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OBSTETRICS

Diagnostic Accuracy of the Foetal Umbilical Artery, Middle Cerebral Artery Doppler Indices and Cerebroplacental Ratios for Predicting Adverse Perinatal Outcomes in Pregnancy-induced Hypertension

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ABSTRACT

Objectives: This study aimed to evaluate the accuracy of the foetal umbilical artery, middle cerebral artery Doppler indices and cerebroplacental ratios to predict adverse perinatal outcomes in pregnancy-induced hypertension.

Materials and Methods: This study was a diagnostic test. The study population comprised 76 women with singleton pregnancies (32-40 weeks gestation) diagnosed with pregnancy-induced hypertension who were admitted to Hatyai Hospital between December 2020 and November 2022. Diagnostic accuracy for all Doppler measurements was evaluated using sensitivity, specificity, accuracy and positive likelihood ratio (LR+) analysis.

Results: The umbilical artery pulsatility index (UA PI) had the highest sensitivity for predicting adverse perinatal outcomes at 80% for predicting neonatal intensive care unit (NICU) admissions ($p = 0.044$), though the Umbilical arterial systolic/diastolic (UA S/D) ratio, The fetal middle cerebral artery pulsatility index (MCA PI) and cerebroplacental ratio (CPR) were poor predictors of NICU admissions ($p > 0.05$). The MCA PI could better predict all perinatal outcomes with LR+ 4.29 ($p = 0.003$).

Conclusion: Fetal umbilical artery Doppler; Middle cerebral artery Doppler; Cerebroplacental ratio, Perinatal outcomes, Pregnancy-induced hypertension

Keywords: fetal umbilical artery Doppler, middle cerebral artery Doppler, cerebroplacental ratio, perinatal outcomes, pregnancy-induced hypertension.

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การวัดเส้นเลือดแดงบริเวณสายสะดือและเส้นเลือดแดงบริเวณสมองทารกในครรภ์ร่วมกับการวัดค่าอัตราส่วนแรงต้านทานระหว่างเส้นเลือดแดงบริเวณสมองกับเส้นเลือดแดงบริเวณสายสะดือทารกเพื่อทำนายผลลัพธ์การคลอดของทารกที่ไม่พึงประสงค์ในหญิงตั้งครรภ์ที่มีภาวะความดันโลหิตสูงขณะตั้งครรภ์

พักตร์ประภา ไชยภักดี

บทคัดย่อ

วัตถุประสงค์: *เพื่อหาความแม่นยำของการใช้เส้นเลือดแดงบริเวณสายสะดือและเส้นเลือดแดงบริเวณสมองทารกในครรภ์ร่วมกับการวัดค่าอัตราส่วนแรงต้านทานระหว่างเส้นเลือดแดงบริเวณสมองกับเส้นเลือดแดงบริเวณสายสะดือทารกเพื่อทำนายภาวะทุพพลภาพของทารกหลังคลอดและทารกตายปริกำเนิดในหญิงตั้งครรภ์ที่มีภาวะความดันโลหิตสูงขณะตั้งครรภ์*

วัสดุและวิธีการ: *การศึกษานี้เป็นการศึกษาแบบทดสอบวินิจฉัยความแม่นยำของการใช้เส้นเลือดแดงบริเวณสายสะดือและเส้นเลือดแดงบริเวณสมองทารกในครรภ์ร่วมกับการวัดค่าอัตราส่วนแรงต้านทานระหว่างเส้นเลือดแดงบริเวณสมองกับเส้นเลือดแดงบริเวณสายสะดือทารกเพื่อทำนายภาวะทุพพลภาพของทารกหลังคลอดโดยทำในสตรีตั้งครรภ์เดี่ยวช่วงอายุครรภ์ตั้งแต่ 32 ถึง 40 สัปดาห์ ที่ได้รับการวินิจฉัยว่ามีภาวะความดันโลหิตสูงขณะตั้งครรภ์ ณ โรงพยาบาลหาดใหญ่ ระหว่างเดือนธันวาคม พ.ศ.2563 ถึงเดือนพฤศจิกายน พ.ศ.2565 โดยวิเคราะห์เป็น ความไว ความจำเพาะ ความแม่นยำ และอัตราส่วนความน่าจะเป็น*

