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Doppler Evaluation of Middle Cerebral Artery and Umbilical Artery Pulsatility Index in the Diagnosis of IUGR Taking Clinical IUGR at Birth as Gold Standard

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ABSTRACT

Objectives: To detect Intrauterine growth restriction pregnancies and evaluate doppler indices as the fetal Middle cerebral artery and the umbilical artery pulsatility index for their diagnostic accuracy and preserve clinically significant IUGR at birth as the gold standard.

Methodology: This descriptive, cross-sectional study was performed at AFIRI, PEMH Rawalpindi from March 30, 2020, to September 29, 2020, AFIRI. There were 123 patients diagnosed with IUGR ranging in age at gestation: 31–40 weeks and ages 31 to 40 years old. Enrollment of all patients in the study was based on inclusion criteria. A 3.5–5 MHz convex array transducer was used to measure doppler indices once fetal biometry was completed. During each examination, each series of measurements was made three times, and the outcomes were averaged.

Results: Following a doppler ultrasonography on all patients, it was discovered that 60 (48.7%) were true positives and 9 (7.3%) were false positives. Of the 54 individuals who tested negative for Doppler, 7 (5.6%) were false negatives, meaning that a clinical examination revealed fetal IUGR after birth, and 47 (38.2%) were true negatives (p=0.0001). In order to diagnose IUGR pregnancies, the Doppler indices overall sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were 89.55%, 83.93%, 86.96%, 87.04%, and 86.99%, respectively, for the fetal MCA and umbilical artery pulse index.

Conclusion: According to the study findings, Doppler indices have a fairly high diagnosis accuracy when it comes to IUGR pregnancies.

Keywords: Fetal Growth Retardation, Doppler Ultrasonography, Pulsatile Flow, Pregnancy Complications.

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Introduction

Intrauterine growth restriction (IUGR) occurs when a fetus does not reach its full genetic potential, which affects 24% of the world's population and is most prevalent in Asia. [1] Increased prenatal risks and neurodevelopmental problems are associated with IUGR.[2] The primary reason is abnormal placentation, which is frequently linked to decreased blood flow.[3] Hazard reduction depends on early discovery. Doppler ultrasonography is essential for assessing the Middle Cerebral Artery Pulsatility Index (MCA PI) and Umbilical Artery Pulsatility Index (UA PI) in high-risk pregnancies as part of fetomaternal surveillance.[4] Perinatal morbidity is indicated by low MCA PI and elevated UA PI.[5] Blood is redistributed to the brain in IUGR patients, resulting in the "brain sparing effect". [6] Antenatal care seeks early identification of IUGR fetuses in order to facilitate timely intervention.[7] Because low birth weight and newborn morbidity are correlated with aberrant blood flow indices, Doppler velocimetry is essential for surveillance [8] Research conducted in India shows that UA PI is 91% sensitive and MCA PI is 87.5% sensitive [9] I want to evaluate the value of color Doppler velocimetry for the diagnosis of IUGR pregnancies. Genetic and environmental variations may prevent studies from other countries from being broadly applicable.

Intrauterine growth restriction (IUGR), which arises when a fetus is unable to fulfill its genetically designed growth potential, is a difficult issue in the field of maternal-fetal medicine.[10] Approximately 24% of neonates worldwide suffer from IUGR, affecting 30 million babies each year.[11] In addition to having a significant negative impact on public health, this illness raises the risk of perinatal death, morbidity, and long-term neurodevelopmental disabilities.

The main cause of IUGR is abnormal placentation, which is frequently associated with decreased placental blood flow that prolongs fetal hypoxia and consequently results in inadequate growth in utero [12] The most frequent cause of IUGR is clearly placental insufficiency, either as a main phenomena or as a downstream effect of maternal conditions like hypertension and malnutrition. Early detection of placental insufficiency is essential for reducing, if not completely eliminating, any potential risks associated with it. [13]

Given that IUGR is linked to poor fetomaternal outcomes, prompt intervention depends on early identification. [14] The identification of fetuses at risk is mostly dependent on ultrasonographic (US) biometry, namely the assessment of the estimated fetal weight (EFW) and the Doppler ultrasonography-based detection of aberrant vascular resistance patterns .[15] Assessing blood flow patterns, Doppler velocimetry has become a critical clinical tool for fetomaternal surveillance in high-risk pregnancies.

