

DOI: <https://dx.doi.org/10.18203/2320-1770.ijrcog20260155>

Original Research Article

## Doppler findings of fetal circulation associated with types of birth and parturients grouped according to Robson's classification

Metodi E. Trajchevski\*

Department of High- Risk Pregnancy, Specialized Hospital for Gynecology and Obstetrics-Mother Tereza Cair, Skopje, North Macedonia

**Received:** 03 December 2025

**Revised:** 12 January 2026

**Accepted:** 13 January 2026

**\*Correspondence:**

Dr. Metodi E. Trajchevski,

E-mail: [trajchevskim11@gmail.com](mailto:trajchevskim11@gmail.com)

**Copyright:** © the author(s), publisher and licensee Medip Academy. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

### ABSTRACT

**Background:** Through the detection of the circulatory conditions in the fetus, an insight into the subsequent events during the course and outcome of the pregnancy and birth is possible. The aim of the study was to gain an insight into the Doppler findings from the prenatal investigations and their association with the types of delivery and the ratio between women in from the Robson classification in relation to the studied variables.

**Methods:** 329 pregnant women at prenatal ultrasound examinations were studied with Doppler assessment of fetal mca(PI) (middle cerebral artery) (pulsatility index), aUPI (umbilical artery) and aUtPI (uterine artery) and followed until delivery when they were grouped according to the Robson classification. Values from Doppler findings as well as data from the current pregnancy and the obstetric history of the included pregnancies were analyzed with statistical tests.

**Results:** A statistically significant association was established between higher values of mcaPI in fetuses delivered by elective cesarean section and lower values in fetuses delivered vaginally, by emergency cesarean section and elective cesarean section after unsuccessful induction of labor. A significant difference was also shown by the comparison between Robson's classes.

**Conclusions:** The Doppler indices of the examined arteries indicating proper fetal circulation were associated with vaginal delivery. Together with the currently confirmed prerequisites for successful induction of labor and vaginal delivery, the findings of fetal circulation studies can serve as an additional parameter for predicting the type of delivery and managing the labor.

**Keywords:** Cesarean section, Delivery, Doppler, Fetus, Parturients, Robson classification

### INTRODUCTION

The fetal state during pregnancy is determined by confirming the increase in weight and estimating regular tissue and organ system oxygenation by assessing blood flow in the fetal circulation and utero-placental blood vessels. The well-being of the fetus is greatly impacted by conditions that diminish placental function and circulation to the placenta and beyond is crucial for placental sufficiency. Thankfully to the capability and safety of ultrasound as well as the regularity of Doppler effect, we are able to estimate blood flow through blood vessels by

assessing resistance and indirectly we can judge for fetal supply with oxygen and nutrients. Placental insufficiency can be caused by low placental perfusion, which could result in fetal distress.<sup>1</sup> Placental insufficiency with following fetal hypoxemia causes centralization of fetal circulation, which means diminished vascular resistance, vasodilatation and increased blood flow in the vital fetal organs.<sup>2</sup> Fetal hypoxia is recognized by ultrasound Doppler findings of increased uterine-placental and fetal-placental resistance, and diminished resistance in the fetal cerebral circulation.<sup>3,4</sup> Acute fetal distress arising in labor, placental abruption, compression of umbilical cord, as

well as chronic fetal distress in preeclamptic women and in cases with fetal growth restriction (FGR) has fetal hypoxia in common, and this is preceded by changes of utero-placental and fetal circulation that can be detected by Doppler ultrasonography.<sup>5,6</sup> Early investigations have confirmed blood flow in umbilical vessels is relatively independent from uterine contractions although if they are exceptionally protracted and strong or if there was persistent chronic placental insufficiency then fetal-placental resistance is rising and on Doppler velocimetry there is an increase of umbilical artery Doppler indices.<sup>7</sup> In pregnancies with hypoxic fetuses, the sequence of Doppler changes in the utero-placental and fetal-placental circulation is known, but they are not suitable as the gold standard in the treatment of each individual case of a fetus with IUGR and impose the need for additional and close monitoring, as well as reservations, especially with regard to the gestational age of the fetuses.<sup>8</sup> Ultrasound detected resistance changes in the uterine, umbilical and middle cerebral arteries of the fetus have a diagnostic value for selecting fetuses with an increased risk of adverse outcome or prediction for operative completion of the delivery, even as a guideline for the induction of labor and prediction of the consequences of fetal hypoxia, but the expected positive predictive value of Doppler ultrasound results were not fulfilled constantly.<sup>9-11</sup> Preventing hypoxic damage to the fetal brain is evident in pregnancies with placental insufficiency when the cerebral circulation adapts, increasing the capacity for brain oxygenation. Vasodilatation and regionalization of cerebral blood flow are responsible for this, depending on the degree of hypoxia and the vital importance of individual brain regions.<sup>12</sup> The detection of these changes in the fetal cerebral circulation through Doppler examinations allows insight not only into the severity of the fetal risk but also potentially allows prediction of the time of delivery even in preterm births.<sup>13</sup>

## METHODS

### *Study type*

This research was conducted as a retrospective observational study.

