

Comparison of Second-Trimester Uterine Artery Doppler Indices between Pregnant Women with and without Prior Cesarean Delivery and Effect on Perinatal Outcomes

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Second-Trimester Uterine Artery Doppler Indices in Pregnant Women with Prior Cesarean Delivery

208

Non-prior cesarean delivery (Non-PCD)



208

Prior cesarean delivery (PCD)



Pregnant women visiting Maternal Fetal Medicine unit of Bhumibol Adulyadej hospital, Bangkok, Thailand Between June 2023 and January 2024



Second trimester Uterine Artery Doppler : Only **UtA-RI** was greater in the PCD group with any statistical significance.



Delivery Outcomes : Earlier GA in PCD women. Maternal and neonatal outcomes of both groups were comparable.

Conclusion: UtA-RI of prior cesarean delivery participants were higher than non-prior cesarean delivery participants and not associated with maternal and neonatal adverse outcomes.

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ABSTRACT

Objective: To evaluate the effects of prior cesarean delivery on second-trimester Uterine Artery (UtA) Doppler and its effect on perinatal outcomes.

Materials and Methods: This prospective cohort study was conducted at the Maternal Fetal Medicine unit of Bhumibol Adulyadej hospital, Bangkok, Thailand between June 2023 and January 2024. Healthy pregnant women aged between 18 and 45 years old were recruited and divided into prior (PCD) and non-prior cesarean delivery (non-PCD) groups. Both groups underwent UtA Doppler study from 18 to 24 weeks of gestation. UtA Doppler indices consisted of pulsatility index (UtA-PI), resistance index (UtA-RI) and systolic/diastolic ratio (S/D). Demographics, maternal and neonatal outcomes were collected.

Results: Total of 416 participants were recruited and divided equally. The mean age of participants was 30.5 years old. Diabetes mellitus in pregnancy and hypertensive disorder were reported as 18.9 (79/416) and 5.5 (23/416) percent, respectively. From univariate analysis, subjects in the PCD group had higher UtA-PI, UtA-RI and UtA S/D than the non-PCD group with statistical significance. After multiple logistic regressions, only UtA-RI was greater in the PCD group with any statistical significance. The mean gestational age at delivery was 38.41 weeks. Prevalence of small for gestational age deliveries, preeclampsia, and preterm birth were 4.4 (17/376), 3.1 (12/376) and 10 percent (38/376), respectively. Maternal and neonatal outcomes of both groups were comparable. Number of cesarean deliveries, parity, miscarriage, and anterior placentation were not associated with UtA Doppler indices.

Conclusion: UtA-RI of prior cesarean delivery participants were higher than non-prior cesarean delivery participants and not associated with maternal and neonatal adverse outcomes.

Keywords: Uterine artery Doppler indices; cesarean deliveries; second trimester (Siriraj Med J 2024; 76: 735-745)

INTRODUCTION

In recent years, the global rate of cesarean delivery has risen.¹⁻³ There are various maternal and fetal adverse consequences associated with increased cesarean delivery rates. Uteroplacental insufficiency is one of these consequences.⁴⁻⁸ According to current evidence, uteroplacental insufficiency contributes to fetal growth restriction, Small for Gestational Age delivery (SGA), and preeclampsia.⁹ Frequent monitoring and early screening for abnormal Uterine Doppler Indices in pregnant women with increased risk of uteroplacental insufficiency due to previous cesarean deliveries might improve the quality of their clinical care.¹⁰⁻¹³

Various tools have been studied to predict uteroplacental insufficiency. However, the most extensively researched one is Uterine Artery Doppler Indices.¹⁴ Uterine Artery Doppler Indices consist of uterine artery pulsatility index (UtA-PI), uterine artery resistance index (UtA-RI), and uterine artery S/D ratio (S/D ratio). The values of UtA-PI higher than the 95th percentile is considered abnormal and indicates uteroplacental insufficiency.¹⁵ High-risk pregnant women with abnormal uterine blood flow in their second trimester have a 45 percent preeclampsia (PE) detection rate.¹⁶ The appearance of a diastolic notch in the uterine artery waveform in the second trimester was also used to monitor pregnant women who may have adverse outcomes.¹⁷ Meta-analysis of fetal growth

restriction (FGR) and PE pregnant women has shown that an increased UtA-PI in concert with presentation of notch had the most positive predictor ratio for PE (21 in a high-risk population and 7.5 in a low-risk population).¹⁸ Previous studies reported a correlation between women with prior cesarean deliveries (PCD) and increased uterine artery Doppler indices especially the UtA-PI.^{19,20} However, some studies showed contradicting results, making the previous claim inconclusive.²¹⁻²⁴

The primary aim of this study was to investigate the difference in uterine artery Doppler indices between PCD and non-PCD pregnant groups. The secondary aim was to correlate index results with perinatal outcomes, including preeclampsia, abruptio placentae, oligohydramnios, preterm deliveries, fetal acidemia, low Apgar score, prolonged neonatal intensive care unit (NICU) stay, and respiratory complications.