The umbilical artery pulsatility index (UA PI) and the middle cerebral artery pulsatility index (MCA PI) are two crucial metrics in the Doppler evaluation procedure. Normal fetal development usually shows minimal diastolic flow in the MCA. Lower MCA PI levels, on the other hand, are seen in IUGR instances and are linked to vasodilatation brought on by fetal hypoxia, which results in a phenomenon called the "brain sparing effect." In order to ensure that the brain receives enough blood flow, this adaptive mechanism redistributes blood from peripheral and stomach veins .[16]

Doppler velocimetry has shown to be an effective method for fetomaternal surveillance, particularly how well it can diagnose IUGR, particularly in the third trimester. There are currently few studies that have really investigated color Doppler velocimetry's diagnostic potential in the local population, with an emphasis on UA PI and MCA PI [17] Variations in genetic makeup and environmental factors may limit the generalizability of studies conducted in different countries.

This is why the current study aims to evaluate the usefulness of color Doppler velocimetry in the diagnosis of IUGR in the context of our local population, with a focus on UA PI and MCA PI. We want to improve our understanding of the diagnostic accuracy and usefulness of these indicators in predicting severe perinatal outcomes associated with IUGR by comparing Doppler findings with clinical outcomes, specifically utilizing clinical IUGR at birth as the gold standard. The work not only contributes to the existing body of information but also addresses the need for insights into IUGR diagnosis and treatment in improving post-natal outcome.

Methodology

The AFIRI, PEMH Rawalpindi carried out this descriptive (cross-sectional) validation study. Between March 30, 2020, and September 29, 2020, the research was conducted. The WHO sample size calculator was used to calculate the sample size using the following statistics: sensitivity of 0.875, specificity of 0.469, confidence level of 95%, absolute precision for sensitivity of 10%, absolute precision for specificity of 5%, and prevalence of 24.9%. Our computation yielded a sample size of 123. The non-probability, consecutive sampling approach was used to carry out this sampling.

All women between the ages of 31 and 40 who are singleton pregnant, with a fetus between the ages of 31 and 40 weeks gestation, and who have a clinically suspected intrauterine development impairment (defined as estimated fetal weight <10th percentile for gestation) are eligible for inclusion. All pregnant women who are fewer than 31 weeks along by LMP or with congenital fetal defects or metabolic disorders in the past pregnancies, or several gestations are excluded. The patients who were part of the trial gave their written informed consent. An advance clearance from the institutional ethical committee was requested. Enrollment of all patients in the trial was based on inclusion and exclusion criteria. On a standardized proforma, pertinent clinical and patient demographic data was gathered. All patients who satisfied the inclusion criteria underwent Doppler ultrasonography after a thorough clinical history and US biometry. First, doppler velocimetry was conducted using a 3.5–5 MHz convex array transducer,

after fetal biometry. When using an umbilical artery Doppler, observe the cord and then choose a free loop that is not too near the placental or fetal cord insertion. Estimates should be made until a reasonable waveform is obtained without the fetal breathing or moving. The Pulsatility Index (PI) was measured in order to determine whether end-diastolic frequencies were present or absent. For MCA Doppler US, a transverse picture of the fetal head at the level of the sphenoid bones was obtained. In the near field, the internal carotid artery should be insonated around 1 cm distal to the MCA. Every measurement sequence was taken three times during each examination, and the average of the data was computed.

Data were recorded and analyzed using the Statistical Package for the Social Sciences (SPSS, version) for Windows. Qualitative data were expressed as frequency and percentage, whereas quantitative parameters (age) were presented as mean + standard deviation. The manipulation of effect modifiers was made possible by stratification. The formulas were used to obtain the positive predictive value (PPV), negative predictive value (NPV), specificity, and sensitivity.

Results

The mean gestational age was 37.91 ± 1.88 weeks, with a range of 31 to 40 weeks. Table I shows that 112 patients (91%) had ages ranging from 36 to 40 weeks.

Table I: Patient distribution based on gestational age.

Gestational Age (weeks)	No. of patients	%
31-35	11	8.94
36-40	112	91.06
Total	123	100

Doppler ultrasonography was performed on each patient, and the results indicated that 60 were true positives and 09 were false positives. As seen in Table II, of the 54 Doppler negative patients, 07 (False negative) patients developed IUGR at delivery, while 47 (TN) patients had no IUGR at birth (p= 0.0001).

Using the umbilical artery and fetal MCA Pulsatility Index, the Doppler velocimetry's overall sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were 89.55%, 83.93%, 86.96%, 87.04%, and 86.99%, respectively, in diagnosing IUGR pregnancies.

