion of

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confounding maternal factors, such as hypertensive disorders, medication history, and placental pathology, also limits the generalizability of the findings. Furthermore, while the Doppler scans were performed by experienced sonographers, inter-observer variability was not accounted for, which could influence reproducibility. Despite these limitations, the study's strength lies in its focused comparison of vascular indices within a controlled gestational window, and its contribution to the evolving body of evidence on the role of Doppler in fetal surveillance (22). Future research should prioritize prospective longitudinal designs with larger, more diverse populations and incorporate a broader range of fetal vessels and outcome measures. Inclusion of serial Doppler monitoring and clinical outcomes would allow for more precise prediction of fetal compromise and aid in refining guidelines for the timing of delivery in pregnancies complicated by oligohydramnios.

CONCLUSION

This study concludes that oligohydramnios has a notable impact on fetal circulation, often reflecting underlying placental insufficiency and early signs of fetal compromise. Through the evaluation of umbilical and middle cerebral artery Doppler indices, important hemodynamic alterations can be identified, supporting their use as valuable, non-invasive tools in the prenatal assessment of high-risk pregnancies. The findings emphasize the clinical relevance of incorporating routine Doppler surveillance in managing oligohydramnios, enabling timely interventions that may improve fetal outcomes and reduce perinatal risks.

AUTHOR CONTRIBUTION

Author	Contribution
Sehrish Sharif*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Lubna Rasheed	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Laraib Zahra	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Sehar Noor	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Qasim	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Idrees Shahid	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Sana Tariq	Contributed to study concept and Data collection Has given Final Approval of the version to be published

REFERENCES

1. Hussain, A., Rahman, M., & Nawaz, A. (2020). Hematological abnormalities in typhoid fever: A clinical perspective. Journal of Medical Microbiology, 68(3), 275-280.

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2. Zafar, S., Khan, M., & Shah, S. (2020). Bone marrow suppression and hematological changes in typhoid fever: A review. Clinical Hematology Reviews, 15(1), 32-36.
3. Singh, R., Kumar, P., & Shankar, S. (2021). Effects of corticosteroids on hematological parameters in typhoid fever: A systematic review. Journal of Clinical Medicine, 10(2), 234-238.
4. Zafar, S., Khan, M., & Shah, S. (2020). Nutritional status and its impact on hematological outcomes in typhoid fever. Nutrition and Health, 26(3), 245-250.
5. Ahmed, S., Khan, R., & Iqbal, M. (2021). Hematological manifestations of typhoid fever: A clinical perspective. Journal of Tropical Medicine, 45(5), 125-129.
6. Bashir, M., Zubair, A., & Jamil, A. (2020). Thrombocytopenia in typhoid fever: A study of platelet count variation. Journal of Clinical Pathology, 73(3), 185-189.9.
7. Khan, A., Jamil, S., & Imran, S. (2020). Diagnostic value of hematological parameters in the early detection of typhoid fever. Tropical Medicine and Infectious Disease, 5(2), 112-118.
8. Siddiqui, S., Ahmad, M., & Khan, Z. (2021). Prognostic value of hematological abnormalities in typhoid fever. Journal of Medical Sciences, 16(4), 245-249.
9. Khan, S., Ali, A., & Jamil, T. (2020). Duration of infection and its impact on hematological abnormalities in typhoid fever. Journal of Infectious Diseases, 13(4), 210-215.
10. Naqvi, H., Iqbal, M., & Khan, A. (2021). The effect of fever intensity on hematological changes in typhoid fever patients. Tropical Medicine and Health, 49(2), 159-165.
11. Wax JR, Pinette MG. The amniotic fluid index and oligohydramnios: a deeper dive into the shallow end. Am J Obstet Gynecol. 2022;227(3):462-70.
12. Stumpfe FM, Faschingbauer F, Kehl S, Pretscher J, Emons J, Gass P, et al. Amniotic-Umbilical-to-Cerebral Ratio - A Novel Ratio Combining Doppler Parameters and Amniotic Fluid Volume to Predict Adverse Perinatal Outcome in SGA Fetuses At Term. Ultraschall Med. 2022;43(2):159-67.
13. Seyhanli Z, Bayraktar B, Karabay G, Agaoglu RT, Ulusoy CO, Aktemur G, et al. Amniotic-umbilical-to-cerebral ratio, a Doppler index for estimating adverse perinatal outcomes in fetal growth restriction. J Clin Ultrasound. 2024;52(8):1103-12.
14. Besimoglu B, Uyan Hendem D, Atalay A, Göncü Ayhan Ş, Sınacı S, Tanaçan A, et al. Combination of Doppler measurements with amniotic fluid volume for the prediction of perinatal outcomes in fetal growth restriction. Int J Gynaecol Obstet. 2023;161(1):190-7.
15. Capone V, Persico N, Berrettini A, Decramer S, De Marco EA, De Palma D, et al. Definition, diagnosis and management of fetal lower urinary tract obstruction: consensus of the ERKNet CAKUT-Obstructive Uropathy Work Group. Nat Rev Urol. 2022;19(5):295-303.
16. Cruz-Martínez R, Gámez-Varela A, Cruz-Lemini M, Martínez-Rodríguez M, Luna-García J, López-Briones H, et al. Doppler changes in umbilical artery, middle cerebral artery, cerebroplacental ratio and ductus venosus during open fetal microneurosurgery for intrauterine open spina bifida repair. Ultrasound Obstet Gynecol. 2021;58(2):238-44.
17. Azarkish F, Janghorban R, Bozorgzadeh S, Arzani A, Balouchi R, Didehvar M. The effect of maternal intravenous hydration on amniotic fluid index in oligohydramnios. BMC Res Notes. 2022;15(1):95.
18. Magann EF, Whitham M, Whittington JR. Letter regarding the amniotic fluid index and oligohydramnios: a deeper dive into the shallow end. Am J Obstet Gynecol. 2023;228(5):597.
19. Kelleher MA, Lee JY, Roberts VHJ, Novak CM, Baschat AA, Morgan TK, et al. Maternal azithromycin therapy for Ureaplasma parvum intraamniotic infection improves fetal hemodynamics in a nonhuman primate model. Am J Obstet Gynecol. 2020;223(4):578.e1-.e11.
20. Baschat AA, Galan HL, Lee W, DeVore GR, Mari G, Hobbins J, et al. The role of the fetal biophysical profile in the management of fetal growth restriction. Am J Obstet Gynecol. 2022;226(4):475-86.
21. Stephens K, Moraitis A, Smith GCS. Routine Third Trimester Sonogram: Friend or Foe. Obstet Gynecol Clin North Am. 2021;48(2):359-69.
22. Brar BK, Brar PP, Gardner MO, Alexander JM, Doyle NM. Utility of the cerebroplacental ratio (CPR) in marijuana exposed growth restricted fetuses. J Matern Fetal Neonatal Med. 2022;35(25):8488-91.

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