MATERIAL AND METHODS

This prospective cohort study was conducted at Bhumibol Adulyadej Hospital (BAH), Bangkok, Thailand, between June 2023 and January 2024. The study was approved by the ethical committee of BAH in 2023 (IRB No. 31/66). Thai Clinical Trials Registry was approved with registration number TCTR20230529002. Participants were singleton pregnant women aged between 18 and 45 years old who were literate in Thai. Gestational age was

corrected by comparing the accuracy of the last menstrual period (LMP) with the results of the ultrasonographic study during the first trimester. Subjects were divided into study and control groups. The study and control groups were cases with prior (PCD) and no history of cesarean deliveries (non-PCD), respectively. Exclusion occurred with pregnant women where major fetal anomalies were detected from first trimester scanning and participants with abnormal genetic testing results. Characteristics of all eligible participants were collected. Information regarding pregnancy outcomes were also collected from labor and delivery records. The gathered data included gestational age at delivery, preterm delivery, gestational diabetes mellitus (GDM), gestational hypertension (GHT), preeclampsia, non-reassuring fetal heart rate status, oligohydramnios, stillbirth, placental abruption, fetal growth restriction (FGR) and small for gestational age delivery (SGA) (birth weight below the 10th percentile according to Borisut's work).²⁵ For neonatal outcomes, collected data consisted of birthweight, low Apgar score, NICU admission, length of NICU stay, and respiratory complications.

Informed consent was obtained from all the participants. Both groups underwent second trimester ultrasonographic study at a gestational age between 18 and 24 weeks. The ultrasonographic study consisted of anomaly scans and uterine artery Doppler studies. The

machine used in this study was a Voluson E10 model (GE, Chicago, IL, USA). The operator was a certified OB-GYN attending the maternal-fetal medicine unit at BAH. The study flow is summarized and presented in Fig 1.

Before starting the ultrasonography, participants were placed in a supine position. The transducer was placed on the inguinal canal and then medially rotated on both sides. The uterine artery was identified at the bifurcation across the iliac vessels. After identification of the uterine artery, measurement was performed at the distal end approximately one centimeter from the bifurcation across the iliac vessels with angle insonation of at less than 30 degrees. Measurement of uterine artery Doppler indices was represented in Fig 2. These measurements were performed on each side of the uterine artery for three times. Mean values were used for further calculation. Doppler indices collected were: UtA-PI, UtA-RI, and UtA S/D ratio. Each parameter was considered abnormal when the values were higher than the 95th percentile for the corresponding gestational age. Bilateral uterine artery notching waveform (UtA-NW) at the beginning of diastole is considered abnormal and therefore be recorded. Notching was defined as a persistent decrease in blood flow velocity in early diastole.²⁶ Collected values were transferred to Viewpoint 6 data collection software (GE, Chicago, IL, USA).