ผลการศึกษา: *เส้นเลือดแดงบริเวณสายสะดือทารกในครรภ์ (UA PI) ช่วยทำนายภาวะเข้ารับการรักษาที่ห้องอภิบาลทารกแรกเกิดภาวะวิกฤติได้ดีที่สุดเมื่อเทียบกับเส้นเลือดอื่นๆ โดยมีความไวร้อยละ 80 นอกจากนี้เส้นเลือดแดงบริเวณสมองทารกในครรภ์ (MCA PI) ยังช่วยทำนายผลลัพธ์การคลอดของทารกโดยรวมได้ดีที่สุด (LR+=4.29)*

สรุป: *เส้นเลือดแดงบริเวณสายสะดือทารกในครรภ์ (UA PI) ช่วยทำนายภาวะเข้ารับการรักษาที่ห้องอภิบาลทารกแรกเกิดภาวะวิกฤติได้ดีที่สุด นอกจากนี้ MCA PI ยังช่วยทำนายผลลัพธ์การคลอดของทารกโดยรวมได้ดีที่สุด (LR+=4.29)*

คำสำคัญ: *เส้นเลือดแดงบริเวณสายสะดือทารกในครรภ์, เส้นเลือดแดงบริเวณสมองทารกในครรภ์, อัตราส่วนแรงต้านทานระหว่างเส้นเลือดแดงบริเวณสมองกับเส้นเลือดแดงบริเวณสายสะดือทารก, ผลลัพธ์การคลอดของทารกที่ไม่พึงประสงค์, ภาวะความดันโลหิตสูงขณะตั้งครรภ์*

Introduction

Pregnancy-induced hypertension (PIH) is the novel onset of hypertension after 20 weeks of gestation and typically returns to normal by 12 weeks postpartum. PIH criteria include gestational hypertension, preeclampsia and chronic hypertension with superimposed preeclampsia[1]. PIH is one of the most common causes of both maternal and neonatal morbidity, affecting about 5-10 % of pregnant women. The incidence of PIH at Hatyai Hospital is about 5 %.

The pathogenesis of PIH has not yet been fully elucidated. However, PIH is associated with reduced uteroplacental perfusion as a result of abnormal cytotrophoblast invasion of spiral arterioles, which may affect intrauterine growth restriction (IUGR), foetal hypoxemia and foetal death[2].

Uteroplacental and fetoplacental circulation can be studied effectively by Doppler ultrasound. Many studies have used foetal vascular Doppler tests, such as umbilical artery, middle cerebral artery indices and cerebroplacental ratios for the prediction of uteroplacental insufficiency and perinatal mortality[3-9].

Despite the aforementioned, few studies in Thailand have focused on foetal Doppler research for the prediction of adverse perinatal outcomes in PIH and the results of previous studies remain inconclusive. Therefore, the objective of this study was to assess the accuracy of the foetal umbilical artery and middle cerebral artery Doppler indices and cerebroplacental ratios were used to predict adverse perinatal outcomes, including neonatal intensive care unit (NICU) admission, and Apgar score < 7 at 5 minutes in PIH. This study was the first in Southern Thailand, which can be used to predict adverse perinatal outcomes in intrauterine growth restriction (IUGR) foetus that has birth weight below the 10th percentile for its gestational age or failing to reach its genetically predetermined growth potential. The prediction of adverse outcomes can be used to counsel patients and help clinicians make decisions concerning the time of delivery, Additionally, it can help to notify NICU teams early for neonatal resuscitation.

Materials and Methods

This study was a diagnostic test. Approval for this research was received by the Institutional Review Board of Hatyai Hospital. The study population included 76 women with singleton pregnancies who were diagnosed with PIH at 32-40 weeks of gestation and were admitted to Hatyai Hospital between December 2020 and November 2022. PIH criteria include gestational hypertension, preeclampsia and chronic hypertension with superimposed preeclampsia according to the ACOG 2019 guidelines. All patients were recruited consecutively and included pregnant women who had medical disorders as well as obstetric risk factors such as diabetes mellitus, chronic hypertension, gestational diabetes mellitus (GDM), obesity, abruptio placenta, large for gestational age (LGA), and myoma uteri, etc.