### *Study place and duration*

Study participants were examined and delivered at the Specialized hospital for obstetrics and gynecology- Majka Tereza, Cair in Skopje, that is classified as a secondary health level in North Macedonian's health system, with 3200-3700 newborns each year. The analyzed period was between August 2018 to September 2019, when 329 included pregnant women in this study gave birth.

### *Selection criteria*

The pregnant women in this study were included as convenient samples for the author on prenatal examinations with doppler investigations of fetal

circulation and later were delivered in the same hospital. Single pregnancies with fetuses in cephalic presentation at birth, without structural anomalies, were enrolled and pregnant women that might have had pregnancy complication but were without any other known concomitant diseases and gave birth to live newborns. Only ultrasonographic findings from examinations performed exceptionally by the author were included in the statistical analysis.

### *Procedure*

The aim of this research was to check out for possible association between doppler findings in fetal circulation and the ways how considered pregnancies ended in a sense if there is a foretell about type of delivery. The procedure encompassed prenatal ultrasound examinations with fetal biometry and estimation of fetal weight (EFW), location in the uterus and degree of placental maturity, assessment of the amount of amniotic fluid, Doppler assessment with pulsatility indices (PI) and peak systolic velocities (PSV) of blood flow through the fetal middle cerebral artery (mca), umbilical artery (aU) and uterine arteries (aUt) were performed on the pregnant women in scope of their prenatal care. Doppler flow measurements were made along the proximal part of the fetal middle cerebral artery, close to its branching from the internal carotid artery, of the umbilical artery in a free convoluted fashion, as well as resistance in the uterine arteries close to their crossover to the external iliac artery during periods of uterine relaxation and under conditions of fetal quiescence.<sup>14</sup> Doppler ultrasound was used to measure resistance in both uterine arteries only in the pregnancies whose fetuses were assessed as SGA (EFW = below the 10<sup>th</sup> percentile for gestational age) and in the pregnancies with elevated blood pressure in addition to suspected placental insufficiency. After delivery, the values of the newborn's birth weights (BW) were used, according to which the 10-th percentile was determined, for the gestational week at delivery, because the difference between EFW (predicted weight) and BW (actual weight) has already been explained.<sup>15</sup> The second step was obtaining data from delivery ward concerning time of delivery, newborn's birth weights from included parturients and types of delivery. The pregnancies in the study sample ultimately ended with vaginal delivery, emergency cesarean section, elective cesarean section before the onset of labor or elective cesarean section performed 24 hours after unsuccessful induction of labor.

Ethical approval was obtained from the institution (Nr.04-14/1) for insight in medical documentation and using data for this research where it was conducted, according to the declaration of Helsinki.

### *Statistical analysis*

The data from the prenatal ultrasound examinations of study participants, the data concerning the newborns, the types of delivery and the time from the ultrasound

examinations until delivery along with the obstetrical history of the included pregnant women were collected and analyzed with the statistical package SPSS 25.0. The pregnancy complications such as preeclampsia and SGA fetuses were analyzed and presented. For statistical processing, the values of the PI and PSV of mca and aU and the mean values of the PI and PSV of both aUt were used as continuous variables. CPR was calculated as a ratio mcaPI / aUPI, already suggested as a parameter for clinical decisions when assessing the condition of the fetus.<sup>16</sup> In the analysis were utilized the converted MoM (multiples of median) values of mcaPI and aUPI, as it was recommended by R. Akolekar and co-authors.<sup>17</sup> Reference values for the 50-th percentile according to gestational week were the values from FMF (Fetal Medicine Foundation).<sup>18</sup> Reference values for neonatal ponderal indices were based on the findings of Roje et al.<sup>19</sup> The pregnant women from the study sample were grouped according to the Robson classification of parturients to find a possible relationship between the classes, comparing Doppler findings of the fetal arteries.<sup>20</sup>

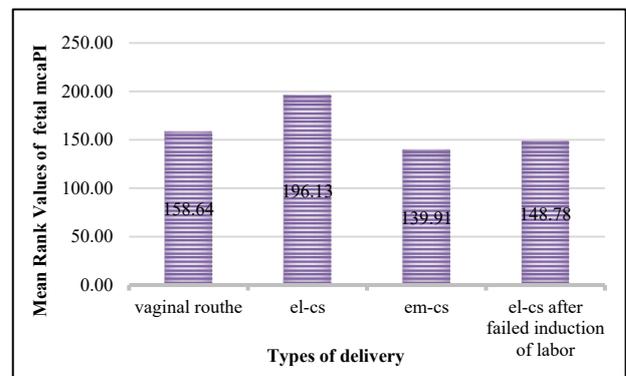
**RESULTS**

The demographic data from included participants in this research are presented in Table 1.

