The Journal of Maternal-Fetal & Neonatal Medicine

ISSN: 1476-7058 (Print) 1476-4954 (Online) Journal homepage: www.tandfonline.com/journals/ijmf20

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To cite this article: Thao Nguyen Nguyen Tran, Hong Trung Nguyen , Ngoc Thanh Cao , Phuc Nhon Nguyen, Linh Giang Truong Thi, Minh Tam Le & Quoc Huy Nguyen Vu (2025) Umbilical cord coiling index in predicting neonatal outcomes: a single-center cross-sectional study from Vietnam, The Journal of Maternal-Fetal & Neonatal Medicine, 38:1, 2517763, DOI: 10.1080/14767058.2025.2517763

To link to this article: https://doi.org/10.1080/14767058.2025.2517763

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Published online: 06 Jul 2025.

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THE JOURNAL OF MATERNAL-FETAL & NEONATAL MEDICINE
2025, VOL. 38, NO. 1, 2517763
https://doi.org/10.1080/14767058.2025.2517763

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ORIGINAL ARTICLE

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Umbilical cord coiling index in predicting neonatal outcomes: a single-center cross-sectional study from Vietnam

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ABSTRACT

Background: Abnormal umbilical coiling (AUC) is one of the common occurrences of umbilical cord abnormalities leading to poor neonatal outcomes.

Objectives: This study aims to investigate the association between antenatal umbilical coiling index (aUCI) and perinatal outcomes as well as the risk factors relating to AUC.

Methods: A cross-sectional study was conducted between June 2022 and June 2024 at Hue University of Medicine and Pharmacy, Vietnam. The study enrolled 337 full-term primigravida with uncomplicated singleton pregnancies who underwent transabdominal ultrasound between 37^{+0} and 41^{+0}weeks of gestation for aUCI by color Doppler ultrasound. The aUCI was calculated as the reciprocal of the distance between a pair of coils. The aUCI was classified as hypo-, hyper-, and normocoiled. The patients were monitored until birth delivery, and any adverse antenatal complications were noted.

Results: The mean aUCI among hypo-, normo-, hypercoiling group were 0.16 ± 0.003, 0.30 ± 0.06, 0.46 ± 0.04. There was a statistically significant different between the resistance index (RI), pulsatility index (PI) of umbilical artery, PI of middle cerebral artery, and the cerebroplacental ratio (CPR) among 3 groups. Overall, the rate of abnormal fetal heart rate tracing, meconium-stained amniotic fluid, cesarean section rate, fetal growth restriction (FGR), and Apgar scores at 5 mins below 7 points was higher in the hypercoiling group (28.2%, 36.6%, 50.7%, 8.5%, 4.2%, respectively) and hypocoiling groups (5.0%, 10.0%, 35.0%, 17.5%, 12.5%, respectively) compared to the normocoiling group (15.0%, 12.4%, 27.9%, 1.8%, 0.9%, respectively), $p < 0.05$. In general, AUC increased significantly the risk of FGR and Apgar score at 5 mins < 7 points with odds ratio (OR): 7.63 (95% confidence interval (CI): 2.34–23.15) and OR: 8.70 (95%CI: 1.82–41.69). More than 2-fold increased rate of meconium-stained amniotic fluid, cesarean delivery, and birth weight below 2500 grams were also observed. After adjusting for gestational age, gestational hypertension disorders, gestational diabetes mellitus, oligohydramnios/hydramnios were significantly related to the development of AUC with OR: 4.99; 7.92, 4.96; 4.56, respectively.

Conclusion: Both abnormal umbilical coiling in the form of either hypocoiling or hypercoiling are associated with adverse pregnancy outcomes. Thus, the antenatal umbilical coiling index ought to be detected during routine antenatal care.

HIGHLIGHTS

- Abnormal antenatal umbilical coiling index is related to adverse antenatal and pregnancy outcomes.
- Abnormal umbilical coiling increased significantly the 7-fold risk of FGR and 8-fold risk of Apgar score at 5 mins < 7 points.
- Among high-risk pregnancies diagnosed with gestational hypertension disorders, GDM, oligohydramnios/hydramnios, the Abnormal umbilical coiling should be detected.

ARTICLE HISTORY
Received 7 April 2025
Revised 4 May 2025
Accepted 3 June 2025

KEYWORDS
Antenatal care; Doppler ultrasound; high-risk pregnancies; umbilical coiling index; Vietnam

Introduction

Abnormal umbilical coiling (AUC) is one of the common occurrences of umbilical cord abnormalities leading to poor neonatal outcomes through fetal blood flow [1]. Normally, the coiled structure of the cord along with amniotic fluid and Wharton's jelly

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helps to protect the umbilical cord. Additionally, the coiled feature increases the flexibility, strength, and to reduce the risk of cord torsion. Hypercoiled umbilical cord refers to increase the coiled structure of umbilical cord. Meanwhile, hypocoiled umbilical cord characterized as decreasing coiled structure of umbilical cord. The degree of the umbilical cord coiling is based on the calculation of the umbilical coiling index (UCI), defined as the number of complete coils per centimeter length of cord [2]. Hypercoiling and hypocoiling of umbilical cord is determined through UCI. Thus, the UCI is a measure of the number of coils in the umbilical cord in relation to its length.

Until now, the etiology of AUC remains poorly understable [1]. Intrinsic abnormality of cord, fetal development, insertion, and early reduced fetal movements may be related to hypocoiling (undercoiled) condition; whereas, increased blood flow or intrinsic abnormal development and early increased fetal movements is related to hypercoiling (overcoiled) condition [2].

