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Difference between Paired Umbilical Arteries Doppler Velocimetry Indices in Singleton Pregnancy

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ABSTRACT

Objectives: To assess variance between paired umbilical artery Doppler velocity indices in pregnancies at 18-37 weeks.

Materials and Methods: We enrolled 450 women with singleton pregnancies, aged 18-37 weeks, between April 2023 and January 2024. They underwent Doppler transabdominal ultrasound to assess both umbilical arteries in a free-floating loop of umbilical cord. We recorded umbilical artery Doppler pulsatility index (PI), resistance index (RI), and systolic/diastolic (S/D) ratio for each umbilical artery.

Results: 418 women were analyzed. Mean PI, RI, and S/D ratio at each gestational age (18 - 37 weeks) significantly differed between paired umbilical arteries ($p < 0.05$). Discrepancies > 10% in PI, RI, and S/D ratio between the two umbilical arteries were observed in 48.6%, 23.9%, and 56.7% of cases, respectively. Discrepancy > 20% were observed in 12.7%, 2.6%, and 22% of cases, respectively.

Conclusion: Significant differences existed in PI, RI, and S/D ratio between the two umbilical arteries. As gestational age advances, there was a gradual decrease in the PI, RI, and S/D ratio. The mean difference in the S/D ratio between the two umbilical arteries tended to decrease as gestational age increased. Further considerations are necessary to determine whether the nomogram values, derived from measuring only one umbilical artery, should be based on higher or lower values, or if they should consider a specific relationship between the two umbilical arteries.

Keywords: paired umbilical arteries, pulsatility index, resistance index, systolic/diastolic ratio (S/D).

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ความแตกต่างระหว่างความเร็วดอปเปอร์เส้นเลือดแดงสายสะดือทารกในครรภ์แต่ละเส้นในหญิงตั้งครรภ์เดี่ยว

เอกพจน์ อนันตวรพจน์, ลัลธพร พัฒนาวิจารย์

บทคัดย่อ

วัตถุประสงค์: *ประเมินความแตกต่างระหว่างดัชนีความเร็วดอปเปอร์ของคู่เส้นเลือดแดงสายสะดือทารกในช่วงการตั้งครรภ์ที่อายุครรภ์ 18-37 สัปดาห์*

วัสดุและวิธีการ: *สตรีตั้งครรภ์เดี่ยวที่มีสุขภาพปกติอายุครรภ์ 18-37 สัปดาห์ จำนวน 450 รายระหว่างเดือนเมษายน 2566 ถึงเดือนมกราคม 2567 ถูกทำการวัดดอปเปอร์ของคู่เส้นเลือดแดงสายสะดือทารกในครรภ์ โดยวัดตำแหน่งสายสะดือบริเวณที่ลอยอิสระ ดัชนีดอปเปอร์ที่วัดได้แก่ ดัชนีการไหลเวียน ดัชนีความต้านทาน และสัดส่วนการไหลเวียนในช่วงบีบตัวและคลายตัว*

ผลการศึกษา: *จากผู้เข้าร่วมการวิจัยทั้งหมด 450 ราย วัดสำเร็จและตามผลการคลอดได้สำเร็จทั้งหมด 418 ราย ได้ถูกนำมาวิเคราะห์ข้อมูล พบว่าดัชนีการไหลเวียน ดัชนีความต้านทาน และสัดส่วนการไหลเวียนในช่วงบีบตัวและคลายตัวของคู่เส้นเลือดแดงสายสะดือในทุกอายุครรภ์ (ช่วง 18-37 สัปดาห์) มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) ค่าดัชนีการไหลเวียน ดัชนีความต้านทาน และสัดส่วนการไหลเวียนในช่วงบีบตัวและคลายตัวที่ต่างกันมากกว่า 10 เปอร์เซ็นต์ อยู่ที่ร้อยละ 48.6, 23.9 และ 56.7 ตามลำดับ และค่าดัชนีการไหลเวียน ดัชนีความต้านทาน และสัดส่วนการไหลเวียนในช่วงบีบตัวและคลายตัวที่ต่างกันมากกว่า 20 เปอร์เซ็นต์ อยู่ที่ร้อยละ 12.7, 2.6 และ 22 ตามลำดับ*