Patients who had intrauterine foetal death, multiple gestations or foetal anomalies were excluded.

The sample size was calculated by the prevalence of adverse perinatal outcomes based on previous studies[10]. Sensitivity and specificity were accepted following the study of Smitha[7], this study needed a sample size of 76 cases to gain power of 80% at 95% confidence interval (CI).

After informed consent was gained, all patients were advised according to the institutional guidelines. Transabdominal ultrasound tests were for foetal weight, amniotic fluid, placenta and Doppler study were done using a GE Voluson E6 ultrasound machine. Doppler waveform analyses of the umbilical artery and middle cerebral artery as well as calculation of cerebroplacental ratio were performed by single level II sonographer in a specialised maternal foetal medicine. The

waveforms were obtained during foetal inactivity and apnoea.

The umbilical artery pulsatility index (UA PI) was obtained from a free loop of cord, while the middle cerebral artery pulsatility index (MCA PI) was obtained at the level of the greater wing of the sphenoid at an angle of insonation near 0 (0-10 degrees). The flow velocity waveforms were computed automatically. Measurements were done three times and the average pulsatility index (PI), standard deviation (SD) were calculated[11].

The UA PI and systolic/diastolic ratio (UA-S/D) were considered abnormal when it was more than the 95th percentile of the reference range. Absent and reverse end diastolic flow of umbilical artery Doppler were considered abnormal.

The MCA PI was automatically calculated and considered abnormal when it was below the 5th percentile of the reference range.

The cerebroplacental ratio (CPR) was automatically calculated and considered abnormal when it was below the 5th percentile of the reference range[11].

Follow-up Doppler studies were performed weekly. The results of the last Doppler ultrasound within one week of delivery were used for analysis.

The collected data included demographic data, comorbidity, Doppler study (UA PI, UA S/D, MCA PI, and CPR) and neonatal outcomes such as fetal distress, intrauterine growth restriction (IUGR), large for gestational age (LGA), neonatal moderate care unit (NMCU) admission, Apgar score < 7 at 1and 5 minutes, The composite neonatal adverse outcome included NICU admission and Apgar score < 7 at 5 minutes.

Foetal distress was defined as category II and III foetal heart rate tracing according to the National Institute of Child Health and Human Development (NICHD) criteria. intrauterine growth restriction (IUGR) was diagnosed based on ultrasound parameters with estimated foetal weight being less than the 10th percentile for gestational age and umbilical Doppler PI > 95th percentile, while LGA was defined as estimated foetal weight being more than the 90th percentile for gestational age.

All data were collected from medical records at Hatyai Hospital.

Statistical analysis was done by Stata/SE for Windows Version 17 Stata Corp. Released 2021, StataCorp LLC College Station, Texas USA. Sensitivity, specificity, accuracy and positive likelihood ratio were calculated for the prediction of adverse perinatal outcomes. P values < 0.05 were considered statistically significant.

Results

Among 76 cases of PIH women, 43.42% had severe preeclampsia (PE) and 36.84% had gestational hypertension (GHT). A previous history of PIH was revealed in about 10.53%. The mean age of patients was 29.68 ± 6.89 years; most patients were less than 35 years old. About 40% of the patients were primigravida, and 38% of the patients were obese. Most of the patients (65.79%) were between 37 and 40 weeks of gestation at the time of Doppler examination and delivery. About 57 cases (75%) had less than a 24-hour interval for the time between assessment and delivery. Most patients (53.95%) had non-medical and obstetric risk factors.

Mode of delivery included vaginal (about 51.32%) and caesarean section (CS) (46.05%), with indications for CS including failed induction (14.47%), unfavourable cervix (13.16%), cephalopelvic disproportion (CPD) (9.21%), foetal distress (3.93%) and previous CS (2.63%). About 30.26% of patients had low birth weight (birth weight < 2,500 g). The data are shown in Table 1.

Table 1. Demographic and obstetric data for the studied patients (n = 76).