Abnormal coiling of umbilical cord is significantly associated with increased prevalence of preterm birth under 37 weeks, requiring for cesarean delivery due to fetal distress, meconium-stained liquor, Apgar scores < 7 at 5 min, small for gestational age (SGA) newborns, fetal anomalies, fetal growth restriction (FGR), fetal heart rate (FHR) abnormalities, fetal acidosis, and fetal death [3,4]. Moreover, AUC was associated with thrombosis of chorionic plate vessels, umbilical venous thrombosis, and cord stenosis. Thus, AUC may be a chronic state (growth retardation) or an acute state (fetal intolerance to labor and fetal demise) which effects on fetal well-being [5]. Nevertheless, the findings relating neonatal outcomes remain variable among different studies.

In general, postnatal UCI is detected accurately. However, antenatal umbilical coiling index (aUCI) could also be observed during ultrasound. In obstetrics and gynecology care, Doppler ultrasound and its parameters play an important role in assessing the blood flow through blood vessels [6,7]. A detection of AUC in both the second and third trimesters is highly related to postnatal AUC [8]. Thus, this study aims to assess the pregnancy outcomes and complications in hypo-, hyper-, and normocoiling as well as the risk factors relating to the development of AUC through Doppler ultrasound.

Materials and methods

Patients and designs

This cross-sectional study was conducted on full-term singleton pregnancies who underwent Doppler ultrasound to measure the prenatal umbilical coiling index. In addition, all pregnant women were admitted for delivery from June 2022 to June 2024 at the Department of Obstetrics and Gynecology, Hue University of Medicine and Pharmacy Hospital.

Sample size

The sample size was calculated using the sample size estimation formula for the mean value:

$$n = \left(\frac{Z_{1-\alpha/2}\sigma}{E} \right)^2$$

with type I alpha error (α) of 0.05, estimated error (E) of 0.01, and a standard deviation (σ) of 0.09 following the study of de Laat et al. (Mean aUCI ± SD was 0.30 ± 0.09) [9]. Finally, 337 pregnant women eligible for study criteria were participated in this study.

Study criteria

The study included all patients had adequate ultrasound images and all antenatal and labor data to meet the study inclusion criteria (Figure 1).

Inclusion criteria

Primipara, singleton pregnancy with a living fetus, gestational age (GA) between 37 weeks 0 days and 41 weeks 6 days. The GA of the pregnant women was calculated from the first day of the last menstrual period for those with regular menstrual cycles. In case of unsure last menstrual period or the pregnant women with irregular cycles, the GA was calculated based on the first-trimester ultrasound.

Exclusion criteria

Abnormal umbilical cord (umbilical cord knotting, single umbilical artery), inadequate longitudinal imaging of the umbilical cord for measuring the antenatal umbilical coiling index (aUCI) on ultrasound, multiple pregnancy, fetal abnormalities, fetal demise, and pregnant women severe comorbidities such as renal failure and heart failure.

Determination of UCI

The antenatal umbilical coiling index (aUCI) was determined *via* abdominal Doppler ultrasound between 37 weeks and 41 weeks 6 days of GA (Figure 2). The distance between a pair of umbilical cord coils was measured in centimeters, from the inner margin of the artery or vein wall to the outer margin of the next coil,

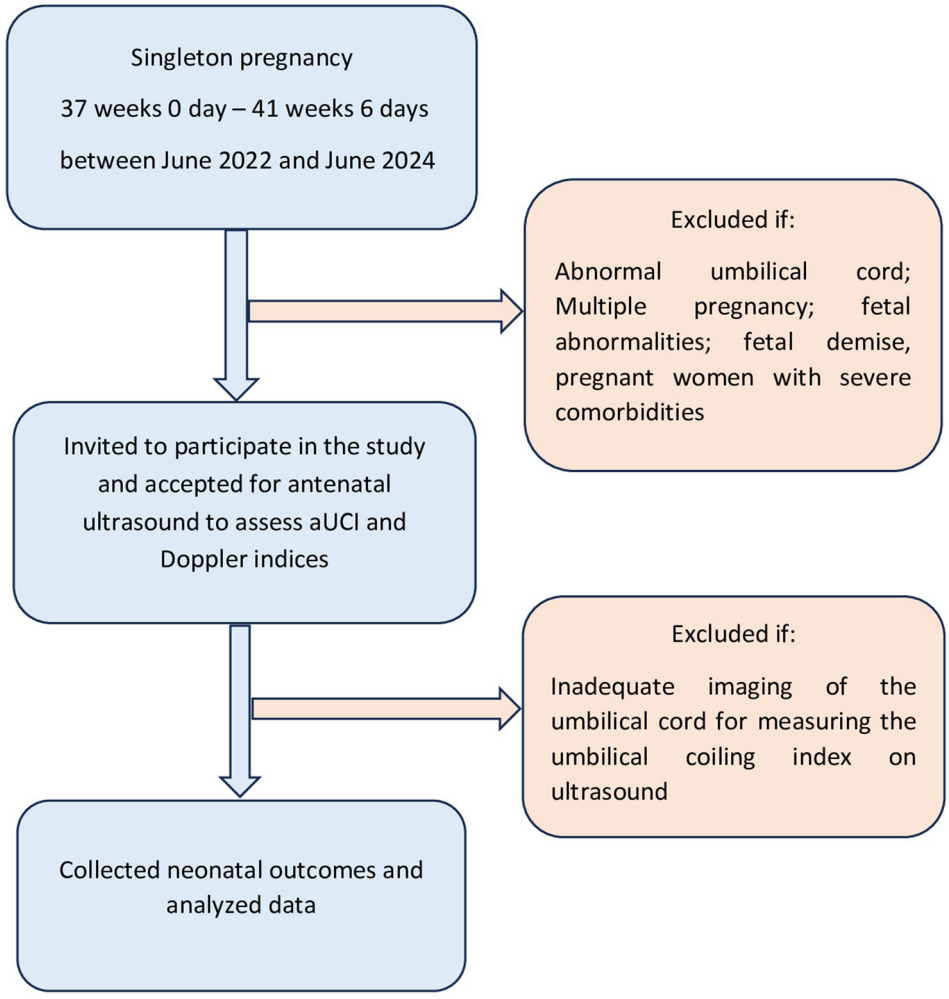

Figure 1. A study flowchart in the present study.