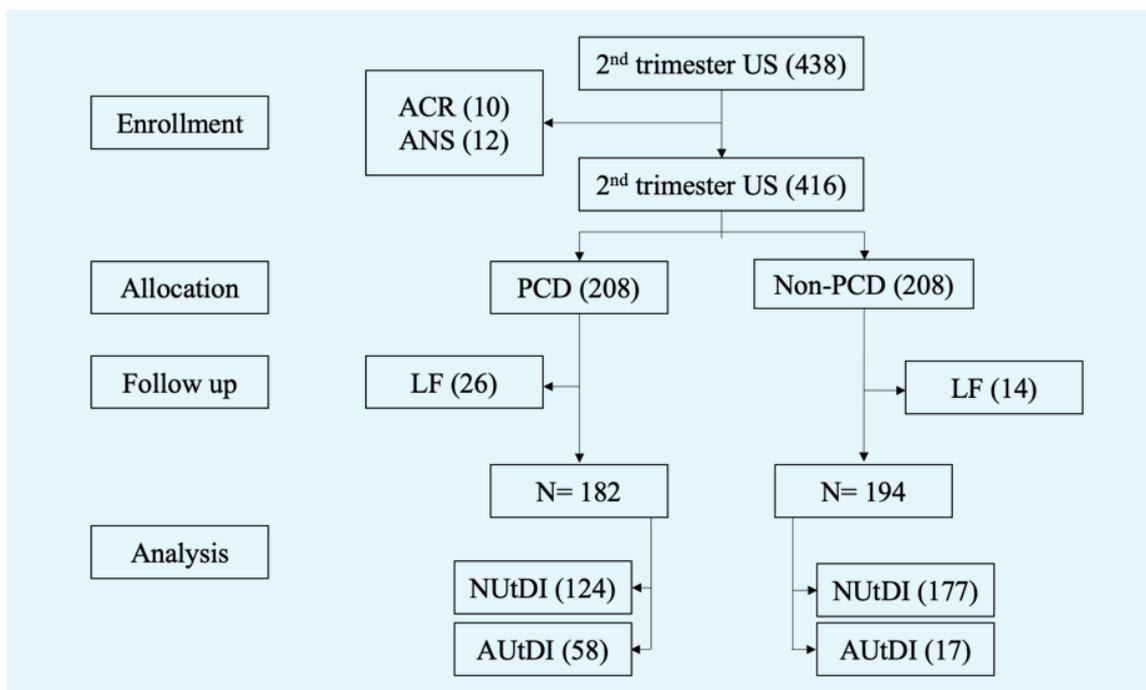


Fig 1. Flow chart of UtADI study in PCD and non-PCD.

Abbreviations: UtADI= uterine artery Doppler indices; PCD= prior cesarean delivery; non-PCD= non-prior cesarean delivery; ACR= abnormal chromosome; ANS= abnormal anatomical structure; US= ultrasound; LF= loss follow up; AUtDI= abnormal uterine artery Doppler indices; NUtDI= normal uterine artery Doppler indices

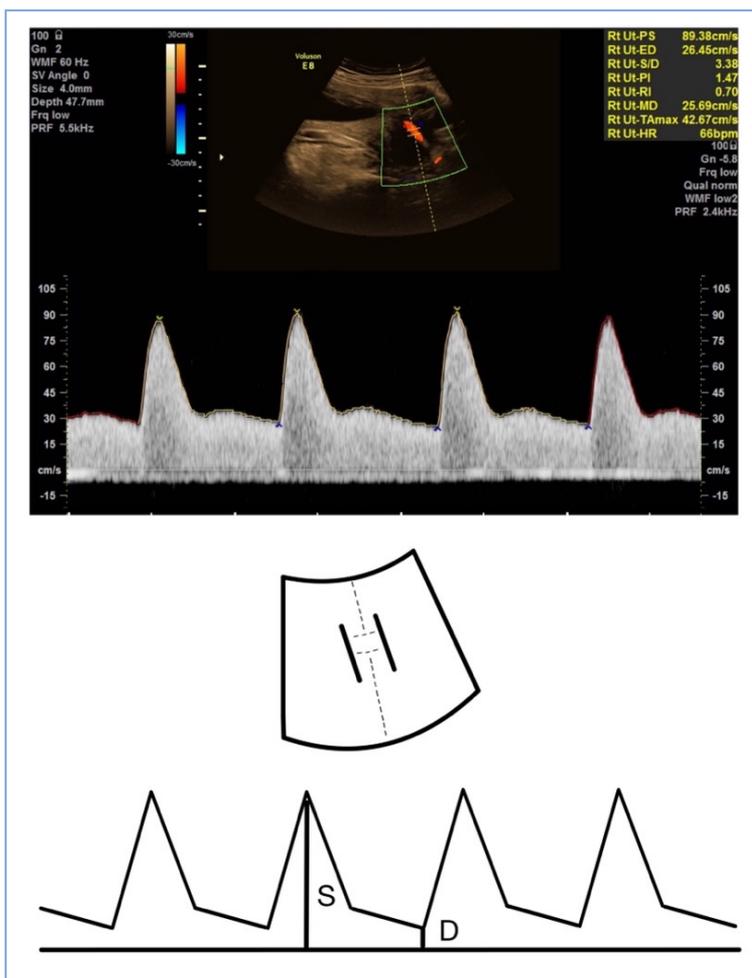


Fig 2. Ultrasonography image demonstrating the measurement of uterine artery Doppler indices.

This Doppler ultrasonography display the peak systolic and diastolic ratio (S= peak systolic velocity, D= end diastolic velocity), Mean= The time average mean velocity is obtained from calculation by computer-digitalized waveforms, S/D ratio= S/D, Resistance index= (S-D)/S, Pulsatility index= (S-D)/Mean