Discussion

Doppler blood flow velocity waveform analysis is suggested by recent studies as a cutting-edge technique for IUGR prenatal diagnosis. As opposed to clinical and ultrasonography assessments, which frequently identify IUGR after the fact, Doppler investigations provide early identification, allowing for prompt delivery and minimizing fetal damage. Color Doppler ultrasonography evaluates blood flow indirectly and offers direct information on vascular resistance .[18]

My study assessed the diagnostic accuracy of Doppler velocimetry, namely the fetal MCA and the umbilical artery Pulsatility Index, in order to diagnosis IUGR pregnancies. The results showed high values of specificity (83.93%), sensitivity (89.55%), negative predictive value (87.04%), positive predictive value (86.96%), and total diagnostic accuracy (86.99%). According to a different Indian study, the sensitivity of MCA PI was 87.5%, whereas the sensitivity of umbilical artery PI was 91%. It was discovered that the UA PI had 84.6% specificity and the MCA PI had 46% .[19]

Predicting IUGR outcomes showed a sensitivity of 44% and a specificity of 61.5% in a trial with a similar design, according to Mehdi et al. The positive and negative predictive values were 83% and 20%, respectively.[20] The inclusion of grayscale-proven IUGR cases may have contributed to the poor negative predictive value and greater prevalence. However, Abdelhai et al. found that the combined umbilical artery indices had a sensitivity of 94%, indicating a noticeably higher sensitivity.[21] They did not, however, outline the requirements for the umbilical artery combined indices. According to Lakhkar et al., there was PPV, 81.8% specificity, and 44.4% sensitivity.

Kale et al. discovered that their prediction of substantial negative outcomes in pregnancies older than 30 weeks had a sensitivity of 44.4%, specificity of 81.8%, PPV of 80%, and NPV of 47.3% using severe preeclampsia and IUGR.[22] They found that UA RI had the following

Table II: Doppler velocimetry comparison with birth clinical results.

	Positive result on birth	Negative result on birth	p-value
Positive result on Doppler velocimetry	60 (TP)*	09 (FP)**	0.0001
Negative result on Doppler velocimetry	07 (FN)***	47 (TN)****	

*-TP= True Positive **-FP=False positive ***-FN= False Negative ****-TN=True Negative

Sensitivity: 89.55%, Specificity: 83.93%, PPV: 86.96%, NPV: 87.04%, Diagnostic Accuracy: 86.99 %

qualities: sensitivity of 58%, specificity of 71.7%, PPV of 35%, and NPV of 86.8%. It also showed a 56.8% diagnostic accuracy for major adverse outcomes and 44.4% sensitivity, 81.8% specificity, 80% PPV, and 47.3% NPV for mild adverse outcomes. UA RI was found by Hassan et al. to be 100% sensitive but only 44% specific at a cut-off of 0.64; with a higher cut-off of 0.81, it was 28% sensitive and 100% specific [23]

According to one study, if pulsatility ratio was less than 1.08, it might predict unfavorable perinatal outcomes in IUGR with 68% sensitivity, 98.4% specificity, 94.4% PPV, 88.8% NPV, and 90% diagnostic accuracy ([24]). The same ratio was used in another investigation, which revealed 95.6% diagnostic accuracy, 94.3% NPV, 100% specificity, 100% PPV, and 83.3% sensitivity. For predicting FGR, Melamed et al. found 47% sensitivity and 91% specificity.[25] Ismail et al. reported that the cerebral umbilical Doppler ratio outperformed individual artery readings, with a 70% diagnostic accuracy for predicting small for gestational age infants and a 90% accuracy for poor perinatal outcomes .[26]

Doppler was reported by Madhu et al. to be 95% accurate in predicting fetal growth retardation, neonatal mortality, and preeclampsia.[27] Yoon et al. found that in preeclampsia patients, aberrant Doppler umbilical artery waveform strongly predicts unfavorable perinatal outcomes. Pregnancy-induced hypertension and/or IUGR in high-risk pregnancies were well predicted by pathological Doppler velocimetry of the uterine and uteroplacental circulation, with a 58.3% chance of illness presentation later in pregnancy. It was demonstrated that using more than one Doppler parameter increased efficiency.