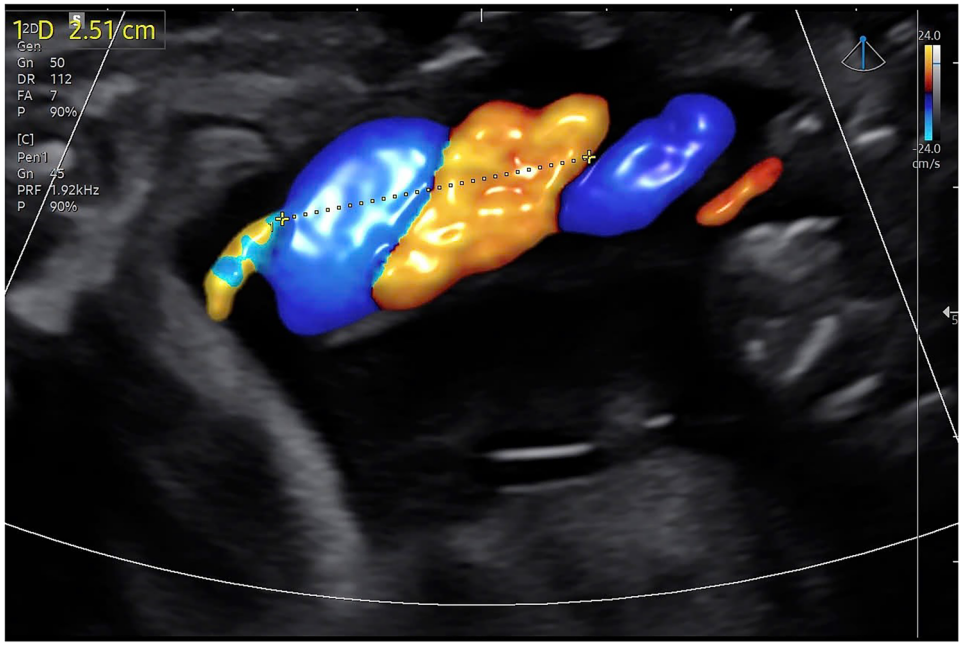

Figure 2. Measurement of the UCI on doppler ultrasound.

along the same side of the cord, from the placental insertion end to the fetal end. The middle region of the cord was observed carefully to measure aUCI. The umbilical coiling index was calculated as the inverse of this distance (aUCI = 1/distance between the inner margin of the artery or vein wall and the outer margin of the next coil). Values of the UCI below the 10th percentile were evaluated as hypocoiled and above the 90th percentile as hypercoiled. Abdominal sonography was performed for all pregnant women using a 5–7.5 MHz abdominal transducer of a sonographic machine (Samsung WS80A, Yongin, Korea). Four sonographers with more than 5 years of experience were randomly allocated to each patient.

Variables and outcomes

Baseline characteristics include maternal age (years), maternal BMI (kg/m^2) following Asia-Pacific classification, ethnics, residency, occupation, gestational age at detection and at labor.

The antenatal umbilical coiling index (aUCI) was classified into three groups: normal umbilical coiling, low umbilical coiling, and high umbilical coiling. Low coiling was defined as an aUCI below the 10th percentile, and high coiling was defined as an aUCI above the 90th percentile. Doppler parameters such as the resistance index (RI), pulsatility index (PI) of the umbilical artery, PI of middle cerebral artery (MCA) Doppler, and cerebroplacental ratio (CPR) were measured and collected as continuous variables.

Adverse pregnancy outcomes included [1] small for gestational age (SGA) [2], mode of delivery [3], presence of meconium-stained amniotic fluid [4], presence of nonreassuring fetal status in labor, and [5] Apgar scores at 1 and 5 min. The pregnant women were then followed until delivery and various parameters were recorded including GA at birth, presence of meconium-stained amniotic fluid, mode of delivery, Apgar score at 1 min and 5 min, birth weight, SGA, and fetal growth restriction (FGR).

Statistical analysis

Data were expressed as frequency (*n*), percentage (%), and $\bar{X}$±standard deviation following the standard distribution of data. A comparison between more than two mean values was performed using one-way ANOVA test. The prenatal characteristics and perinatal outcomes of the three groups were compared and statistically analyzed using the Chi-square test and Fisher's exact test with two-tailed *p*-values. The odds ratio (OR) and adjusted odds ratio (aOR) with 95% confidence intervals (CI) were calculated according to univariate and multivariable logistic regression. Multivariable logistic regression was calculated based on all variables with $p < 0.05$ from univariate logistic regression and adjusted for GA. The ranges for the area under optimal threshold for prediction of poor neonatal outcomes were determined using a receiver operating curve (ROC) and Youden Index values. The cutoff point with the highest sensitivity (Se) and specificity (Sp) was chosen. Data were analyzed using SPSS version 25 software (IBM Corp., Armonk, NY, USA). *P*-value <0.05 was considered to be statistically significant.

Results

A total of 337 pregnancies was enrolled in the study. The participants were divided into three groups consisting of 40 pregnancies with hypocoiling cord (11.8%), 226 pregnancies with normocoiling cord (67.1%), and 71 pregnancies with hypercoiling cord (21.1%). The mean maternal age was 24.60 ± 4.31 (years). Mean maternal age, gestational hypertension disorders, gestational diabetes mellitus, length of umbilical cord coiling, and mean aUCI were significantly different among groups (Table 1 and Figure 3).