Statistical analyses were performed using SPSS statistical software (version 18.0.0: PASW, Chicago, IL, USA). Numerical data was presented with mean, standard deviation (SD) and median with interquartile range (IQR). Categorical data was presented in percentages. Correlation between control and study groups was analyzed using the Chi-square test, Fisher’s exact test and independent sample t-test. To determine the effects of prior cesarean delivery on the Doppler measurement, Mann-Whitney U test were used. Our study then included all the concerning baseline characteristic including maternal age, BMI, gestational age at measurement, history of abortion and anterior placental location into linear regression analysis in order to adjust the confounding factors. The sample size was calculated using the N4 study calculation program.²⁷ Data used for sample size calculation was based on a previously published prospective cohort study from Iskanan, conducted between 18 and 24 weeks of gestation that reported the mean ± SD of UtA-PI in PCD and non-PCD groups of 1.18 ± 0.40 and 1.07 ± 0.35, respectively.²⁰ Testing of two independent means was generated with 80 percent power with alpha and beta errors of 0.05 and 0.2, respectively. The estimated odd ratios with 95% confidence intervals (95% CI) and

p-values less than 0.05 were considered statistically significant. The calculated sample size was 184 cases per group. After including the loss to follow-up rate at 10 percent, the sample size required for each group was 203 cases. This resulted in a total of 406 participants.

RESULTS

Our prospective cohort study recruited 416 participants. Subjects were equally divided into PCD and non-PCD groups. The average age of subjects was 30.5 years old. Advanced maternal age (AMA) was 22.3 percent (93/416). Half of the participants (215/416) were classified as obese. One-fifth (79/416) of participants had Diabetes mellitus in pregnancy. Hypertensive disorder was 5 (23/416) percent. The mean age of participants, parity, and incidence of gestational diabetes mellitus (GDM) in the study group were all higher than the control group with statistical significance. Baseline maternal characteristics and uterine artery Doppler indices were presented in [Table 1](#).

For uterine artery Doppler measurement showed that the median with interquartile range (IQR) of UtA-PI, UtA-RI, and S/D ratio were 0.94 (0.80-1.21), 0.57 (0.52-0.65) and 2.38 (2.07-2.90), respectively. From univariate

TABLE 1. Baseline demographic data and comparison of the uterine artery (UtA) Doppler indices between study (prior cesarean delivery: n=208) and control group (non-prior cesarean delivery: n=208), simple and multiple linear regression of uterine artery Doppler indices.

	Total*	Study*	Control*	p-value
Age (years)	30.5±5.7	31.4±5.5	29.7±5.2	0.002
AMA**	93 (22.36)	55 (26.44)	38 (18.27)	0.045
BMI (kg/m ²)	25.9±5.3	26.4±5.4	25.4±5.0	0.075
Obesity**	215 (51.68)	114 (54.81)	101 (48.56)	0.202
GA (weeks)	21.3±2.3	21.7±2.6	21.0±2.1	0.010
Parity	1 (0 - 1)	1 (1 - 1)	0 (0 - 1)	<0.001
Multiparity	299 (71.88)	208 (100)	91 (43.75)	<0.001
Abortion**	81 (19.47)	43 (20.67)	38 (18.27)	0.536
UD**				
CHT	16 (3.86)	10 (4.81)	6 (2.90)	0.312
GHT	7 (1.69)	3 (1.44)	4 (1.93)	0.724
DM	12 (2.89)	4 (1.92)	8 (3.86)	0.238
GDM	67 (16.14)	44 (21.15)	23 (11.11)	0.005
AP location**	205 (49.28)	109 (52.4)	96 (46.15)	0.202
UtA Doppler***				
PI	0.94 (0.80-1.21)	0.98 (0.84 - 1.23)	0.91 (0.75 - 1.19)	0.022
RI	0.57 (0.52 - 0.65)	0.58 (0.54 - 0.66)	0.56 (0.50 - 0.65)	0.010
S/D ratio	2.38 (2.07 - 2.90)	2.42 (2.16 - 2.94)	2.29 (2.01 - 2.87)	0.038
Notching	81 (19.47)	45 (21.63)	36 (17.31)	0.265
Abnormal PI	70 (16.83)	35 (16.83)	35 (16.83)	1.000
Abnormal RI	140 (33.65)	79 (37.98)	61 (29.33)	0.062
	Simple ϕ		Multiple ϕ	
	β (95% CI)	p-value	β (95% CI)	p-value
PI	0.04 (-0.04 - 0.12)	0.347	0.05 (-0.03 - 0.13)	0.223
RI	0.02 (0.01 - 0.04)	0.017	0.03 (0.01 - 0.05)	0.006
S/D ratio	-0.03 (-0.25 - 0.19)	0.775	-0.02 (-0.24 - 0.21)	0.879

* mean \pm standard deviation (SD), ** n (%), ***median with interquartile range (IQR), AMA: advance maternal age (\geq 35 years old), BMI: body mass index, Obesity: BMI \geq 25 kg/m², GA: gestational age, AP location: placenta located at anterior wall of uterus, abortion: history of abortion, UD; underlying disease, PI: pulsatility index, RI: resistance index, S/D ratio: systolic/diastolic ratio, Notching: persistent bilateral notching, ϕ ; adjusted for age, BMI, GA, abortion and AP location.

analysis, subjects in the PCD group had significantly greater UtA-PI, UtA-RI and UtA S/D than in the non-PCD group (0.98/0.91, 0.58/0.56 and 2.42/2.29) as shown in Table 1 and Fig 3. After adjusting related confounding factors with multiple logistic regression, it was determined that only mean UtA-RI values were higher in the PCD group. UtA-NW was found in 19.5 percent (81/416) of the participants. Both groups had comparable UtA-NW percentages, with 21.6% (45/208) in the study group and 17.3% (36/208) in the control group.