Fetuses with umbilical artery reversed flow had a higher rate of neonatal mortality, according to Contag et al. Furthermore, there was a greater prevalence of perinatal morbidity and mortality in fetuses with low birth weight, absent or reversed ductus venosus flow, and idiopathic growth restriction.[28] Sruti et al. found that abnormal venous Doppler waveforms in preterm IUGR fetuses with ARED flow were strongly associated with poorer fetal and postnatal outcomes prior to 32 weeks of gestation .[29] Vesna et al.'s study indicates that expectant treatment does not reduce long-term morbidity and is linked to greater perinatal loss in IUGR cases with umbilical Doppler AEDF/REDF. The study looked at children with aberrant umbilical artery Doppler ultrasounds in terms of short- and long-term morbidity and mortality .[30]

Conclusion

According to this study, Doppler velocimetry—more specifically, the fetal MCA and umbilical artery Pulsatility Index measurements—is a highly reliable method of detecting IUGR pregnancies. In order for both the mother and the fetus to reduce perinatal mortality and morbidity, it therefore recommends using them to detect IUGR early and take prompt preventive treatment.

References

1. Rescinito R, Ratti M, Payedimarri AB, Panella M. Prediction models for intrauterine growth restriction using artificial intelligence and machine learning: A systematic review and meta-analysis. Healthcare (Basel). 2023;11(11):1617. https://doi.org/10.3390/healthcare11111617
2. Sacchi C, O'Muircheartaigh J, Batalle D, Counsell SJ, Simonelli A, Cesano M, et al. Neurodevelopmental outcomes following intrauterine growth restriction and very preterm birth. J Pediatr. 2021;238:135-144.e10. https://doi.org/10.1016/j.jpeds.2021.07.002
3. Jansen CHJR, Kastelein AW, Kleinrouweler CE, Van Leeuwen E, De Jong KH, Pajkrt E, et al. Development of placental abnormalities in location and anatomy. Acta Obstet Gynecol Scand. 2020;99(8):983-93. https://doi.org/10.1111/aogs.13834
4. Setiawan D, Mose JC, Azis MA. Fetal middle cerebral artery and umbilical artery pulsatility index Doppler associations with pregnancy risk and neonatal outcomes. Int J Childbirth. 2023;12(2):97. https://doi.org/10.1891/IJC-2022-0049
5. Bonnevier A, Maršál K, Brodszki J, Thuring A, Källén K. Cerebroplacental ratio as predictor of adverse perinatal outcome in the third trimester. Acta Obstet Gynecol Scand. 2021;100(3):497-503. https://doi.org/10.1111/aogs.14031
6. Misan N, Michalak S, Kapska K, Osztynowicz K, Ropacka-Lesiak M. Blood-brain barrier disintegration in growth-restricted fetuses with brain sparing effect. Int J Mol Sci. 2022;23(20):12349. https://doi.org/10.3390/ijms232012349
7. Judd FA, Haran SS, Everett TR. Antenatal fetal wellbeing. Obstet Gynaecol Reprod Med. 2020;30(7):197-204. https://doi.org/10.1016/j.ogrm.2020.03.008
8. Tolu LB, Ararso R, Abdulkadir A, Feyissa GT, Worku Y. Perinatal outcome of growth restricted fetuses with abnormal umbilical artery Doppler waveforms compared to growth restricted fetuses with normal umbilical artery Doppler waveforms at a tertiary referral hospital in urban Ethiopia. PLoS One. 2020;15(6):e0234810. https://doi.org/10.1371/journal.pone.0234810
9. Kamath BR, Gandhi R. Efficacy of third trimester fetal Doppler assessment in predicting perinatal outcome [dissertation].
10. National Research Council. Effects of perinatal opioid exposure. Vol. 2. Washington (DC): National Academies