In the present study, there was a statistically significant difference in the incidence of volume of amniotic fluid, estimation of fetal weight, the resistance index, pulsatility index of the umbilical artery (PI-UA), cerebroplacental ratio (CPR), and abnormal heart rate tracing among three aUCI groups ($p < 0.05$). The incidence of oligohydramnios/polyhydramnios, EFW < 10th percentile, RI-UA >95th percentile, PI-UA > 95th percentile, PI-MCA > 5th percentile, CPR > 5th percentile, FGR, and abnormal heart rate tracing were higher in hypocoiling group and hypercoiling group compared to normocoiling group. Using one-way ANOVA test, the study found only RI-UA was significantly different among 3 groups (Table 2).

Among hypo-, normo-, hypercoiling groups, the incidence of cesarean delivery was 35.0%, 27.9%, 50.7%, respectively. The rate of meconium-stained amniotic fluid was 10.0%, 12.4%, 36.6%, respectively. The Apgar score at 1 min below 7 points was 12.5%, 1.8%, 9.9%, respectively. The Apgar score at 5 min below 7 points was 12.5%, 0.9%, 4.2%, respectively. The low birth weight below 10th percentile was 30.0%, 16.8%, 33.8%, respectively. All these neonatal outcomes were significantly different with $p < 0.001$ (Table 3). Table 4 shows AUC increased significantly the adverse neonatal outcomes in the present study.

Table 1. Baseline characteristics in the present study.

Characteristics		Total (*N* = 337)	Hypocoiling (*N* = 40)	Normocoiling (*N* = 226)	Hypercoiling (*N* = 71)	*P*-Value
Maternal age group (years)	Mean ± SD (min-max)	24.60 ± 4.31 (15-37)	26.35 ± 3.52 (19-34)	24.70 ± 4.19 (15-37)	23.41 ± 4.73 (15-35)	**<0.001**[a]
	<20	41 (12.2)	2 (0.6)	23 (6.8)	16 (4.7)	**0.034**[c]
	20-35	294 (87.2)	38 (95.0)	201 (88.9)	55 (77.5)	
	>35	2 (0.6)	0 (0.0)	2 (0.9)	0 (0.0)	
Ethnics	Kinh	322 (95.5)	39 (95.5)	217 (96.0)	66 (93.0)	0.509[b]
	Minority	15 (4.5)	1 (2.5)	9 (4.0)	5 (7.0)	
Residency	Urban	94 (27.9)	13 (32.5)	62 (27.4)	19 (26.8)	0.806[b]
	Rural	243 (72.1)	27 (67.5)	164 (72.6)	52 (73.2)	
Occupation	Staff	65 (19.3)	10 (25.0)	45 (19.9)	10 (14.1)	NA
	Worker	109 (32.3)	14 (35.0)	72 (31.9)	23 (32.4)	
	Farmer	5 (1.5)	0 (0.0)	4 (1.8)	1 (1.4)	
	Seller	36 (10.7)	4 (10.0)	29 (12.8)	3 (4.2)	
	Housewife	87 (25.8)	10 (11.5)	51 (22.6)	26 (36.6)	
	Others	35 (10.4)	2 (5.0)	25 (11.1)	8 (11.3)	
Maternal BMI (kg/m^2)	Mean ± SD (min-max)	22.24 ± 2.97 (15.80-31.10)	22.74 ± 3.17 (17.60-30.70)	22.26 ± 3.02 (15.80-31.10)	21.91 ± 2.67 (16.20-29.10)	0.369[a]
	≤18.5	38 (11.3)	2 (5.0)	29 (12.8)	7 (9.9)	0.433[c]
	18.5–22.9	164 (48.7)	20 (50.0)	104 (46.0)	40 (56.3)	
	23–24.9	73 (21.7)	7 (17.5)	52 (23.0)	14 (19.7)	
	≥25	62 (18.4)	11 (27.5)	41 (18.1)	10 (14.1)	
Hypertension disorders in pregnancy	Yes	15 (4.5)	5 (12.5)	5 (2.2)	5 (7.0)	**0.006**[c]
	No	322 (95.5)	35 (87.5)	221 (97.8)	66 (93.0)	
Gestational diabetes mellitus	Yes	9 (2.7)	6 (15.0)	2 (0.9)	1 (1.4)	**<0.001**[c]
	No	34 (85.0)	224 (99.1)	70 (98.6)	328 (97.3)	
GA at US detection (weeks)		39.14 ± 1.07 (32.0-41.4)	39.10 ± 1.13 (37.0-41.4)	39.18 ± 1.05 (32.0 – 41.4)	39.01 ± 1.10 (37.0-41.4)	0.488[a]
Length of coiling umbilical cordon (cm)		3.57 ± 1.30 (1.50-6.97)	6.32 ± 0.15 (6.15-6.97)	3.53 ± 0.75 (2.44-5.90)	2.18 ± 0.14 (1.50-2.38)	**<0.001**[a]
Mean aUCI		0.31 ± 0.10 (0.14-0.67)	0.16 ± 0.003 (0.14-0.16)	0.30 ± 0.06 (0.17-0.41)	0.46 ± 0.04 (0.42-0.67)	**<0.001**[a]

Data was presented as mean ± SD, n (%).
[a]One-way ANOVA test, [b]Fisher freeman halton exact test, [c]Pearson Chi-square (Exact sig. 2-sided).
Abbreviations: aUCI, antenatal umbilical coiling index; BMI, body mass index (kg/m^2); GA, gestational age; US, ultrasound.
Bold values indicate *p*-value < 0.05.