Characteristics	n (%)
Age (years)	
< 35	59 (77.63)
≥ 35	17 (22.37)
mean (SD)	29.68 (6.89)
Gravida	
Primi	31 (40.00)
Multi	45 (59.00)
BMI (kg/m^2)	
≥ 30	29 (38.16)
Gestational age at examination (weeks)	
32-36^{+6}	26 (34.21)
37-40	50 (65.79)
Type of PIH	
GHT	28 (36.84)
Mild PE	9 (11.84)
Severe PE	33 (43.42)
CHT with superimposed severe PE	6 (7.89)
Previous history of PIH	8 (10.53)
Medical and obstetric risk factors	
None	41 (53.95)
1	30 (39.47)
≥ 2	5 (6.58)
Gestational age at delivery (weeks)	
32-36^{+6}	26 (34.21)
37-40	50 (65.79)
Time interval between assessment and delivery (days)	
<1	57 (75.00)
1	10 (13.16)
≥ 2	9 (11.84)
Mode of delivery	
Vaginal	39 (51.32)
Caesarean section	35 (46.05)
Vacuum extraction	2 (2.63)
Indication of CS	
Foetal distress	3(3.95)
CPD	7(9.21)
Abnormal foetal presentation	4(5.26)
Failed induction	11(14.47)
Unfavourable cervix	10(13.16)
Previous CS	2(2.63)
COVID	1(1.32)
Birthweight (grams)	
< 2500	23 (30.26)
≥ 2500	53 (69.74)

SD: standard deviation, BMI: body mass index, PIH: pregnancy-induced hypertension, GHT: gestational hypertension, PE: preeclampsia, CS: caesarean section, CPD: cephalopelvic disproportion, COVID: coronavirus disease

All perinatal outcomes were experienced in approximately 55.26% and there were 28 cases (36.84%) with perinatal outcomes, including foetal distress, IUGR, NICU admission, NMCU admission,

and Apgar score < 7 at 1 and 5 minutes. Most of them were NMCU admission at 22.37%, and the second was IUGR at 15.79%. However, 6.58% of patients had NICU admission. The data are shown in Table 2.

Table 2. All perinatal outcomes (n = 42).

Outcome parameters	n (%)
Foetal distress	3 (3.95)
Intrauterine growth restriction	12 (15.79)
Neonatal intensive care unit admission	5 (6.58)
Neonatal moderate care unit admission	17 (22.37)
Apgar score at 1 minute < 7	4 (5.26)
Apgar score at 5 minutes < 7	1 (1.32)

There was a significant association between UA PI and NICU admission (p = 0.04). The UA PI could predict NICU admission with LR+ 2.58 and had the highest sensitivity (80%) when compared to other Doppler indices. However, the UA S/D ratio, CPR and MCA PI were poor predictors for NICU admission (p > 0.05). The data are shown in Table 3.

Table 3. Accuracy of Doppler indices for predicting NICU admission.

Doppler	Results	NICU (n=5)	Non-NICU (n=71)	p value *	Sensitivity (95%CI)	Specificity (95%CI)	Accuracy (%)	+ LR
UA PI	Abnormal	4	22	0.044	80.00	69.1	69.74	2.58
	Normal	1	49		(28.36, 99.49)	(56.92, 79.46)		
UA S/D	Abnormal	2	20	0.623	40.00	71.83	69.74	1.42
	Normal	3	51		(5.27, 85.34)	(59.90, 81.87)		
MCA PI	Abnormal	1	13	1.000	20.00	81.69	77.63	1.09
	Normal	4	58		(0.5, 71.64)	(70.73, 89.87)		
CPR	Abnormal	2	21	0.635	40.00	70.42	68.42	1.35
	Normal	3	50		(5.27, 85.34)	(58.41, 80.67)		

Values are given as a number, sensitivity, specificity, accuracy and likelihood ratio, Fisher's exact test (*)
NICU: neonatal intensive care unit, LR: likelihood ratio, CI: confidence interval, UA PI: umbilical artery pulsatility index, UA S/D: umbilical arterial systolic/diastolic, MCA PI: middle cerebral artery pulsatility index, CPR: cerebroplacental ratio

There were only 4 cases of Apgar score at 1 minute < 7. This study found that these Doppler indices (UA PI, UA S/D ratio, MCA PI and CPR) were not significantly associated with Apgar score at 1 minute < 7 (p > 0.05).