**Table 1: Demographic characteristics.**

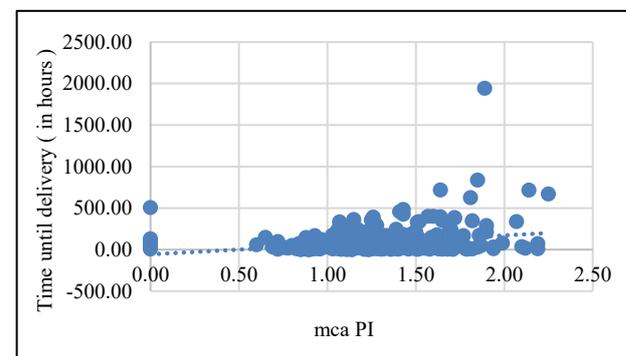
Characteristics	Frequency	Percentage
<b>Age (in years)</b>		
<20	10	3
20-25	70	23.4
26-30	137	41.7
31-35	78	23.7
36-40	26	7.9
<b>Parity</b>		
0	207	62.9
1	71	21.3
2	34	10.3
3	12	3.7
4	5	1.5
<b>Mode of delivery</b>		
Vaginal	167	50.8
Elective c-section	71	21.6
Emergent c-section	66	20.0
Elective cs after failed labor induction	25	7.6
<b>Gestational age at birth [gestational weeks (gw)]</b>		
<36.6 gw	12	3.6
37.1-40.0 gw	153	46.6
40.1-42.6 gw	164	49.8
<b>Neonatal birth weight in grams</b>		
1990-2490	20	6.1
2520-3500	90	27.4
3510-4000	188	57.1
4010-4710	31	9.4

The discrete variables included in the statistical analysis are listed in Table 2 and Table 3. The Kolmogorov Smirnov test was used to detect normality in the distribution of the values of the continuous variables and were analyzed with appropriate statistical tests. The Kruskal Wallis H test determined a significant difference between the mean range value of mcaPI in fetuses born with different types of birth [ $H(3) = 13.435, p = 0.004$ ], and the Mann Whitney U test defined the difference between fetuses born vaginally and those born by elective cesarean section ( $U = 4281, p = 0.004$ ). A significant difference was also found in the comparison of the mean rank values of mcaPI of fetuses from mothers delivered by elective versus emergency cesarean section ( $U = 1471, p = 0.001$ ), as well as in the comparison of the mean rank values of mcaPI between fetuses delivered by elective cesarean section due to unsuccessful labor induction and those delivered by elective cesarean section without prior regular uterine contractions ( $U = 597, p = 0.029$ ) (shown graphically in Figure 1).



**Figure 1: Delivery types in pregnant women were associated with differences in fetal mca-PI.**

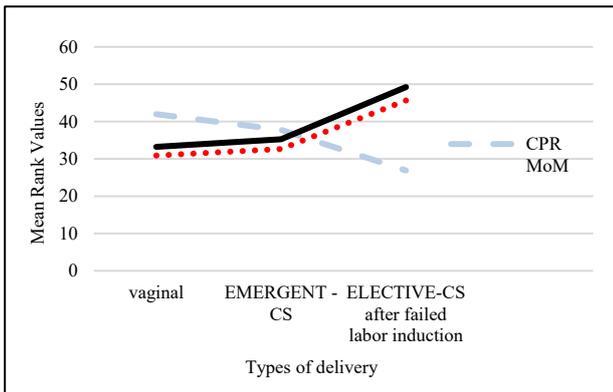
mcaPI = middle cerebral artery pulsatility index. A non-parametric test was used to analyze fetal mcaPI (rank values) and it was found that there were significant differences between fetuses and were differently delivered ( $H(3), p = 0.004$ ); cs= "cesarean section".



**Figure 2: Relations of the fetal mcaPI with elapsed time until childbirths as evidence that proximity to delivery diminishes their values.**

mca PI= fetal middle cerebral artery pulsatility index; Time until delivery=from ultrasound examinations until delivery (in hours) and Regression line.