Noticeably, any of hypocoiling or hypercoiling events related to 7-fold increase of FGR and 8-fold increase of Apgar scores below 7 points. Using univariate and multivariate logistic regression, the study found that presence of gestational hypertension disorders, gestational diabetes mellitus, oligohydramnios, hydramnios were significantly related to the development of abnormal cord coiling with OR: 4.99; 7.92, 4.96; 4.56, respectively (Table 5).

Discussion

Among 337 cases, the incidence of hypo-, normo-, and hypercoiling were 11.8%, 67.1%, and 21.1%, respectively, in the present study. Similarly, Machin et al. showed 21.0% of cords were overcoiled and 13.0% of cords were undercoiled [5]. Meanwhile, normocoiled, hypercoiled, hypocoiled, and noncoiled groups were found at 77.2%, 10.4%, 9.4%, and 3.0%, respectively, in

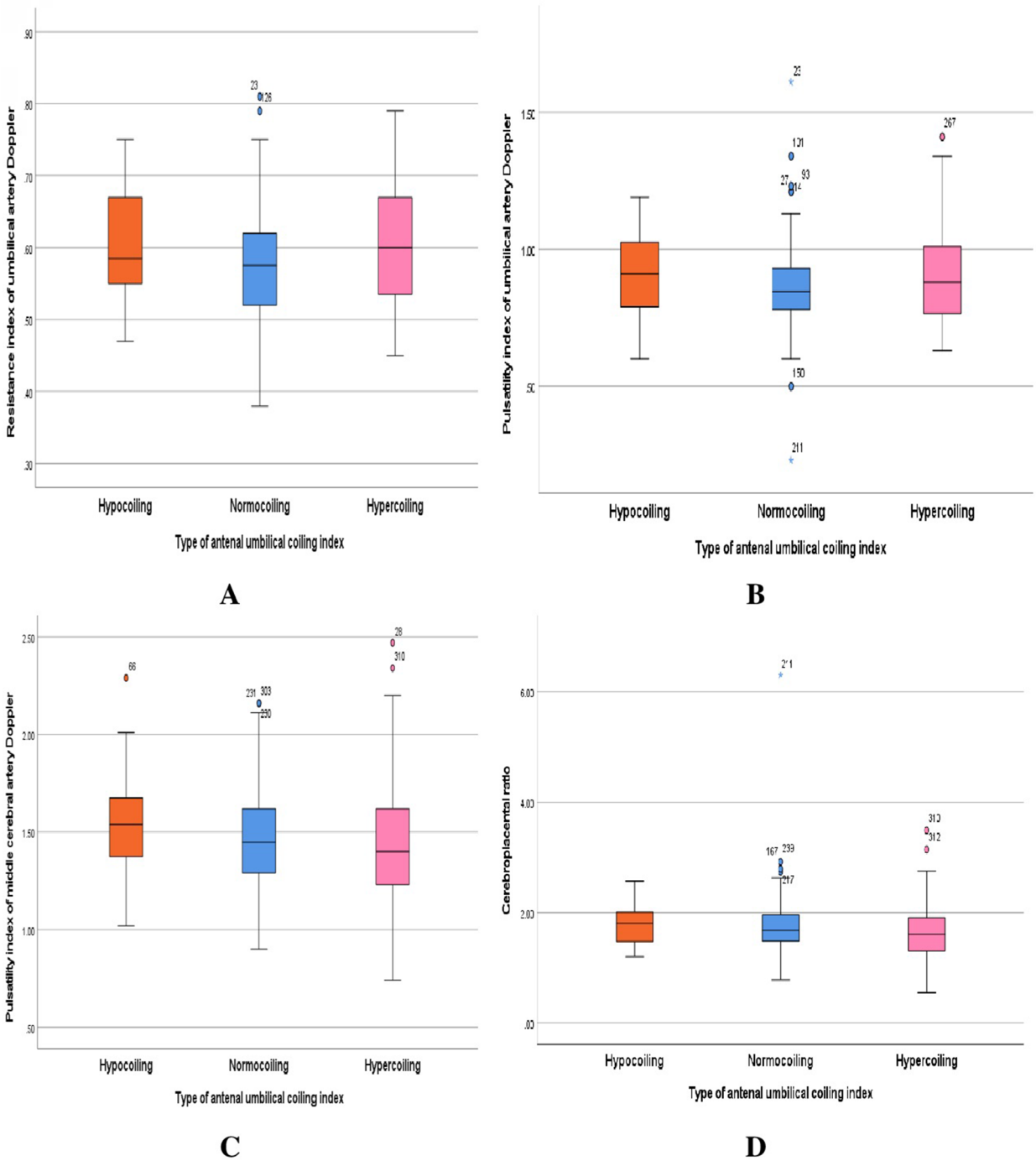

Figure 3. Box plot shows the type of aUCI according to RI of umbilical artery doppler (a), PI of umbilical artery doppler (B), PI of Middle cerebral artery doppler (C), and CPR index (D).

the study of Ezimokhai et al. [10]. In our study, the antenatal umbilical coiling index (aUCI) was measured at 0.31 ± 0.10. A few studies reported different average values for aUCI varying from 0.36 to 0.41 [11–13]. These studies measured the aUCI in the second trimester. However, the average aUCI in the study by de Laat et al. was 0.30 among pregnancies from 28 weeks to full term, that was similar to our findings [14].