สรุป: *พบความแตกต่างของดัชนีการไหลเวียน ดัชนีความต้านทาน และสัดส่วนการไหลเวียนในช่วงบีบตัวและคลายตัวของคู่เส้นเลือดแดงสายสะดืออย่างมีนัยสำคัญทางสถิติ ในอายุครรภ์ที่มากขึ้นพบว่าดัชนีทั้ง 3 จะมีค่าที่ค่อยๆ ลดลง นอกจากนี้ในอายุครรภ์ที่เพิ่มขึ้นค่าเฉลี่ยของความแตกต่างของสัดส่วนการไหลเวียนในช่วงบีบตัวและคลายตัวของคู่เส้นเลือดแดงสายสะดือยังค่อยๆ ลดลงด้วย จากข้อมูลการศึกษาพบว่าการนำค่าปกติที่มีการประเมินเส้นเลือดแดงสายสะดือทารกด้วยการใช้ค่าปกติของเส้นเลือดสายะสะดือเพียงค่าเดียว อาจต้องพิจารณาคำนึงถึงความแตกต่างระหว่างคู่เส้นเลือดแดงสายสะดืออีกเส้นด้วย เพื่อไปใช้ในดูแลทารกในครรภ์ต่อไป*

คำสำคัญ: *คู่เส้นเลือดแดงสายสะดือ, ดัชนีการไหลเวียน, ดัชนีความต้านทาน, สัดส่วนการไหลเวียนในช่วงบีบตัวและคลายตัว*

Introduction

There has been extensive investigation of the umbilical vessel in pregnancy. In 99% of cases, there are three umbilical vessels: two umbilical arteries and one umbilical vein[1]. These vessels play crucial roles in transporting nutrients, exchanging oxygen, and eliminating waste products from the fetus to the placenta. Utilizing Doppler velocity of the umbilical artery can aid in monitoring pregnancies, devising treatment plan, and determining the appropriate gestational age for delivery in cases of fetal growth restriction. This approach has the potential reduce postnatal mortality by up to 29%[2]. The recommended site for measuring Doppler velocity is at the free loop of the umbilical artery. Both the 2019 American College of Obstetricians and Gynecologists (ACOG) guidelines and the 2022 Society for Maternal-Fetal Medicine (SMFM) guidelines advocate for the use of Doppler velocity of the umbilical artery to assess fetal health during pregnancy[3, 4].

The circulation of the umbilical artery flows from the fetus to the placenta. Color Doppler enables assessment of blood flow velocity, which varies according to the heartbeat in systole and diastole. During systole, the blood velocity in the umbilical artery is high, as represented by an S waveform. Subsequently, the velocity gradually decreases during diastole, depicted by a D waveform. To derive the pulsatility index (PI), the resistance index (RI), and the systolic/diastolic (S/D) ratio, the values of S and D are calculated. The PI is calculated by dividing the difference between S and D by the means of S and D. The RI is obtained by dividing difference between S and D by S. S/D is determined by dividing S by D[5]. These measurements assist in assessing umbilical artery blood flow and are instrumental in diagnosing conditions associated with blood circulation.

The Doppler velocity of the umbilical artery in pregnancy serves as an indicator of fetal health. Typically, the umbilical arteries exhibit similar sizes since they are interconnected near their distal ends by Hyrtl's anastomosis. This anastomosis is typically situated near the entry points of arteries into the placenta, thereby ensuring equalized pressure values in both umbilical arteries[6]. However, each umbilical artery may provide different size or velocity values. Variations in vascular resistance, blood flow dynamics, and placental attachment sites can lead to differing Doppler velocity indices between the two arteries. Additionally, any asymmetry in the development or function of the placenta can contribute to these discrepancies[7-11]. Studies have reported differences between the two umbilical arteries in several Doppler velocity indices: up to 13.1% in the RI in low-risk pregnancies, and even up to 38%[7], and up to 16.7% in the PI[8]. Physicians typically measure the Doppler velocity at the free loop of one umbilical artery and subsequently utilize the obtained values to plan fetal care. Despite each umbilical artery in pregnancy providing different Doppler velocity values, the current nomogram for umbilical artery Doppler velocity indices has been derived from measuring only one umbilical artery[12, 13]. Therefore, our aim was to investigate the differences in the Doppler velocity indices of both umbilical arteries in low-risk singleton pregnancies. This endeavor may provide valuable information that could potentially lead to a revision of the current concept of the nomogram for umbilical artery Doppler indices.

Materials and Methods

Between April 2023 and January 2024, this prospective cross-sectional study recruited singleton pregnant women between 18 to 37 weeks of gestation at Rajavithi Hospital, Thailand. Four hundred fifty pregnant women who underwent prenatal visit care were enrolled. The eligibility inclusion criteria encompassed age ≥ 18 years, singleton low-risk pregnancy, and gestational age determined last menstrual period (LMP) and confirmed by ultrasonography of at least 18 weeks. Because the aim of this study was to evaluate low risk pregnancy. Women who had preexisting diabetes mellitus, gestational diabetes mellitus, thyroid disease, systemic lupus erythematosus, chronic hypertension, smoking, a single umbilical artery, umbilical cord abnormality, absent or reverse end-diastolic flow, fetal structural abnormalities and fetal genetic abnormalities were excluded. The study protocol received approval from the ethics committee of Rajavithi Hospital (No.