Doppler resistance to blood flow in the fetal middle cerebral artery is referred to as Doppler indices, and these have a normal range according to gestational age. The values of mcaPI, in relation to the elapsed time from ultrasound examination until delivery, are presented in Figure 2, showing a decreasing trend as delivery approaches. Of the 329 women in the study, 78 had their labor induced. 32 of them delivered vaginally, 21 by emergency cesarean section, and 25 of the pregnant women were delivered by elective cesarean section 24 hours after failed induction of labor. The Kruskal Wallis test found a significant difference between the mean rank values of aUPI, [H (2) =7.867, p=0.020], between MoM converted values of the umbilical artery pulsatile indices, aUPIMoM, [H (2) =7.041, p=0.030] and between the MoM converted values of the cerebroplacental ratio, CPRMoM, [H (2) =6.720, p=0.035]. The difference was defined between induced and vaginally delivered versus induced and delivered by elective cesarean section after failed induction, statistically confirmed with the Mann-Whitney U test for the mean rank values of aUPI (U=222, p=0.010), aUPIMoM, (U=178, p=0.018), and CPRMoM (U=176, p=0.015), as well as between induced and vaginally delivered versus induced and delivered by urgent cesarean section, but only in the middle rank values of aUPI, (U=171, p=0.027) and aUMoM, (U=147, p=0.026) (Figure 3).

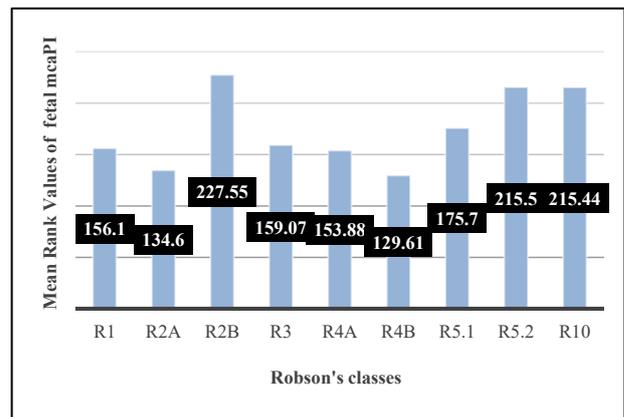


**Figure 3: The fetal Doppler parameters that were analyzed have mean rank values that are related to the types of delivery in labor induced pregnancies.**

aUPI = umbilical artery pulsatility indices (black continuous line); aUPIMoM=Multiples of Median for umbilical artery pulsatility indices (red dashed line); CPRMoM= multiples of median for cerebroplacental ratio (blue dashed line); Types of delivery exhibit statistically significant differences in Doppler parameters.

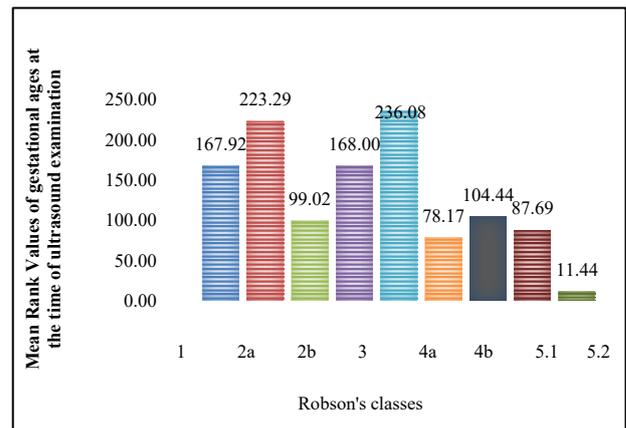
The values of the Doppler indices of the examined arteries of the fetuses in the pregnancies from the study sample distributed according to the Robson classification were statistically analyzed, while the Kruskal Wallis test for the

mean ranges of mca PI showed the existence of a statistically significant difference between the fetuses on the antenatal Doppler examinations [H (8) =28.660, p=0.000]. Mann Whitney test defined significant differences in the rank values of mca PI of fetuses from pregnancies present between the classes: R1 and R2b, (U=795, p=0.000), R2a and R2b, (U=412, p=0.000), R 2a and R10, (U=162, p=0.025), R2b and R3 (U=439, p=0.004), R2b and R4a (U=133, p=0.001), R4a and R5.2 (U45, p=0.045), R4a and R10 (U=50, p=0.003) (Figure 4).



**Figure 4: Parturients in distinct Robson's classes were with fetuses that had significantly different mean rank values of mcaPI on antenatal Doppler assessments.**

Robson classes = parturients grouped according to Robson's classification; mean rank values of fetal mcaPI (middle cerebral artery pulsatility indices on prenatal ultrasound examination that respond to fetuses of pregnancies related with parturients from distinct Robson's classes, analyzed with Kruskal-Wallis H-test (H (8) =28.660, p=0.000).