The differences in the average aUCI values may be explained by the different gestational ages at which the UCI was calculated. Higher average aUCI values are typically observed earlier in the pregnancy. This can be explained by the fact that although the umbilical cord length increases as fetal development, the total number of twists in the umbilical cord remains unchanged. Therefore, as gestational age increases, the distance between two consecutive twists also increases, leading to a decreased UCI. Additionally, umbilical cord coiling modulates noticeably blood flow through the umbilical cord. More prominent umbilical coiling (higher

Table 2. Intrapartum characteristics among hypo-, normo-, and hypercoiling groups.

Characteristics		Total (*N* = 337)	Hypocoiling (*N* = 40)	Normocoiling (*N* = 226)	Hypercoiling (*N* = 71)	*P*-value
EFW	Mean ± SD (min-max)	3129.52 ± 378.82 (2000-4300)	3035.18 ± 541.82 (2048-4300)	3178.97 ± 314.54 (2356-4300)	3025.25 ± 428.08 (2000-4150)	**0.003**[a]
	<10th	20 (5.9)	7 (17.5)	6 (2.8)	7 (10.3)	**< 0.001**[b]
	10th–90th	300 (89.0)	29 (72.5)	210 (92.9)	61 (85.9)	
	>90th	17 (5.0)	4 (10.0)	10 (4.4)	3 (4.2)	
RI-UA	Mean ± SD (min-max)	0.588 ± 0.0783 (0.38–0.81)	0.596 ± 0.083 (0.47–0.75)	0.579 ± 0.073 (0.38–0.81)	0.609 ± 0.089 (0.45–0.79)	**0.015**[a]
	>95th	42 (12.5)	9 (22.5)	16 (7.1)	17 (23.9)	**<0.001**[b]
	≤95th	295 (87.5)	31 (77.5)	210 (92.9)	54 (76.1)	
PI- UA	Mean ± SD (min-max)	0.874 ± 0.148 (0.23–1.61)	0.903 ± 0.153 (0.60–1.19)	0.864 ± 0.141 (0.23–1.61)	0.891 ± 0.167 (0.63–1.41)	0.169[a]
	>95th	21 (6.2)	6 (15.0)	9 (4.0)	6 (8.5)	**0.024**[b]
	≤95th	316 (93.8)	34 (85.0)	217 (96.0)	65 (91.5)	
PI-MCA	Mean ± SD (min-max)	1.468 ± 0.268 (0.74–2.46)	1.548 ± 0.257 (1.02–2.29)	1.458 ± 0.235 (0.90–2.16)	1.453 ± 0.355 (0.74–2.47)	0.131[a]
	≥5th	310 (92.0)	38 (95.0)	213 (94.2)	59 (83.1)	**0.012**[b]
	<5th	27 (8.0)	2 (5.0)	13 (5.8)	12 (16.9)	
CPR	Mean ± SD (min-max)	1.732 ± 0.467 (0.74–2.47)	1.772 ± 0.346 (1.20–2.57)	1.742 ± 0.469 (0.78–6.30)	1.679 ± 0.519 (0.55–3.49)	0.515[a]
	<5th	27 (8.0)	1 (2.5)	13 (5.8)	13 (18.3)	**0.003**[b]
	≥5th	310 (92.0)	39 (97.5)	213 (94.2)	58 (81.7)	
Volume of amniotic fluid	Oligohydramnios	23 (6.8)	7 (17.5)	9 (4.0)	7 (9.9)	**<0.002**[b]
	Polyhydramnio	29 (8.6)	3 (7.5)	12 (5.3)	14 (19.7)	
	Normal	285 (84.6)	30 (75.0)	205 (90.7)	50 (70.4)	
FGR	Yes	17 (5.0)	7 (17.5)	4 (1.8)	6 (8.5)	**< 0.001**[b]
	No	320 (95.0)	33 (82.5)	222 (98.2)	65 (91.5)	
CTG group	I	281 (83.4)	38 (95.0)	192 (85.0)	51 (71.8)	**0.004**[b]
	II-III	56 (16.6)	2 (5.0)	34 (15.0)	20 (28.2)	

Data was presented as mean ± SD and n (%).
[a]One-way ANOVA test, [b]Fisher freeman halton exact test (Exact sig. 2-sided).
Abbreviations: CPR, Cerebroplacental ratio; PI-MCA, Pulsatility index of middle cerebral artery; PI-UA, Pulsatility index of umbilical artery; FGR, Fetal growth restriction; RI-UA, Resistance index of umbilical artery.
Bold values indicate *p*-value < 0.05.

aUCI values) has a protective effect on blood flow in terms of decreased arterial resistance and higher blood flow velocities, as well as increased venous blood flow [15]. In our study, the rate of RI-UA >95th percentile, PI-UA > 95th percentile, PI-MCA > 5th percentile, and CPR > 5th percentile was higher in hypocoiling group or hypercoiling group compared to normocoiling group. Nevertheless, using one-way ANOVA test, the study found only RI-UA was significantly different among three groups.

In addition, the association between hypocoiling and oligohydramnios as well as hypercoiling and polyhydramnios is remarkable. This may be explained by Edmonds' hypothesis which suggests that the rotational movement of the fetus in different cavities of amniotic fluid volume, resulting in increasing or decreasing UCI [11]. A similar association between hypocoiling and oligohydramnios was noted by Chitra et al. [16]. However, Kashanian et al. showed that hypercoiling was significantly associated with oligohydramnios [17].

Regardless of pregnancy outcomes, the significant association between hypercoiling and meconium-stained amniotic fluid (36.6%) compared to hypocoiling and meconium-stained amniotic fluid (10.0%), $p < 0.001$, as well as with abnormal CTG in groups II-III ($p = 0.004$) suggests that increased twisting of the umbilical cord

Table 3. Pregnancy outcomes among hypo-, normo-, and hypercoiling groups.