056/2566). Each participant provided informed consent prior to enrollment.

The participants underwent two-dimensional (2D) transabdominal ultrasound utilizing a GE Voluson S8 or S10 ultrasound machine equipped with a 2–5 MHz curved array transducer. Ultrasonography was performed by a single operator (PC), who was undergoing a maternal-fetal medicine fellowship and had been trained in umbilical artery Doppler measurements. Color Doppler ultrasound was employed to identify the paired umbilical arteries in the free-floating loop of the umbilical cord, with insonation optimized to be parallel to the vessel or at an angle of insonation not exceeding 30°. To confirm the measurement of each umbilical artery in this study, during the Doppler ultrasound examination, both umbilical arteries within a free-floating loop of the umbilical cord, lying parallel to each other, can be visualized simultaneously (Fig. 1). The pulsed-wave Doppler examination was conducted in the absence of fetal movement or breathing. Doppler ultrasound was performed three times consecutively for each vessel, capturing at least five uniform cardiac cycles during each session. The PI, RI, and S/D ratio were determined from the average of multiple flow velocity waveforms, each comprising a minimum of three consistent cardiac cycles. The measurement selected was the one exhibiting the most uniform wave with the lowest angle of insonation (Fig. 1). If each umbilical artery provided a different PI, then the artery with the higher PI was designated as "umbilical artery M," while the one with the lower PI was designated as "umbilical artery N." The scanning time was kept under 15 minutes for each woman. Additionally, it is important to note that Doppler ultrasound, while generally considered safe, can generate a thermal index that could potentially affect the fetus if not monitored and controlled properly. If ultrasound was unsuccessful, the patient was excluded from the study. Each participant underwent a single routine ultrasonographic examination, which included fetal standard biometry, estimated of fetal weight, and screening for fetal anomalies. The following maternal baseline characteristics were recorded: age, parity, and pre-pregnancy body mass index (BMI). The following pregnancy-related outcomes were recorded: route of delivery, gestational age of delivery, birth weight, sex of the baby, APGAR score, neonatal respiratory distress syndrome, and any obstetrical complications.

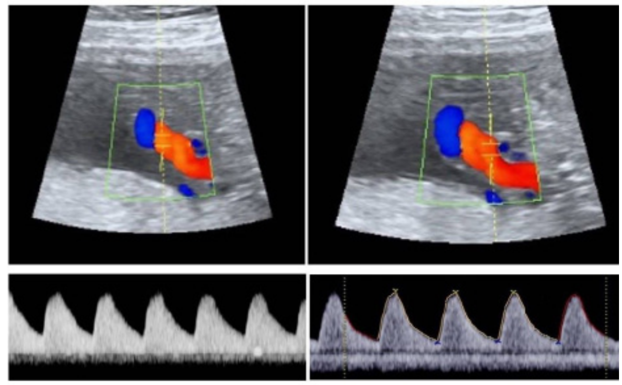

Fig. 1. Measurement the paired umbilical artery Doppler.

Statistical analysis

The sample size was calculated from the previous study[14] by using this formula.

$$n = \frac{(Z_{\alpha/2} + Z_{\beta})^2 \chi(\sigma_1^2+\sigma_2^2)}{(\mu_1 - \mu_2)^2}$$

n = sample size, $\alpha = 0.05$, $Z_{\alpha/2} = 1.96$, $Z_{\beta} = 0.842$, $\sigma 1 = 0.13$, $\sigma 2 = 0.15$, $\mu_1 = 0.74$, $\mu_2 = 0.70$

The subjects included 280 cases with a 30% drop-out rate, resulting in a total sample size of at least 400 cases per each umbilical artery Doppler with gestational age between 18 - 37 weeks.

Data analysis was conducted using SPSS version 22.0 for Windows (IBM Corp., Armonk, NY, USA). Categorical and continuous variables are presented as frequency, percentage, mean ± standard deviation (SD) or median (minimum–maximum). The normality of the data was assessed using the Kolmogorov–Smirnov test. Correlations between the PI, RI, S/D ratio, and gestational age were determined using Pearson's correlation analysis. A p value of < 0.05 was considered statistically significant. The intraclass correlation coefficient (ICC) was employed to evaluate the inter- and intra-rater reliability.