Based on the obstetric statistics from labor and delivery records, the study group showed statistically lower gestational age at delivery than the control group (38.1 vs 38.7 weeks). Approximately one-third (71/194) of subjects of non-PCD group underwent cesarean delivery. Other adverse outcomes collected in the study were comparable between groups as shown in Table 2. Prevalence of small for gestational age at delivery (SGA), preeclampsia and preterm birth was 4.4 (17/376), 3.1 (12/376) and 10 percent (38/376), respectively. Total adverse outcome in the current study was 20.7 (78/376) percent. Placental abruption, stillbirth, and 5 min Apgar score lower than 7 were not found in this study.

Focusing on abnormal uterine artery Doppler indices in all participants, there were effects on abnormal outcome as shown in Table 3. Abnormal UtA-PI showed significantly more cases of preterm birth, fetal growth restriction, oligohydramnios, non-reassuring fetal status, adverse maternal outcome, neonatal outcome and total adverse outcome. In the same trend as abnormal UtA-RI and UtA-NW. However, this correlation was shown only in all participants but were not shown in subanalysis for PCD group.

In our study, the analysis of the placental location and the number of previous cesarean deliveries were performed. Moreover, parity and history of abortion were also included in the analysis. However, our study showed no significant effect regarding uterine artery Doppler indices of the current pregnancy from all previously mentioned aspects.

DISCUSSION

The current study found that only the UtA-RI of the PCD group was significantly higher than the non-PCD group. This supported Torabi’s report from Iran in 2018 that the mean UtA-PI and UtA-NW of the PCD group were significantly higher than the non-PCD group.¹⁹ Another study of Iskalan from Turkiye showed UtA-PI in multiple of median (MoM), which is the ratio between PI values of the patients and the median PI values for gestational age, the study also reported values