Pregnancy outcomes		Total (*N* = 337)	Hypocoiling (*N* = 40)	Normocoiling (*N* = 226)	Hypercoiling (*N* = 71)	*P*-value
Gestational age at delivery (weeks)		39.14 ± 1.07 (32.0–41.4)	39.31 ± 1.14 (37.0–41.4)	39.52 ± 0.94 (32.0–41.4)	39.32 ± 1.07 (37.0–41.1)	0.196[a]
Birth weight (gram)		3118.10 ± 395.81 (1800–4500)	3102.50 ± 572.66 (2000–4500)	3149.56 ± 331.23 (2300–4300)	3026.00 ± 452.60 (1800–4100)	0.071[a]
Birth delivery	Cesarean section	113 (33.5)	14 (35.0)	63 (27.9)	36 (50.7)	**0.002**[b]
	Vaginal birth	224 (66.5)	26 (65.0)	163 (72.1)	35 (49.3)	
Newborn sex	Male	158 (46.9)	17 (42.5)	107 (47.3)	34 (47.9)	0.852[b]
	Female	179 (53.1)	23 (57.5)	119 (52.7)	37 (52.1)	
Birth weight (percentile)	<10th	74 (22.0)	12 (30.0)	38 (16.8)	24 (33.8)	**< 0.001**[c]
	10th –90th	254 (75.4)	25 (62.5)	185 (81.9)	44 (62.0)	
	>90th	9 (2.7)	3 (7.5)	3 (1.3)	3 (4.2)	
Color of amniotic fluid	Meconium-stained amniotic fluid	58 (17.2)	4 (10.0)	28 (12.4)	26 (36.6)	**< 0.001**[c]
	Clear	279 (82.8)	36 (90.0)	198 (87.6)	45 (63.4)	
APGAR at 1 min (points)	<7	16 (4.7)	5 (12.5)	4 (1.8)	7 (9.9)	**< 0.001**[c]
	≥7	321 (95.3)	35 (87.5)	222 (98.2)	64 (90.1)	
APGAR at 5mins (points)	<7	10 (3.0)	5 (12.5)	2 (0.9)	3 (4.2)	**< 0.001**[c]
	≥7	327 (97.0)	35 (87.5)	224 (99.1)	68 (95.8)	

Data was presented as mean ± SD, n (%).
[a]One-way ANOVA test, [b]Fisher freeman halton exact test, [c]Pearson Chi-square (Exact sig. 2-sided).
Bold values indicate *p*-value < 0.05.

Table 4. Pregnancy outcomes relating to abnormal UCI.

Pregnancy outcomes		Abnormal UCI (*N* = 226)	Normal UCI (*N* = 111)	OR (95%CI)	*P*-value
FGR	Yes	13 (76.5)	4 (23.5)	7.36 (2.34–23.15)	**<0.001**[a]
	No	98 (30.6)	222 (69.4)	1	
Color of amniotic fluid	Meconium-stained	30 (51.7)	28 (48.3)	2.62 (1.47–4.66)	**0.001**[a]
	Clear	81 (29.0)	198 (71.0)	1	
CTG group	II-III	22 (39.3)	34 (60.7)	1.40 (0.77–2.52)	0.279[a]
	I	89 (31.7)	192 (68.3)	1	
Birth delivery	Cesarean section	50 (44.2)	63 (55.8)	2.12 (1.32–3.41)	**0.002**[a]
	Vaginal birth	61 (27.2)	163 (72.8)	1	
Birth weight (gram)	< 2500	26 (55.3)	21 (44.7)	2.98 (1.59–5.60)	**0.001**[a]
	≥2500	85 (29.3)	205 (70.7)	1	
Apgar score at 5 mins (points)	<7	8 (80.0)	2 (20.0)	8.70 (1.82–41.69)	**0.003**[b]
	≥7	103 (31.5)	224 (68.5)	1	

[a]Pearson Chi-square (Exact sig. 2-sided), [b]Fisher Exact test (Exact sig. 2-sided).
Abbreviations: CTG, cardiotocography; FGR, fetal growth restriction; UCI, umbilical coiling index.
CI, Confidence interval; OR, odds ratio.
Bold values indicate *p*-value < 0.05.

may reduce blood flow, leading to adverse fetal outcomes during labor. The significant relationship between hypercoiling and CS rate may be explained by the association between AUC and abnormal fetal heart rate during labor, resulting in a higher rate of intervention during birth delivery. This is consistent with findings

Table 5. Univariate and multivariate logistic regression in association between materno-pregnancy characteristics and abnormal cord coiling.

		Univariate				Multivariate			
				Crude OR				Adjusted OR	
Factors		B	S. E	95%CI	*P*-value	B	S. E	95%CI	*P*-value
Maternal age (year)		0.027	0.029	1.03 (0.97–1.09)	0.356	–	–	–	–
Gestational hypertension/ preeclampsia	Yes	1.72	0.57	5.56 (1.83–16.95)	**0.003**	1.61	0.57	4.99 (1.61–15.43)	**0.005**
	No			Ref				Ref	
Gestational diabetes mellitus	Yes	2.12	0.84	8.36 (1.60–43.71)	**0.012**	2.07	0.84	7.92 (1.52–41.34)	**0.014**
	No			Ref				Ref	
Volume of amniotic fluid	Oligohydramnios	0.16	0.58	1.18 (0.38–3.67)	0.778	1.60	0.46	4.96 (2.01–12.27)	**<0.001**
	Polyhydramnio	1.48	0.45	4.38 (1.80–10.68)	**0.001**	1.52	0.43	4.56 (1.96–10.60)	**<0.001**
	Normal			Ref				Ref	