Results

A total of 450 singleton pregnant women were recruited in the study and underwent fetal umbilical artery Doppler measurements. Thirty-two women were excluded: 21 (4.6%) women were lost to follow-up, 10 (2.2%) women developed gestational diabetes mellitus, and 1 (0.2%) woman had a discordant umbilical artery Doppler pattern (one with a positive end-diastolic flow (EDF) and one with an absent EDF). Thus, 418 women were included in the analysis.

The mean ± SD maternal age and pre-pregnancy BMI were 29.91 ± 6.54 years and 23.46 ± 4.03 kg/m^2, respectively. Twenty-six (6.2%) women were classified as obese. Nearly half of the women (48.8%) were nulliparous. The mean ± SD gestational age at delivery was 38.63 ± 1.11 weeks. Most of them had a vaginal delivery (73%). The mean ± SD birth weight was 3037.52 ± 340.10 grams. Tables 1 and 2 provide the maternal characteristics and pregnancy outcomes, respectively.

Table 1. Maternal characteristics of the study population.

Characteristics	Total (n = 418)	
	n	%
Age (years)		
< 20	17	4.1%
20 - 35	312	74.6%
> 35	89	21.3%
Mean ± SD	29.91 ± 6.54	
Min - max	18 - 48	
BMI		
< 18.5	23	5.5%
18.5 - 22.9	196	46.9%
23 - 24.9	61	14.6%
25 - 29.9	112	26.8%
> 30	26	6.2%
Mean ± SD	23.46 ± 4.03	
Parity		
Nulliparous	204	48.8%
Multiparous	214	51.2%
Gestational age (weeks) Mean ± SD	27.47 ± 5.68	

SD: standard deviation, BMI: body mass index, n: number.

Table 2. Pregnancy outcomes of the study population.

	Total (n = 418)	
	n	%
Delivery route		
Vaginal delivery	305	73.0%
Cesarean section (CS)	113	27.0%
Indication of CS (n = 113)		
Previous CS	23	20.4%
Non-reassuring FHS	26	23.0%
Elective CS	35	31.0%
failed induction	10	8.8%
CPD	17	15.0%
Malpresentation	2	1.8%
Gestational age of delivery		
< 37	17	4.1%
≥ 37	401	95.9%
Mean ± SD	38.63 ± 1.11	
Neonatal gender		
Male	229	54.8%
Female	189	45.2%
Birth weight (gram)		
< 2,500	26	6.2%
≥ 2,500	392	93.8%
Mean ± SD	3037.52 ± 340.10	
Percentile		
AGA	404	96.7%
SGA	5	1.2%
LGA	9	2.2%
APGAR at 1 min		
≤ 7	10	2.4%
> 7	408	97.6%
Mean ± SD	8.54 ± 0.57	
APGAR at 5 min		
> 7	418	100%
Mean ± SD	9.53 ± 0.53	
RDS	13	3.1%
Developed FGR	4	1.0%
Preeclampsia	2	0.5%

SD: standard deviation, CS: cesarean section, CPD: cephalopelvic disproportion, AGA: appropriate for gestational age, SGA: small for gestational age, LGA: large for gestational age, APGAR: Activity-Pulse-Grimace-Appearance-Respiration score, RDS: respiratory distress syndrome, FGR: fetal growth restriction.

The mean "umbilical artery M" and "umbilical artery N" PI, RI, and S/D ratio for a gestational age of 18–37 weeks are shown in Table 3.

Table 3. Comparison the mean values of pulsatility index, resistance index, and systolic/diastolic between the two umbilical artery Doppler.