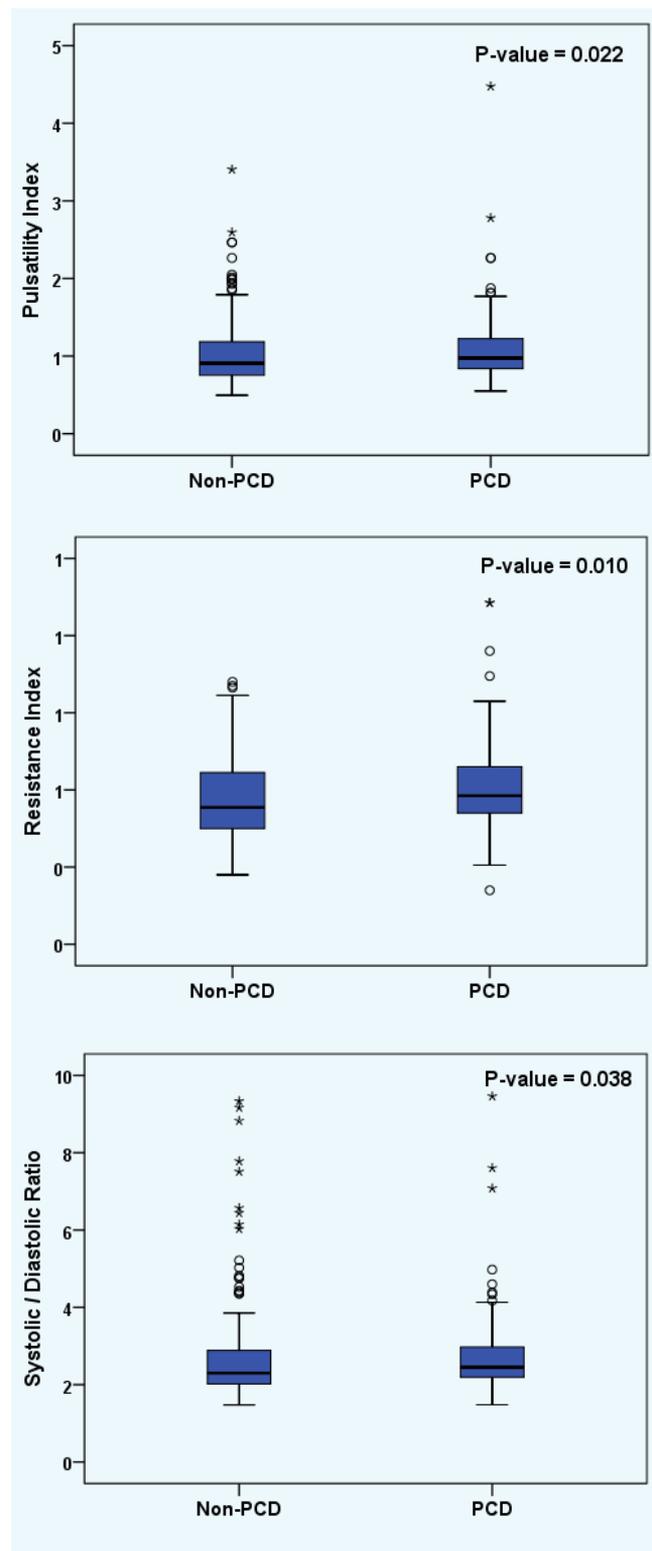


Fig 3. (A) A boxplot comparing the distribution of UtA-PI between non-PCD and PCD. (B) A boxplot comparing the distribution of UtA-RI between non-PCD and PCD. (C) A boxplot comparing the distribution of UtA-S/D between non-PCD and PCD.

Abbreviations: UtA-PI= uterine artery pulsatility index; UtA-RI= uterine artery resistance index; UtA-S/D= uterine artery systolic/diastolic ratio; non-PCD= non-prior cesarean delivery; PCD= prior cesarean delivery

TABLE 2. Neonatal outcome, gestational age at delivery (GAD) and complication from uteroplacental insufficiency between study (prior cesarean delivery) and control group. (non-prior cesarean delivery).

	Study (n= 182)*	Control (n= 194)*	p-value
Maternal			
GAD (weeks)**	38.10 ±1.06	38.72± 1.39	<0.001
Preterm birth	21 (11.54)	17 (8.76)	0.372
SGA	5 (2.75)	12 (6.19)	0.109
FGR	1 (0.55)	6 (3.09)	0.123
Oligohydramnios	1 (0.55)	4 (2.06)	0.372
Preeclampsia	6 (3.30)	6 (3.09)	0.910
Nonreassuring	1 (0.55)	4 (2.06)	0.373
PPROM	6 (3.30)	3 (1.55)	0.325
Preterm labor	11 (6.04)	5 (2.58)	0.096
AMO	36 (19.78)	40 (20.62)	0.840
Neonatal			
Birthweight (kg) **	3.121±0.46	3.09±0.48	0.563
NICU admission	9 (4.95)	4 (2.06)	0.126
NICU stay (days) ***	16 (11-12)	6.5 (2.5-26.5)	0.355
NCO	16 (8.79)	17 (8.76)	0.992
TAO	41 (22.53)	40 (20.62)	0.653

*n (%), **mean ± standard deviation (SD), ***median with interquartile range (IQR), NCO; neonatal composite outcome namely small for gestational age (SGA), fetal growth restriction (FGR) and neonatal complication, AMO; adverse maternal outcome, TAO; total adverse outcomes.

in their PCD group significantly higher than the non-PCD group.²⁰ In contrast, Yapan's study from Thailand in 2021 reported no difference in UtA-PI, UtA-RI, UtA S/D ratio and UtA-NW between PCD and non-PCD groups.²¹ Baron from Israel and Flo from Norway also reported PCD and non-PCD groups had comparable mean UtA-PI values.^{22,23}

The primary outcome of this study can be explained by cesarean deliveries causing increased resistance in the uterine artery from uterine scar formation. During cesarean delivery, the lower segment of the uterus is incised and sutured. This supports the theory that cesarean delivery may have consequences on uterine artery hemodynamics by interfering with normal trophoblastic invasion and normal uterine blood flow.¹⁰ Our study, in line with findings from Torabi and Iskanan, found that high values of UtA-PI, UtA-NW and UtA-RI, strongly indicated decreased uterine blood flow.^{19,20} Torabi's study indicated anterior placentation as a factor causing increased UtA-PI¹⁹ this association however could not be duplicated in the current study.

In contrast to this study, Yapan's, Baron's and Flo's studies reported that cesarean delivery was not associated with increased UtA Doppler indices.²¹⁻²³ The reason behind the contradicting result could be that UtA Doppler indices are multifactorial and are affected by multiple different baseline characters. Further study with strict confounder controls and larger sample sizes is needed for future investigation.