**Figure 5: Significant difference among gestational ages when the fetal US-exam was performed at pregnancies in distinct Robson's classes.**

Presented significant differences between Robson's classes at times when ultrasound examinations were performed (H (8) = 100.448, p=0.000) during prenatal care.

**Table 2: Frequency of variables in distinct types of childbirth and significance of differences.**

Mode of delivery		Elective cesarean section	Emergent cesarean section	Vaginal	Chi-square test or Fisher's exact test/ANOVA
Induction of labor	No	71	45	135	§ N/S
	Yes	25	21	32	
Uterine contractions during ultrasound examination	No	96	56	127	*P=0.000
	Yes	0	10	40	
Parity of mother	Multiparous	41	13	68	*P=0.005
	Nulliparous	55	53	99	
Appropriateness of birthweight according to gestational age	<sup>a</sup> AGA	54	51	140	*P=0.000
	<sup>b</sup> SGA	34	8	19	
	<sup>c</sup> LGA	8	7	8	
Neonatal nutritional status according to Neonatal ponderal index (percentiles)	≤10	23	12	46	§ N/S
	10-90	65	50	118	
	>90	8	4	3	
Preeclampsia	No	90	64	167	*P=0.006
	Yes	6	2	0	
<sup>d</sup> EFW (in grams)	Mean	3096	3424	3311	**F=10.564
	<sup>f</sup> St. dev.	616	446	442	P=0.000
<sup>e</sup> BW (in grams)	Mean	3131	3435	3412	**F=13.279
	<sup>f</sup> St. dev.	609	480	417	P=0.000
Neonatal Ponderal Index (in gr/cm <sup>3</sup> )	Mean	2.65	2.68	2.58	**F=7.163
	<sup>f</sup> St. dev	0.25	0.23	0.19	P=0.000

<sup>a</sup>AGA =appropriate for gestational age; <sup>b</sup>SGA =small for gestational age; <sup>c</sup>LGA =large for gestational age; <sup>d</sup>EFW =estimated fetal weight, <sup>e</sup>BW =birth weight; <sup>f</sup>St. dev =standard deviation; \*non-parametric tests: Chi-square test and Fisher's-exact test, \*\*F=statistics of ANOVA= (analysis of variance); §N/S= not significant

**Table 3: Frequency of variables in parturients classified according to Robson and significance of differences.**

Variables		R1	R2a	R2b	R3	R4a	R4b	R5.1	R5.2	R10	Chi-square test or Fisher's exact test
<b>Parity of mother</b>	Nulliparous	106	67	29	0	0	0	0	0	5	*P=0.000
	Multiparous	0	0	0	52	22	7	27	10	4	
<b>Appropriateness of birthweight according to gestational week</b>	<sup>a</sup> AGA	86	52	14	43	20	2	16	6	6	*P=0.001
	<sup>b</sup> SGA	13	9	12	8	1	3	10	2	3	
	<sup>c</sup> LGA	7	6	3	1	1	2	1	2	0	
<b>Preeclampsia</b>	NO	106	66	26	52	22	7	26	9	7	*P=0.000
	YES	0	1	3	0	0	0	1	1	2	
<b>Mode of delivery</b>	<sup>d</sup> EL-CS	0	0	29	0	0	7	22	8	5	*P=0.000
	<sup>e</sup> EM-CS	25	28	0	4	2	0	5	2	0	
	Vaginal	81	16	0	48	19	0	0	0	3	
	<sup>f</sup> EL-CS after failed labor induction	0	23	0	0	1	0	0	0	1	

<sup>a</sup>AGA=appropriate for gestational age; <sup>b</sup>SGA=small for gestational age; <sup>c</sup>LGA=large for gestational age; <sup>d</sup>EL-CS=elective cesarean section; <sup>e</sup>EM-CS=emergent cesarean section; <sup>f</sup>EL-CS=elective cesarean section after failed labor induction 24 hours apart; non-parametric tests with significance, \*P=significance of differences.

The analysis of gestational weeks when Doppler examinations of fetuses were carried out, from the women grouped according to Robson and showed a significant difference between their mean rank values [H (8) =100.448, p=0.000] graphically presented in Figure 5. The correlation of fetal mcaPI values with gestational age is substantial, Spearman's rho=0.66 (p=0.008).