Gestational age (weeks)	n	Umbilical artery M Mean ± SD	Umbilical artery N Mean ± SD	Difference Mean (95% CI)	p value
Pulsatility index (PI)					
18	18	1.366 ± 0.178	1.236 ± 0.185	0.152 (0.096, 0.208)	< 0.001*
19	18	1.356 ± 0.156	1.191 ± 0.115	0.130 (0.089, 0.171)	< 0.001*
20	30	1.356 ± 0.193	1.191 ± 0.176	0.164 (0.107, 0.222)	< 0.001*
21	19	1.348 ± 0.168	1.198 ± 0.143	0.150 (0.102, 0.198)	< 0.001*
22	20	1.271 ± 0.143	1.150 ± 0.170	0.120 (0.097, 0.144)	< 0.001*
23	22	1.253 ± 0.126	1.156 ± 0.111	0.097 (0.066, 0.128)	< 0.001*
24	20	1.163 ± 0.169	1.081 ± 0.149	0.182 (0.144, 0.220)	< 0.001*
25	18	1.155 ± 0.142	1.023 ± 0.123	0.132 (0.077, 0.187)	< 0.001*
26	17	1.151 ± 0.231	1.003 ± 0.232	0.149 (0.079, 0.219)	< 0.001*
27	18	1.142 ± 0.239	1.018 ± 0.169	0.124 (0.079, 0.169)	< 0.001*
28	28	1.138 ± 0.132	0.988 ± 0.097	0.150 (0.091, 0.209)	< 0.001*
29	20	1.103 ± 0.211	0.959 ± 0.167	0.144 (0.100, 0.188)	< 0.001*
30	23	1.076 ± 0.134	0.937 ± 0.083	0.139 (0.098, 0.180)	< 0.001*
31	18	1.068 ± 0.122	0.935 ± 0.115	0.132 (0.087, 0.178)	< 0.001*
32	28	1.015 ± 0.203	0.911 ± 0.153	0.104 (0.056, 0.152)	< 0.001*
33	30	0.967 ± 0.164	0.859 ± 0.150	0.108 (0.066, 0.150)	< 0.001*
34	19	0.955 ± 0.137	0.847 ± 0.103	0.108 (0.069, 0.146)	< 0.001*
35	18	0.942 ± 0.203	0.851 ± 0.216	0.091 (0.058, 0.124)	< 0.001*
36	17	0.929 ± 0.113	0.849 ± 0.112	0.081 (0.054, 0.107)	< 0.001*
37	17	0.883 ± 0.159	0.791 ± 0.177	0.092 (0.057, 0.128)	< 0.001*
Resistance index (RI)					
18	18	0.750 ± 0.051	0.702 ± 0.069	0.048 (0.020, 0.075)	0.002*
19	18	0.759 ± 0.047	0.716 ± 0.038	0.043 (0.025, 0.061)	< 0.001*
20	30	0.756 ± 0.045	0.720 ± 0.083	0.036 (0.000, 0.071)	0.048*
21	19	0.763 ± 0.053	0.718 ± 0.053	0.046 (0.034, 0.057)	< 0.001*
22	20	0.731 ± 0.048	0.690 ± 0.059	0.041 (0.032, 0.050)	< 0.001*
23	22	0.732 ± 0.048	0.697 ± 0.047	0.035 (0.020, 0.050)	< 0.001*
24	20	0.691 ± 0.055	0.634 ± 0.061	0.057 (0.045, 0.069)	< 0.001*
25	18	0.709 ± 0.052	0.662 ± 0.048	0.048 (0.026, 0.069)	< 0.001*
26	17	0.693 ± 0.080	0.639 ± 0.080	0.053 (0.024, 0.083)	0.001*
27	18	0.702 ± 0.080	0.660 ± 0.067	0.042 (0.029, 0.055)	< 0.001*
28	28	0.694 ± 0.038	0.646 ± 0.034	0.048 (0.030, 0.067)	< 0.001*
29	20	0.678 ± 0.079	0.622 ± 0.065	0.056 (0.040, 0.071)	< 0.001*
30	23	0.681 ± 0.053	0.622 ± 0.036	0.060 (0.042, 0.077)	< 0.001*
31	18	0.662 ± 0.046	0.617 ± 0.054	0.045 (0.027, 0.062)	< 0.001*
32	28	0.639 ± 0.079	0.603 ± 0.076	0.036 (0.022, 0.051)	< 0.001*
33	30	0.623 ± 0.060	0.570 ± 0.070	0.053 (0.033, 0.073)	< 0.001*
34	19	0.623 ± 0.066	0.583 ± 0.079	0.041 (0.024, 0.057)	< 0.001*
35	18	0.588 ± 0.074	0.568 ±0.102	0.020 (0.023, 0.063)	0.004
36	17	0.614 ± 0.051	0.575 ± 0.052	0.039 (0.030, 0.048)	< 0.001*
37	17	0.594 ± 0.066	0.546 ± 0.079	0.048 (0.030, 0.067)	< 0.001*

Table 3. Comparison the mean values of pulsatility index, resistance index, and systolic/diastolic between the two umbilical artery Doppler. (Cont.)