Press; [cited 2024 Jul 12]. Available from: https://books.google.com.pk/

11. Universidade de Lisboa. Nutrition support of preterm infants in intensive care unit [Internet]. Available from: https://repositorio.ul.pt/handle/10451/53828
12. Mecacci F, Avagliano L, Lisi F, Clemenza S, Serena C, Vannuccini S, et al. Fetal growth restriction: Does an integrated maternal hemodynamic-placental model fit better? Reprod Sci. 2021;28(9):2422-35. https://doi.org/10.1007/s43032-020-00393-2
13. Ganguly E, Hula N, Spaans F, Cooke CLM, Davidge ST. Placenta-targeted treatment strategies: An opportunity to impact fetal development and improve offspring health later in life. Pharmacol Res. 2020;157:104836. https://doi.org/10.1016/j.phrs.2020.104836
14. Tsikouras P, Antsaklis P, Nikolettos K, Kotanidou S, Kritsotaki N, Bothou A, et al. Diagnosis, prevention, and management of fetal growth restriction (FGR). J Pers Med. 2024;14(7):698. https://doi.org/10.3390/jpm14070698
15. Debbink MP, Son SL, Woodward PJ, Kennedy AM. Sonographic assessment of fetal growth abnormalities. Radiographics. 2021;41(1):268-88. https://doi.org/10.1148/rg.2021200081
16. Visentin S, Carli S, Sartor F, D'Errico I, Cosmi E. Fetal growth monitoring and issues: The intrauterine monitoring of middle cerebral artery and its role in neuronal development of the newborn. In: Innovative Technologies and Signal Processing in Perinatal Medicine. 2024. p.1–9. https://doi.org/10.1007/978-3-031-32625-7_1
17. Ferreira GT. An evaluation of the physiological variability inherent in common maternal-fetal Doppler parameters [thesis]. 2021. Available from: http://hdl.handle.net/1959.4/100242
18. Meola M, Ibeas J, Lasalle G, Petrucci I. Basics for performing a high-quality color Doppler sonography of the vascular access. J Vasc Access. 2021;22(1):18-31. https://doi.org/10.1177/11297298211018060
19. Sood N, Jobta A, Ganju S. Clinical significance of cerebro-placental ratio in antenatal surveillance. Int J Clin Obstet Gynaecol. 2020;4(3):213-8. https://doi.org/10.33545/gynae.2020.v4.i3d.606
20. Mehdi SA, Bukhari H, Dogar IH, Shabbir I. Diagnostic accuracy of color Doppler of cerebral and umbilical pulsatility in diagnosing IUGR, taking birth weight as gold standard. Prof Med J. 2020;27(3):651-9. https://doi.org/10.29309/TPMJ/2020.27.03.4309
21. Abdelhai MA, Mohamed MA, Mahmoud MA, Gaber YZ. Role of fetal umbilical artery and middle cerebral artery Doppler in post-term pregnancy and neonatal outcome. Benha J Appl Sci. 2020;5(2 Pt 1):151-60. https://doi.org/10.21608/bjas.2020.135470
22. Kale RM, Tirupathi RG, Sheela SR. Role of ultrasonography and color Doppler in the assessment of high-risk pregnancies and their accuracy in predicting fetal outcome. Cureus. 2023;15(5):e39017. https://doi.org/10.7759/cureus.39017
23. Hassan HA, Yosri LM, Ali EH. Prediction of fetal growth restriction using combined fetal biometry and maternal serum inhibin A in pregnant women with type 1 diabetes. J Recent Adv Med. 2022;3(1):1-9. Available from: https://jram.journals.ekb.eg/article_165142.html
24. Mehdi S, Bukhari H, Dogar IH, Bukhari H. Diagnostic accuracy of Color Doppler of cerebral and umbilical pulsatality in diagnosing IUGR, taking birth weight as gold standard. Professional Med J 2020; 27(3):651-659.DOI: 10.29309/TPMJ/2020.27.3.4309
25. Melamed N, Baschat A, Yinon Y, Athanasiadis A, Mecacci F, Figueras F, et al. FIGO initiative on fetal growth: Best practice advice for screening, diagnosis, and management of fetal growth restriction. Int J Gynaecol Obstet. 2021;152(Suppl 1):3. https://doi.org/10.1002/ijgo.13522
26. Ismail A, Ibrahim A, Rabiu A, Muhammad Z, Garba I. Predictive value of Doppler cerebroplacental ratio for adverse perinatal outcomes in postdate pregnancies in Northwestern Nigeria. Niger J Clin Pract. 2022;25(4):406-14. https://doi.org/10.4103/njcp.njcp_14_21
27. Madhu P. Role of Doppler ultrasound in pregnancy induced hypertension and perinatal outcome [unpublished dissertation].
28. Contag S, Visentin S, Goetzinger K, Cosmi E. Use of the renal artery Doppler to identify small for gestational age fetuses at risk for adverse neonatal outcomes. J Clin Med. 2021;10(9):1835. https://doi.org/10.3390/jcm10091835
29. Sruti K. Comparative evaluation of the arterial and venous Doppler in predicting perinatal outcome in fetus with IUGR [dissertation].
30. Mandić-Marković V, Bogavac M, Miković Ž, Panić M, Pavlović DM, Mitrović J, et al. Diagnostic tests in the prediction of neonatal outcome in early placental fetal growth restriction. Medicina (Kaunas). 2023;59(2):406. https://doi.org/10.3390/medicina59020406