## DISCUSSION

The global increase in the percentage of cesarean sections in the total number of births, as an indicator of perinatal outcome and the vulnerability of newborns and mothers, obliges health care workers and institutions to detect contributing factors and if possible, to prevent them.<sup>21</sup> The Robson classification of parturients (Table 4) was desirable to be included in this study because its main aim was to detect potential factors for the increase in cesarean section rate.<sup>22</sup>

**Table 4: Robson classification with subdivisions (modified for the purpose of this study).**

Group	Obstetric population
<b>R1</b>	Nulliparous women with a single cephalic pregnancy, ≥37 weeks gestation in spontaneous labor
<b>R2</b>	Nulliparous women with a single cephalic pregnancy, ≥37 weeks gestation who had labor induced or were delivered by CS
<b>R2a</b>	Labor induced
<b>R2b</b>	Pre-labor CS
<b>R3</b>	Multiparous women without a previous CS, with a single cephalic pregnancy, ≥37 weeks gestation in spontaneous labor
<b>R4</b>	Multiparous women without a previous CS, with a single cephalic pregnancy, ≥37 weeks gestation who had labor induced or were delivered by CS before labor
<b>R4a</b>	Labor induced
<b>R4b</b>	Pre-labor CS
<b>R5</b>	All multiparous women with at least one previous CS, with a single cephalic pregnancy, ≥37 weeks gestation
<b>R5.1</b>	With one previous CS
<b>R5.2</b>	With two or more previous CSs
<b>R10</b>	All women with a single cephalic pregnancy <37 weeks gestation, including women with previous CS(s)

Pregnant women with fetuses who had higher values of fetal mcaPI on prenatal Doppler assessments were associated with elective cesarean delivery. The vaginal deliveries, emergency cesarean deliveries and elective cesarean deliveries after unsuccessful induction of labor performed 24 hours apart were associated with statistically lower values of mcaPI. Lower mcaPI values are a sign of cerebral vasodilation, and the explanation is that it is an adaptive mechanism or a precursor to labor.<sup>23</sup> In this study

the pregnant women with induced labors and vaginal births had fetuses with lower mean rank values of aUPI and aUPIMoM, also higher values of CPRMoM on prenatal Doppler assessments. Contrary pregnant women delivered by elective cesarean section after failed labor induction, had fetuses with higher mean rank values of aU and aUMoM, also lower values of CPRMoM. Pregnant women who had induced labor and were delivered by emergency cesarean section had fetuses with significantly lower values for aUPI and aUPIMoM at antenatal check-ups compared to those who were delivered by elective cesarean section 24 hours after failed induction of labor. Summary these values may indicate increased fetal-placental circulation associated with labor, regardless of whether the labor ended with vaginal delivery or emergency cesarean section. In consequence the inferential statistic favors successful induction of labor and vaginal delivery in pregnant women with fetuses who had lower values for aUPI and aUPIMoM at antenatal Doppler examinations, which has also been previously recognized as a prognostic factor for labor induction.<sup>24</sup> In this study, an association was found between higher values for CPRMoM and vaginal delivery. Some authors dispute the predicting value of CPR, but there are also opposing opinions.<sup>25,26</sup> The parturients of the Robson classes: R1, R2a, R3 and R4 during pregnancy their fetuses had lower values for mcaPI, unlike parturients in classes R2b, R5.1, R5.2 and R10, whose fetuses had statistically significantly higher values for mcaPI on prenatal ultrasound Doppler measurements. These findings might be consequences of the changes in the fetal cerebral circulation associated with the special characteristics of the fetuses of the women grouped according to Robson. The parturients of class R5.1 were delivered by elective or emergency cesarean section. Those who gave birth by elective cesarean section on the prenatal Doppler examinations of the fetal mca had lower values of the Doppler indices, but also all the fetuses in this group were SGA fetuses. Low values of mcaPI are a well-known finding of brain sparing in SGA fetuses. Robson class 10 includes parturients under 37 weeks of gestation and in this study were delivered vaginally or by elective cesarean section. There was no statistical significance in the differences in values of fetal mcaPI depending on the type of delivery but in this study SGA fetuses and pregnancies complicated by preeclampsia were frequent at parturients in R10, so the inferential statistic favors the dominant influence of chronic fetal distress on the values of mca PI. For parturients in R4b, the statistical tests did not reveal a significant difference in relation to the other classes considering prenatal doppler findings of mca, but the analysis of this class showed frequent births of SGA and LGA fetuses. The low mca PI values in undernourished fetuses is explained above and are a sign of increased cerebral circulation in fetuses with a higher weight for gestational age as was previously noted.<sup>27</sup> Presented diversity of characteristics for parturient in distinct Robson classes and the uniformity of some classes considering findings of mcaPI, justifies the efforts to find parameters that would facilitate the detection of the way to adjust the rate of birth by cesarean section to be as close as

possible to the acceptable norms for WHO. The value of mcaPI in prediction successful induction of labor is confirmed in previous and recently published researches.<sup>28,29</sup> The need for more reliable criteria for successful induction of labor in order to reduce the cesarean section rate has been previously recognized.<sup>30</sup>

Implication will be detection of fetuses predisposed to vaginal birth and this prediction could be made by Doppler findings. Pregnant women with such fetuses should deserve more care during labor in direction to be prevented cesarean delivery especially in nulliparous.