There were significant associations between MCA PI and the perinatal outcomes such as foetal distress, IUGR, NICU admission, NMCU admission, Apgar score at 1 minute < 7 and Apgar score at 5 minutes < 7 (p = 0.003). The MCA PI can predict the perinatal outcomes with LR+ 4.29 by sensitivity and specificity of 35.71% and 91.67%, respectively.

Discussion

Among pregnant women, PIH is associated with reduced uteroplacental perfusion as a result of the abnormal cytotrophoblast invasion of spiral arterioles, which may affect foetal growth restriction, foetal hypoxemia and foetal death[1]. Uteroplacental and fetoplacental circulation can be studied effectively by Doppler ultrasound. Many studies have used foetal vascular Doppler such as umbilical artery, middle cerebral artery indices and cerebroplacental ratios to predict uteroplacental insufficiency and perinatal mortality.

In the present study, the focus was on the accuracy of the foetal umbilical artery, middle cerebral artery Doppler indices and cerebroplacental ratios in women with third-trimester gestation with PIH to predict adverse perinatal outcomes (NICU admission and Apgar score < 7 at 5 minutes).

This study found that the UA PI could predict NICU admission with LR+ 2.58, similar to Alalfy et al[13] who showed the UA PI could predict NICU admission with LR+ 2.84. Moreover, this study found that the UA PI, UA S/D ratio, MCA PI and CPR indices were not associated with an Apgar score at 1 minute < 7.

This study showed that an MCA PI < 5th percentile could predict all perinatal outcomes with LR+ 4.29 (p = 0.003) more than other Doppler indices, similar to the observations made by Devi et al [14] and Lakhar et al[15]. The middle cerebral artery is the branch of the circle of Willis that carries 80% of the blood flow to the ipsilateral cerebral hemisphere, so it is a more sensitive parameter for foetal oxygenation status than umbilical blood flow[3, 7].

This study likewise found that the UA PI and CPR had the sensitivity (42.80 and 42.86%, respectively) to predict perinatal outcomes, similar to Gutierrez et al[16] and Fong et al[17].

This study was not correlated with Konwar et al[2], who reported that the CPR PI had more sensitivity (84.8%) than the current study (42.86%) for diagnosing perinatal outcomes. This may be due to the difference in the Doppler indices for examination and measurement. The Doppler indices in Konwar's study were obtained by manual plotting, while those in the current study were computed automatically. Moreover, the measurement for MCA PI angle and the abnormal reference of CPR PI were not similar to this study.

The results of the study can be applied for counselling patients with PIH about abnormal Doppler study to predict adverse perinatal outcomes as well as help with proper management.

The strength of this study was its complete delivery outcomes. There were no previous studies on foetal Doppler tests to predict adverse perinatal outcomes in pregnant women with PIH in Thailand. This research is presented as the first investigation in southern Thailand. Additionally, ultrasonography was performed only by the single level II sonographer to decrease interobserver variation. Still, there were some limitations of this study. Because this study was undertaken at a single centre that could not represent the general population, its results should be interpreted with caution when assessing the correlation between foetal Doppler study indices and adverse perinatal outcomes.

We suggest that future studies investigate the use of many centers and should use additional parameters such as clinical history combined with Doppler indices for better prediction of adverse perinatal outcomes.

Conclusion

The UA PI had the highest sensitivity for the detection of adverse perinatal outcomes (NICU admission). Furthermore, the MCA PI was the better predictor of perinatal outcomes.

Potential conflicts of interest

The authors declare no conflicts of interest.