Gestational age (weeks)	n	Umbilical artery M	Umbilical artery N	Difference	p value
		Mean ± SD	Mean ± SD	Mean (95% CI)	
Systolic/diastolic(S/D)					
18	18	4.441 ± 1.116	3.679 ± 0.781	0.785 (0.378, 1.192)	0.001*
19	18	4.302 ± 0.811	3.600 ± 0.408	0.702 (0.359, 1.044)	< 0.001*
20	30	4.217 ± 0.744	3.546 ± 0.672	0.671 (0.479, 0.864)	< 0.001*
21	19	4.192 ± 1.031	3.408 ± 0.668	0.785 (0.378, 1.192)	0.001*
22	20	3.867 ± 0.684	3.341 ± 0.451	0.526 (0.281, 0.772)	< 0.001*
23	22	3.834 ± 0.672	3.346 ± 0.710	0.487 (0.385, 0.590)	< 0.001*
24	20	3.788 ± 1.211	3.006 ± 0.381	0.782 (0.219, 1.345)	0.009*
25	18	3.616 ± 1.080	3.060 ± 0.701	0.557 (0.307, 0.806)	< 0.001*
26	17	3.462 ± 0.882	2.923 ± 0.756	0.539 (0.222, 0.856)	0.003*
27	18	3.356 ± 0.697	2.814 ± 0.500	0.542 (0.411, 0.673)	< 0.001*
28	28	3.329 ± 0.442	2.852 ± 0.290	0.477 (0.257, 0.697)	< 0.001*
29	20	3.299 ± 0.863	2.733 ± 0.533	0.566 (0.368, 0.764)	< 0.001*
30	23	3.085 ± 0.488	2.675 ± 0.262	0.410 (0.235, 0.584)	< 0.001*
31	18	3.023 ± 0.434	2.660 ± 0.382	0.362 (0.235, 0.490)	< 0.001*
32	28	2.883 ± 0.577	2.579 ± 0.418	0.304 (0.144, 0.463)	0.001*
33	30	2.741 ± 0.651	2.439 ± 0.572	0.302 (0.173, 0.431)	< 0.001*
34	19	2.724 ± 0.882	2.475 ± 0.654	0.248 (0.074, 0.423)	0.008*
35	18	2.706 ± 0.487	2.426 ± 0.314	0.280 (0.141, 0.420)	< 0.001*
36	17	2.614 ± 0.360	2.393 ± 0.295	0.221 (0.129, 0.313)	< 0.001*
37	17	2.519 ± 0.420	2.288 ± 0.457	0.232 (0.136, 0.328)	< 0.001*

p value from paired t-test, * significant at p value < 0.05

SD: standard deviation, CI: confidence interval, n: number, PI: pulsatility index, RI: resistance index, S/D: systolic/diastolic

For each gestational age category included 17–30 measurements. Fig. 2, 3, and 4 display the mean PI, RI, and S/D ratio, respectively at each gestational age. Significant differences were observed in the PI, RI, and S/D ratio between the umbilical arteries ($p < 0.05$).

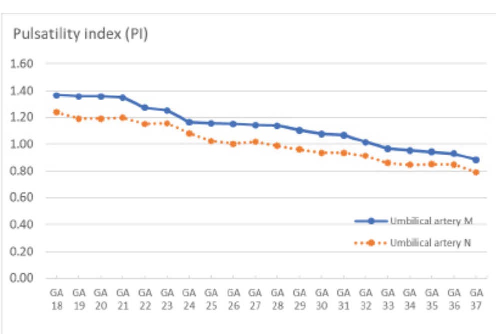

Fig. 2. Illustrating the graph depicting the values of pulsatility index (PI) for each umbilical artery Doppler measurement at different gestational ages.

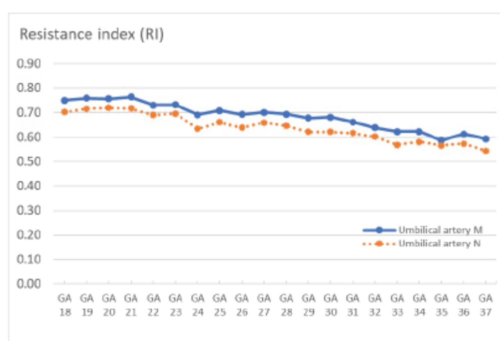

Fig. 3. Illustrating the graph depicting the values of resistance index (RI) for each umbilical artery Doppler measurement at different gestational ages.

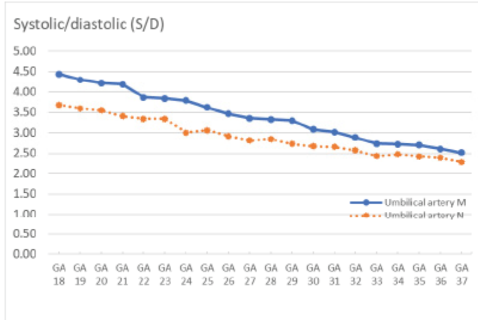

Fig. 4. Illustrating the graph depicting the values of systolic-diastolic (S/D) for each umbilical artery Doppler measurement at different gestational ages.

The mean percentage differences between the paired umbilical artery PI, RI, and S/D ratio are summarized in Table 4. Pregnancy outcomes associated with a difference of > 20% in the PI, RI, and S/D ratio are presented in Table 5.