The limitations are related to the ambiguity arising from the retrospective nature of the study and the convenient sample. The Doppler examinations used for analysis were performed by one person, on the other hand, numerous obstetricians participated in the births of the newborns and decided on indications for the birth types.

## CONCLUSION

The study concluded that a statistically significant association was inspected between vaginal and emergency cesarean deliveries with lower values of fetal mcaPI on their antenatal ultrasound examinations compared to those who were delivered by elective cesarean section and who were associated with higher values of mcaPI. Next, preterm deliveries, pregnant women who had a previous cesarean section and parturients with unsuccessful induced labor were associated with higher rank values of their fetal mcaPI and were delivered mainly by elective cesarean section. At last, for successful labor induction and vaginal birth, this study emphasizes the findings of aUPI, aUPIMoM, and CPRMoM as indicators of adequate perfusion of the placenta and good fetal condition.

*Funding: No funding sources*

*Conflict of interest: None declared*

*Ethical approval: The study was approved by the Institutional Ethics Committee*

## REFERENCES

1. Turner JM, Mitchell MD, Kumar SS. The physiology of intrapartum fetal compromise at term. *Am J Obstet Gynecol.* 2020;222(1):17-26.
2. Kane AD, Kothmann E, D A Giussani DA. Detection and response to acute systemic hypoxia. *BJA Educ.* 2020;20(2):58-64.
3. Mulrooney JS. Uterine artery Doppler of the gravid uterus as a predictor identifying at-risk pregnancies: a meta-analysis. *J Diagn Med Sonograph.* 2015;31(1):64-9.
4. Khalil AA, Morales-Rosello J, Morlando M, Hannan H, Bhide A, Papageorghiou A, et al. Is fetal cerebroplacental ratio an independent predictor of intrapartum fetal compromise and neonatal unit admission? *Am J Obstet Gynecol.* 2015;213(1):54-e1.
5. Mathewlynn S, Beriwal S, Ioannou C, Cavallaro A, Impey L. Abnormal umbilical artery pulsatility index in appropriately grown fetuses in the early third trimester: an observational cohort study. *J Matern Fet Neonat Med.* 2023;36(1):2152670.
6. Eslamian L, Samaei Nouroozi A, Jamal A, Farahbod F. The role of intrapartum doppler of uterine and middle cerebral artery evaluation on prediction and prevention of adverse perinatal outcome in normal size fetuses at term. *Radiol Diagn Imag.* 2020;4:1-7.
7. Lear CA, Dhillon SK, Nakao M, Lear BA, Georgieva A, Ugwumadu A, et al. The peripheral chemoreflex and fetal defenses against intrapartum hypoxic-ischemic brain injury at term gestation. *Semin Fet Neonat Med.* 2024;29(4-5):101543.
8. Turan OM, Turan S, Gungor S, Berg C, Moyano D, Gembruch D, et al. Progression of Doppler abnormalities in intrauterine growth restriction. *Ultrasound Obstet Gynecol.* 2008;32(2):160-7.
9. Fracalozzi JD, Okido MM, Crott GC, Duarte G, Cavalli RD, Araujo Júnior E, et al. Maternal, obstetric, and fetal Doppler characteristics in a high-risk population: prediction of adverse perinatal outcomes and of cesarean section due to intrapartum fetal compromise. *Radiol Brasil.* 2023;56:179-86.
10. Ali S, Heuving S, Kawooya MG, Byamugisha J, Grobbee DE, Papageorghiou AT, Klipstein-Grobusch K, Rijken MJ. Prognostic accuracy of antenatal Doppler ultrasound for adverse perinatal outcomes in low-income and middle-income countries: a systematic review. *BMJ Open.* 2021;11(12):e049799.
11. Morales Roselló J, Hervás Marín D, Perales Marín A. Can we predict delivery date with obstetric ultrasound? *J Matern Fet Neonat Med.* 2013;26(18):1807-11.
12. Hernandez-Andrade E, Figueroa-Diesel H, Jansson T, Rangel-Nava H, Gratacos E. Changes in regional fetal cerebral blood flow perfusion in relation to hemodynamic deterioration in severely growth-restricted fetuses. *Ultrasound Obstet Gynecol.* 2008;32(1):71-6.
13. Morales-Roselló J, Khalil A, Salvi S, Townsend R, Premakumar Y, Perales-Marín A. Abnormal middle cerebral artery Doppler associates with spontaneous preterm birth in normally grown fetuses. *Fet Diagnos Ther.* 2016;40(1):41-7.
14. ISUOG Practice Guidelines (updated): use of Doppler velocimetry in obstetrics. *Ultrasound Obstet Gynecol* 2021;58:331-9.
15. Nicolaides KH, Wright D, Syngelaki A, Wright A, Akolekar R. Fetal medicine foundation fetal and neonatal population weight charts. *Ultrasound Obstet Gynecol.* 2018;52(1):44-51.
16. Oros D, Ruiz-Martinez S, Staines-Urias E, Conde-Agudelo A, Villar J, Fabre E, et al. Reference ranges for Doppler indices of umbilical and fetal middle cerebral arteries and cerebroplacental ratio: systematic review. *Ultrasound Obstet Gynecol.* 2019;53(4):454-64.