From the study by Iskanan, more than two repeated cesarean deliveries were associated with increase in UtA-PI, UtA-RI and UtA S/D ratio.²⁰ Considering the effects of multiple cesarean deliveries, most of the subjects in the current study and Yapan's study had only one cesarean delivery prior to their participation in both works.²¹ Nearly half (34/73) of the participants in Iskanan's study had a history of multiple cesarean deliveries. In contrast, our study and Yapan's, participants had multiple cesarean deliveries for only 3.5 (5/140) and 3 (8/269) percent of participants, respectively. Therefore, the number of multiple cesarean deliveries in our study was too small to fully analyze for any association.

TABLE 3. Comparison of neonatal outcome, gestational age at delivery (GAD) and complication from uteroplacental insufficiency between normal and abnormal Doppler indices including abnormal pulsatility index (PI), abnormal resistance index (RI) and persistent bilateral notching.

	Normal PI (n= 306)*	Abnormal PI (n= 70)*	p-value	Normal RI (n= 236)*	Abnormal RI (n= 140)*	p-value	No notching (n=295)*	Notching (n=81)*	p-value
Maternal									
GAD (weeks)**	38.56±1.19	38.14±1.46	<0.001	38.57±1.21	38.14±1.34	0.002	38.54±1.22	37.94±1.39	<0.001
Preterm birth	23 (7.52)	15 (21.43)	<0.001	18 (7.63)	20 (14.29)	0.038	26 (8.81)	12 (14.81)	0.112
SGA	6 (1.96)	11 (15.71)	0.071	6 (2.54)	11 (7.86)	0.016	8 (2.71)	9 (11.11)	0.001
FGR	3 (0.98)	4 (5.71)	0.007	2 (0.85)	5 (3.57)	0.059	3 (1.02)	4 (4.94)	0.021
Oligohydramnios	2 (0.65)	3 (4.29)	0.017	2 (0.85)	3 (0.21)	0.289	3 (1.02)	2 (2.47)	0.312
Preeclampsia	5 (0.16)	7 (10.00)	<0.001	3 (1.27)	9 (6.43)	0.006	5 (1.69)	7 (8.64)	0.002
Nonreassuring	2 (0.65)	3 (4.29)	0.017	2 (0.85)	3 (2.14)	0.289	5 (1.69)	0	-
PPROM	7 (2.29)	2 (1.43)	0.779	5 (2.12)	4 (2.86)	0.651	8 (2.71)	1 (1.23)	0.441
Preterm labor	12 (3.92)	5 (7.14)	0.242	8 (3.39)	9 (6.43)	0.170	14 (4.75)	3 (3.70)	0.689
AMO	47 (15.36)	29 (41.43)	<0.001	36 (15.30)	40 (28.57)	0.002	53 (17.97)	23 (28.40)	0.038
Neonatal									
Birthweight (kg) **	3.18±0.42	2.77±0.54	<0.001	3.18±0.44	2.95±0.50	<0.001	3.17±0.43	2.87±0.53	<0.001
NICU admission	9 (2.94)	4 (5.71)	0.252	9 (3.81)	4 (6.67)	0.624	9 (3.05)	4 (4.94)	0.410
NICU stay (days) **	15.2±11.8	19.8±17.9	0.643	15.2 ±11.8	19.7 ±17.8	0.643	15.4±11.5	19.3±18.4	0.758
NCO	19 (6.21)	14 (20.00)	<0.001	18 (7.63)	15 (10.71)	0.192	21 (7.12)	12 (14.81)	0.018
TAO	52 (16.99)	29 (41.43)	<0.001	41 (17.40)	40 (28.57)	0.011	57 (19.32)	24 (29.63)	0.046

*n (%), **mean ± standard deviation (SD), ***median with interquartile range (IQR), NCO; neonatal composite outcome namely small for gestational age (SGA), fetal growth restriction (FGR) and neonatal complication, AMO; adverse maternal outcome, TAO; total adverse outcomes.

Differences between UtA-RI and UtA-PI came from the calculation between systolic and diastolic flow. In the worst cases that diastolic flow is zero, values of RI and PI would be one and two, respectively. Mean UtA-RI and UtA-PI in the current study were 0.57 and 0.94, respectively. When classified into abnormal RI and PI according to the reference values, one-third (140/416) and one-sixth (70/416) of RI and PI were classified as abnormal values, respectively. In our opinion, UtA-RI could also be used as an indicator of decreased uterine blood flow in the same way as UtA-PI because the calculation were based from the same values as previously mentioned.

Torabi had presented an association of increased UtA-PI and adverse maternal outcomes including preterm birth, SGA delivery, preeclampsia, and placental

abruption.¹⁹ Yapan's study reported PCD and non-PCD groups had comparable Doppler indices and maternal/neonatal outcomes.²¹ Our current study also reported no significant difference in maternal and neonatal outcomes between study and control group. When comparing Torabi to current study PIH, SGA and preterm birth were 5 (20/400) vs 3.2 (12/376), 11.5(35/400) vs 4.5(17/376) and 5 (20/400) vs 10.1 (38/376) percent, respectively.¹⁹ From our current study, the contradicting outcome to the result of Torabi's study might be a consequence of low prevalence of PIH and SGA among participants in our current study.¹⁹ In addition, multifactorial factors may be attributed to maternal and neonatal outcomes. Data from the previous studies were summarized and presented in [Table 4](#).