Adjusted: gestational age at ultrasound detection.
Abbreviations: B, Beta-coefficient; CI, Confidence interval; OR, odds ratio; S.E, standard error.
Statistically significant *p*-values (< 0 .05) are written in bold.

from Chitra et al. [16]. Both hypercoiling and hypocoiling were significantly associated with low birth weight (LBW), similar to the study by Mital et al. [13]. Our findings also show a significant association between abnormal aUCI and FGR, similar to the study by Mital et al. [13]. According to Jo et al. the incidence of neonates with LBW in the hypocoiled group was 36.4%, which was significantly greater than the normocoiled group. In the hypocoiled group, 27.3% of newborns were admitted to the neonatal intensive care unit (NICU) which was significantly greater than the normocoiled and hypercoiled groups [18]. In line with Patil et al., there was a significant correlation between the hypercoiled cords and FGR ($p < 0.001$). Hypocoiled cords were significantly associated with meconium staining, CS rates, and NICU admission [19].

According to Steinl et al., hypocoiling was associated with a lower gestational age (GA) at birth when compared to normocoiling and hypercoiling (36.3 ± 3.6 weeks vs 37.8 ± 2.7, $p < 0.01$, and 38.2 ± 2.6, $p < 0.01$, respectively) [20]. In the study of Machine et al., abnormal UCI was observed at different gestational ages. Principally, clinical correlations in hypercoiled cords were fetal death (37%), fetal intolerance to labor (14%), FGR (10%), and chorioamnionitis (10%). Regarding hypocoiled cords, the rate of these adverse outcomes were 29%, 21%, 15%, and 29%, respectively [5]. Similarly, on 294 pregnancies, Predanic et al. revealed that abnormal UCI was associated significantly with small for gestational age (SGA) newborns at birth and non-reassuring fetal status in labor. Nine of 58 newborns (15.5%) with AUC were SGA newborns compared with 15 of 236 SGA newborns (6.4%) who had normal UCI. A nonreassuring fetal status in labor was observed in 25.7% of fetuses with AUC compared with 11.0% of fetuses with normal UCI. Meanwhile, no statistical difference for Apgar scores at 1 and 5 min or higher prevalence of interventional deliveries and meconium-stained amniotic fluid during labor between the normal and abnormal UCI group were observed [11]. Meanwhile, Ndolo et al. found that abnormal aUCI was not associated with SGA; however, there was a statistical association with preterm birth (OR: 3.3 (95% CI: 1.4–7.7, $p = 0.003$) [21].

Some have suggested that risk factors relating to abnormal UCI including lower serum ferritin, multiparity, and LBW [20]. In our study, using univariate and multivariate logistic regression, the study found that presence of gestational hypertension disorders, gestational diabetes mellitus (GDM), oligohydramnios/hydramnios were significantly related to the development of abnormal UCI. Ezimokhai et al. found that maternal risk factors for abnormal UCI were older maternal age for hyper-coiling; obesity, GDM, and preeclampsia for noncoiling [10]. Recently, Nitheesha Reddy DD et al. showed that abnormal UCI including hypercoiling and hypocoiling had a higher incidence of complications such as GDM, polyhydramnios, and hypertensive disorders [22]. Similarly, Najafi et al. revealed that hypocoiling abnormalities were significantly more frequent in GDM pregnancies than non-GDM pregnancies in both antenatal groups at 18-23 weeks of GA and 37-41 weeks of GA [23]. Accordingly, GDM is one of the most significant risk factors for abnormal UCI since it damages the connective tissue components of the Wharton's jelly and the umbilical arteries [24]. Li-Juan Lv et al. demonstrated that excessive UCI, and its interaction with increased feto-placental vascular resistance, as novel risk factors for nocturnal blood pressure elevation and preeclampsia [25]. Clinically, UCI could become a part of the routine ultrasound scan. This allows obstetrician to decide an appropriate management strategies to ensure better pregnancy outcomes.

Strengths and limitations

This study was the first study in Vietnam concerning the AUC and pregnancy outcomes. The study was conducted at a university hospital with the experienced sonographers on the same ultrasound machine; thus, the results are reliable. However, the ultrasound was performed by different sonographers, thus, the bias could not be avoided. The study evaluated the UCI at 37-41 weeks of GA without assessing in the second trimester. Therefore, our study could not assess the issue of preterm birth and could not conclude that gestational hypertensive disorders are the consequence of excessive UCI or its cause. The effects on neurological status of survivors in long-term outcome are also unknown. In addition, the subgroup by GA at detection and at labor were not analyzed.

Conclusions

In summary, abnormal UCI is associated with adverse perinatal outcomes. Therefore, the measurement of UCI using ultrasound could be a useful tool for prediction of adverse perinatal outcomes. Further studies are necessary to underscore these findings.

Acknowledgments

The authors are grateful to all colleagues working at the Department of Delivery and the Department of Prenatal Diagnosis for their contribution.

Ethics approval and consent to participate

The study was approved by the Ethics Council in Biomedical Research Decision at Hue University of Medicine and Pharmacy with number H2022/045. The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Informed consent to participate was naturally waived for retrospective study.

Author contributions

CRediT: **Thao Nguyen Nguyen Tran**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization; **Hong Trung Nguyen**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft; **Ngoc Thanh Cao**: Conceptualization, Methodology, Project administration, Supervision, Validation, Visualization; **Phuc Nhon Nguyen**: Conceptualization, Formal analysis, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Linh Giang Truong Thi**: Data curation, Validation, Visualization; **Minh Tam Le**: Project administration, Validation, Visualization; **Quoc Huy Nguyen Vu**: Project administration, Supervision, Validation, Visualization.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to the restricted policy of the hospital but are available from the corresponding author on reasonable request.

Funding

No funding was required in the preparation of the manuscript.

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