17. Akolekar R, Sarno L, Wright A, Wright D, Nicolaides KH. Fetal middle cerebral artery and umbilical artery pulsatility index: effects of maternal characteristics and medical history. *Ultrasound Obstet Gynecol.* 2015;45(4):402-8.
18. Ciobanu A, Wright A, Syngelaki A, Wright D, Akolekar R, Nicolaides KH. Fetal Medicine Foundation reference ranges for umbilical artery and middle cerebral artery pulsatility index and cerebroplacental ratio. *Ultrasound Obstet Gynecol.* 2019;53(4):465-72.
19. Roje D, Ivo B, Ivica T, Mirjana V, Vesna C, Aljosa B, et al. Gestational age-the most important factor of neonatal ponderal index. *Yonsei Med J.* 2004;45(2):273-80.
20. Robson Classification: Implementation Manual. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO.
21. Patil SB, Rajitha D. Robson classification: beyond caesarean rates. *Int J Reprod Contracept Obstet Gynecol.* 2023;12(7):2241-6.
22. Angolile CM, Max BL, Mushemba J, Mashauri HL. Global increased cesarean section rates and public health implications: a call to action. *Health Sci Rep.* 2023 May;6(5):e1274.
23. Morales-Roselló J, Hervás-Marín D, Perales-Marín A. Proximity of term labor deepens the fall of Doppler impedance in the fetal cerebral arteries. *J Matern Fet Neonat Med.* 2014;27(3):283-90.
24. Widschwendter P, Lato K, Friedl TW, Janni W, Friebe-Hoffmann U. Foetal Doppler parameters as a prognostic marker before induction of labour. *Geburtshilf Frauenheilkund.* 2018;78(09):859-65.
25. Gregory R DeVore GR. The importance of the cerebroplacental ratio in the evaluation of fetal well-being in SGA and AGA fetuses. *Am J Obstet Gynecol.* 2015;213(1):5-15.
26. Wise AJ, Nicolaou E, Lombaard H. The use of the cerebroplacental ratio in the latent phase of labour to predict adverse outcomes in a resource-limited (SA). *S Afr J Obstet Gynecol.* 2020;26(2):48-53.
27. Abdella RM, Ahmed SA, Moustafa MI. Sonographic evaluation of fetal abdominal circumference and cerebroplacental Doppler indices for the prediction of fetal macrosomia in full term pregnant women. Cohort study. *Middle East Fertil Soc J.* 2014;19(1):69-74.
28. Belal D, Al Mohammady M, Mohamed S, Mahmoud M. Fetal middle cerebral artery Doppler in post term pregnancy: a predicting factor for induction of labor outcome. *Egypt J Fertil Steril.* 2023;27(5):14-22.
29. Vannuccini S, Torricelli M, Bocchi C, Severi FM, Di Tommaso M, Petraglia F. Fetal middle cerebral artery Doppler in late-term pregnancy: a predicting factor for failed induction of labor. *J Matern Fet Neonat Med.* 2018;31(20):2756-62.
30. Gautam V, Gaikwad HS, Nath B, Shukla M, Kumari P. Prediction model for successful induction of labor by fetal middle cerebral artery pulsatility index and obstetric factors in term pregnancy: a prospective cohort study. *Obstet Gynecol Int.* 2025;7881711:9.

**Cite this article as:** Trajchevski ME. Doppler findings of fetal circulation associated with types of birth and parturients grouped according to Robson's classification. *Int J Reprod Contracept Obstet Gynecol* 2026;15:404-11.