References

1. Kor-anantakul O. Preterm birth. In: Kor-anantakul O, editor. High risk pregnancy. 2nd ed. Songkhla:

Chanmuang Press 2019;143-9.
2. ACOG practice bulletin no.202: Gestational hypertension and preeclampsia. Obstet Gynecol 2019;133:e1-e25.
3. Gaikwad PR, Gadnhewar MR, Rose N, Suryakar V. Significance of obstetric Doppler studies in prediction of perinatal outcome in pregnancy induced hypertension. Int J Reprod Contracept Obstet Gynecol 2017;6:2354-60.
4. Yoon BH, Lee CM, Kim SW. An abnormal umbilical artery wave form: A strong and independent predictor of adverse perinatal outcome in patients with preeclampsia. Am J Obstet Gynecol 1994;171:713-21.
5. Ozeren M, Dinc H, Ekmen U, Senakayli C, Aydemir V. Umbilical and middle cerebral artery doppler indices in patients with preeclampsia. Eur J Obstet Gynaecol Reprod Biol 1999;82:11-6.
6. Shahinaj R, Manoku N, Kroi E, Tasha L. The value of the middle cerebral to umbilical artery Doppler ratio in the prediction of neonatal outcome in patient with preeclampsia and gestational hypertension. J Prenat Med 2010;4:17-21.
7. Smitha K, Sowmya K, Malathi T. Study of Doppler waveforms in pregnancy induced hypertension and its correlation with perinatal outcome. Int J Reprod Contracept Obstet Gynecol 2014;3:428-33.
8. Yadav J, Shukla M, Jain PK, Kumar D. Role of umbilical artery doppler velocimetry in predicting the adverse perinatal outcomes in hypertensive disorder of pregnancy. Int J Reprod Contracept Obstet Gynecol 2017;6:4382-8.
9. Alanwar A, Ayman AEN, Mandooh ME, Abdelazim IA, Abbas L, Abbas AM, et al. Prognostic accuracy of cerebroplacental ratio for adverse perinatal outcomes in pregnancies complicated with severe pre-eclampsia; a prospective cohort study. Pregnancy Hypertens 2018;14:86-9.
10. Sukphadung K, Petchud A, Prommas S, Smanchat B. The prevalence of abnormal cerebro-placental doppler indices ratio [CPR] in hypertensive disorders of pregnancy. J Med Assoc Thai 2018;101:1025-9.
11. Chittrakul S, Tongsong T. Common Doppler studies in obstetrics. Med CMU [internet]. 2013 [cited 2000 Sep 19]. Available from https://w1.med.cmu.ac.th/obgyn/index.php?option=com_content&view =article&id=878:common-doppler-studies-in-obstetrics&catid=45&Itemid=561
12. Khanduri S, Parashari UC, Bashir S, Bhadury S, Bansal A. Comparison of diagnostic efficacy of umbilical artery and middle cerebral artery waveform with color Doppler study for detection of intrauterine growth restriction. J Obstet Gynaecol India 2013;63:249-55.
13. Alalfy M, Eltaieb E. The value foetal umbilical artery and middle cerebral artery doppler indices in women with pregnancy induced hypertension in the prediction of adverse perinatal outcome. Austin J Obstet Gynecol 2019;6:1138.
14. Devi J, Kumar D, Shukla M, Jain PK. Doppler interrogation of fetoplacental circulation in hypertensive disorder of pregnancy and their perinatal outcomes. Int J Res Med Sci 2017;5:2687–93.
15. Lakhkar BN, Rajagopal KV, Gourisankar PT. Doppler prediction of adverse perinatal outcome in PIH and IUGR. Ind J Radiol Imag 2006;16:109-16.
16. Gutierrez RG, Barajas AI, Curiel CA, Ponce de Leon PAL. Prediction of foetal wellbeing with Doppler flowmetric profile in pregnant hypertensive women. Gynaecol Obstet Mex 2001;69:480-6.
17. Fong KW, Ohlsson A, Hannah ME, Grisaru S, Kingdom J, Ryan M, et al. Prediction of perinatal outcome in fetuses suspected to have intrauterine growth restriction: Doppler US study of foetal cerebral, renal, and umbilical arteries. Radiology 1999;213: 681-9.
18. Konwar R, Basumatari B, Dutta M, Mahanta P, Saikia A, Rashmi UK. Role of doppler waveforms in pregnancy-induced hypertension and its correlation with perinatal outcome. Cureus 2021;13: e18888.