The ICCs for the PI, RI and S/D ratio measurements indicated good agreement (Table 6). The intra-observer ICCs were as follows: 0.94 (95% confidence interval [CI] 0.89–0.96) for the PI, 0.91 (95% CI 0.88–0.97) for the RI, and 0.92 (95% CI 0.85–0.96) for the S/D ratio. The inter-observer ICCs were 0.93 (95% CI 0.87–0.96) for the PI, 0.91 (95% CI 0.86–0.95) for the RI, and 0.90 (95% CI 0.85–0.94) for the S/D ratio.

Table 4. The percentage difference of pulsatility index, resistance index, and systolic/diastolic values for each umbilical artery Doppler.

	Total (n = 418)	
	n	%
%diff PI		
≤ 5.0%	104	24.9
5.01-10.0%	111	26.6
10.01-15.0%	85	20.3
15.01-20.0%	65	15.6
> 20.0%	53	12.7
%diff RI		
≤ 5.0%	176	42.1
5.01-10.0%	142	34.0
10.01-15.0%	66	15.8
15.01-20.0%	23	5.5
> 20.0%	11	2.6
%diff S/D		
≤ 5.0%	92	22.0
5.01-10.0%	89	21.3
10.01-15.0%	85	20.3
15.01-20.0%	60	14.4
> 20.0%	92	22.0

%diff PI: percentage difference in the pulsatility index, %diff RI: percentage difference in the resistance index, %diff S/D: percentage difference in the systolic/diastolic ratio, n: number, PI: pulsatility index, RI: resistance index, S/D: systolic/diastolic

Table 5. Pregnancy outcomes associated with a difference of more than 20% in the values of PI, RI, and S/D of umbilical artery Doppler.

	Total (n = 418)		%Diff PI				p value	%Diff PI				p value	%Diff PI				p value
			> 20% (n = 53)		≤ 20% (n = 365)			> 20% (n = 53)		≤ 20% (n = 365)			> 20% (n = 53)		≤ 20% (n = 365)		
	n	%	n	%	n	%		n	%	n	%		n	%	n	%	
Delivery GA							0.146					1.000					1.000
< 37	17	4.1%	0	0%	17	4.7%		0	0%	17	4.2%		3	3.3%	14	4.3%	
≥ 37	401	95.9%	53	100%	348	95.3%		11	100%	390	95.8%		89	96.7%	312	95.7%	
Birth weight (gm)							0.060					1.000					0.228
< 2,500	26	6.2%	0	0%	26	7.1%		0	0%	26	6.4%		3	3.3%	23	7.1%	
≥ 2,500	392	93.8%	53	100%	339	92.9%		11	100%	381	93.6%		89	96.7%	303	92.9%	
Percentile							0.803					1.000					0.443
AGA	404	96.7%	53	100%	351	96.2%		11	100%	393	96.6%		89	96.7%	315	96.6%	
SGA	5	1.2%	0	0%	5	1.4%		0	0%	5	1.2%		2	2.2%	3	0.9%	
LGA	9	2.2%	0	0%	9	2.5%		0	0%	9	2.2%		1	1.1%	8	2.5%	
APGAR at 1 min							1.000					1.000					0.464
≤ 7	10	2.4%	1	1.9%	9	2.5%		0	0%	10	2.5%		3	3.3%	7	2.1%	
> 7	408	97.6%	52	98.1%	356	97.5%		11	100%	397	97.5%		89	96.7%	319	97.9%	
Complications																	
RDS	13	3.1%	2	3.8%	11	3.0%	0.674	0	0%	13	3.2%	1.000	3	3.3%	10	3.1%	1.000
FGR	4	1.0%	0	0%	4	1.1%	1.000	0	0%	4	1.0%	1.000	2	2.2%	2	0.6%	0.212
Preeclampsia	2	0.5%	1	1.9%	1	0.3%	0.238	0	0%	2	0.5%	1.000	1	1.1%	1	0.3%	0.392

p values from Fisher's exact test

%diff PI: percentage difference in the pulsatility index, %diff RI: percentage difference in the resistance index, %diff S/D: percentage difference in the systolic/diastolic ratio, N: number. Delivery GA: Gestational age of delivery, AGA: appropriate for gestational age, SGA: small for gestational age, LGA: large for gestational age, APGAR: Activity-Pulse-Grimace-Appearance-Respiration score, RDS: respiratory distress syndrome, FGR: fetal growth restriction.

Table 6. Intraclass correlation coefficients (ICC) for reliability in measurement of PI, RI, S/D (n = 45).