TABLE 4. Comparison of the current study to previous studies.

	Present		Yapan		Isikalan		Torabi		Baron		Flo	
Years	2024		2021		2020		2018		2015		2014	
Country	Thailand		Thailand		Turkiye		Iran		Israel		Norway	
Case (n)	416		538		153		400		106		64	
Trimester	2		1, 2, 3		2		2		PP		2	
Age (yr)	30.5		31.23		29.3		32.95		30.5		33	
BMI (kg/m ²)	25.1		24.05		25.86		26.7					
UtA PI	NS		NS		P>NP		P>NP		NS		NS	
Type	Me		MoM		MoM		M		M		M	
UtA RI	P>NP		NS		NS							
S/D ratio	NS		NS		NS							
Notching	NS		NS		NS		P>NP				NS	
Increased PI	NS				P>NP		P>NP					
	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP
Parity	1	1			2	2			3	3		
BW (kg)	3.1	3.1	3.1	3.1	3.0	3.1			3.4	3.3	3.5	4.0
Preterm birth	11.5	8.7	9.1	5.2			6	4				
SGA	2.8	6.2	9.8	8.1			12	10.5			6.3	9.4
PIH	3.3	3.1	3.4	3.4			7.5	2.5				
Oligo	0.5	1.9	0.0	1.5			4.5	4	0.0	0.0		
PA	NS	NS	NS	NS			1.5	0.5				
AMO	19.78	20.62										
NAO	8.79	8.76										
TAO	22.5	20.6					23.5	14				

Abbreviations: PA; placental abruption, AMO; adverse maternal outcome, NAO; neonatal adverse outcome, TAO; total adverse outcome, P; prior cesarean delivery group, NP; non-prior cesarean delivery group, Me; median, M; mean, MoM; multiple of median, NS; not significant.

For the strength of this study, information about neonatal outcome was studied in extensive aspects and collected as neonatal composite outcome. Moreover, our sample size calculation was powered and sufficient for the primary objective. In addition, analysis of the primary outcome with confounding factors were adjusted by multiple logistic regressions which made the results sound. Sub analysis was performed with all possible aspects to find a correlation with uterine artery Doppler. However, limitations include underpowered sub analysis due to small sample size. For example, our study also had too small number of multiple cesarean deliveries participants to determine the effects of number of cesarean deliveries on concerning outcomes. In addition, some participants failed to follow up which may affect the results for labor and delivery outcomes.

In conclusion, this study confirms that cesarean delivery is potentially a significant causative factor in decreased uterine blood flow. Only uterine artery resistance index (UtA-RI) had an association with cesarean delivery. However, this study could not represent an association between cesarean delivery and perinatal outcomes. For the UtA Doppler measurement, we recommend using all three parameters including UtA-PI, UtA-RI and UtA S/D ratio as each index all represent an alteration of uterine artery blood flow. It is important that cesarean delivery should be performed only when indicated as recommended by the WHO to minimize adverse outcomes.¹ We recommend measuring uterine artery Doppler indices in all participants with maternal risk factors of PE and/or FGR, whether with PCD or non-PCD. The optimal time or uterine artery Doppler assessment is in the second trimester.

What is already known in this topic?

Uteroplacental insufficiency is one of the consequences of cesarean delivery. Uteroplacental insufficiency contributes to fetal growth restriction, small for gestational age, and preeclampsia. Uterine artery Doppler indices (UtA-PI, UtA-RI, S/D ratio) indicate uteroplacental insufficiency. There were inconclusive effects of cesarean delivery and uterine artery Doppler indices.

What has this study contributed to this topic?

Cesarean delivery affected the subsequent pregnancy by alteration of uterine artery Doppler indices. UtA-RI of prior cesarean delivery participants were higher than non-prior cesarean delivery participants and not associated with maternal and neonatal adverse outcomes.

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DECLARATION

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Conflict of Interest

The authors declare that they have no conflicts of interest.

Author Contributions

Conceptualization and methodology, B.C., S.M. and B.S.; Investigation, B.C., S.M.; Formal analysis, B.C., S.M. and B.S.; Visualization and writing – original draft, B.C., S.M., B.S., K.S. and K.B.; Writing – review and editing, B.C., S.M. and B.S.; Funding acquisition, B.C.; Supervision, B.C., S.M. and K.S. All authors have read and agreed to the final version of the manuscript.

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