Measurement	Inter-rater Reliability		Intra-rater Reliability	
	ICC	95% CI of ICC	ICC	95% CI of ICC
PI	0.932	0.872 – 0.965	0.941	0.891 – 0.968
RI	0.914	0.864 – 0.951	0.912	0.882 – 0.967
S/D	0.902	0.846 – 0.943	0.922	0.852 – 0.959

%diff PI: percentage difference in the pulsatility index, %diff RI: percentage difference in the resistance index, %diff S/D: percentage difference in the systolic/diastolic ratio, n: number, PI: pulsatility index, RI: resistance index, S/D: systolic/diastolic

Discussion

Umbilical artery Doppler ultrasound examination is a valuable method to assess fetal well-being. Despite its wide use, the normal ranges for umbilical artery Doppler ultrasound indices are generally from one umbilical artery. In this prospective cross-sectional study, our aim was to evaluate the discrepancy between paired umbilical arteries in low-risk pregnancy. This endeavor might contribute to changes in normative values for umbilical artery Doppler ultrasound indices.

We demonstrated a relationship between three fetal umbilical artery Doppler indices (the PI, RI, and S/D ratio) and gestational age: All three decreased significantly as gestation advanced. This finding aligned with previous reports[8,15]. Studies examining paired umbilical arteries have indicated differences in size[9,16]. Subsequent investigations into the structure and velocity flow of umbilical artery have become widespread. Hyrtl's anastomosis between the umbilical arteries occurs within the umbilical cord, within 3 cm of placental cord insertion, which facilitates flow between the two umbilical arteries[17, 18]. This mechanism helps balance or equalize the pressure in the arteries or bring them closer before entering the placenta, acting as a safety valve[6]. Hyrtl's anastomosis aids in redistributing blood from the fetal side to the placental side and serves as a buffer in cases where the placenta encounters issues, helping regulate blood pressure within the placental lobes[17, 19, 20].

However, umbilical artery Doppler velocity parameters such as the PI, RI, and S/D ratio vary at the fetal and placental ends[21], and both umbilical arteries might provide different Doppler velocity index values. Predanic and Perni[7] found significant discordance in the PI of two parallel umbilical arteries. Raio et al[11] showed that the RI was higher in a smaller artery than in a large artery (0.71 [0.59–0.8] versus 0.6 [0.48–0.75], $p < 0.01$). Dolkart et al[9] reported that the mean difference in the S/D ratio between two umbilical arteries was significant ($p < 0.001$). Predanic et al[16] found a higher overall maximum S/D ratio compared with the overall minimum S/D ratio (2.62 ± 0.58 versus 2.27 ± 0.40, respectively, $p < 0.001$). Our findings were similar to those studies. We observed a significant difference between small and large arteries regarding the PI, RI, and S/D ratio at a gestational age of 18-37 weeks.

Predanic and Perni[7] noted that the S/D ratio of both umbilical arteries differed by > 20% in 29% of cases, which aligned with our study. We found a discrepancy of > 10% between the two umbilical arteries regarding the PI, RI, and S/D ratio in 48.6%, 23.9%, and 56.7% of cases, respectively, while there was a discrepancy of > 20% in 12.7%, 2.6%, and 22% of cases, respectively. Notably, Cahill et al[22] reported that the paired umbilical arteries provided different PIs, with discrepancies of > 25%, reaching as high as 38%. However, we did not observe a significant increase in adverse perinatal outcomes in patients with umbilical artery discordance > 20%. The pregnancy outcomes did not differ when we compared the groups that had > 20% and ± 20% discrepancies between the umbilical arteries.

This study evaluated paired umbilical artery Doppler indices in low-risk pregnancies and showed significant differences. This finding was similar to the previous large high-risk pregnancy study (fetal growth restriction cohort) by Steller et al[8], which found that the overall discrepancy between the two umbilical artery pulsatility indices was 11.7%.

The strength of this study lied in the follow-up of all cases until delivery. We minimized selection bias by including all cases that had prenatal visits and met the inclusion criteria. Additionally, our study covered multiple gestational ages from 18 to 37 weeks. However, a limitation of the study was that all measurements were performed by a single operator.

Conclusion

In conclusion, our study revealed significant differences in the PI, RI, and S/D ratio between the two umbilical arteries. This suggests that several considerations need to be addressed regarding the determination of nomogram values derived from measuring only one umbilical artery. It prompts questions about whether these values should be based on higher or lower values, or whether they should reflect a specific relationship between the two umbilical arteries. Understanding these discrepancies is crucial for accurately assessing fetal health and identifying possible complications. Further research is warranted to explore these considerations and their implications for clinical practice.

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Potential conflicts of interest

The authors declare no conflicts of interest.

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