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Effect of Antenatal Umbilical Coiling Index on Doppler Parameters of Umbilical Cord Vessels

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ABSTRACT

Purpose: To assess the effect of antenatal umbilical coiling index on Doppler parameters of umbilical cord vessels.

Material and Methods: This cross-sectional analytical study was conducted in a large health services hospital and a total of 48 pregnant women were included in the study. These women were 28-42 weeks of gestation. Transabdominal sonography was used to study the antenatal umbilical coiling index and its relationship with Doppler parameters of umbilical vessels' blood flow .

Results: The mean gestational age of was 31.47 ± 2.45 weeks. The antenatal umbilical coiling index was found to be 0.42 ± 0.1 with values 0.27 and 0.57 being 10^{th} and 90^{th} percentile, respectively. In terms of the coiling pattern, 8% exhibited hypercoiling, 10% showed hypocoiling, and the remaining 82% were classified as normocoiled. There was a non-significant correlation of UCI with PSV (r=0.202, P=0.169) and RI (r=0.018, P=0.905) of umbilical arteries. The correlation of UCI with umbilical vein velocity (r=0.432, P=0.002) and blood flow rate (r=0.668, P=0.00) was strong and significant.

Conclusion: The antenatal umbilical coiling index can be assessed on ultrasonography and there was a significant relationship between the Doppler flow parameters of umbilical vein and the umbilical coiling index. Our study showed that umbilical coiling does promote venous blood flow in the umbilical vein. Moreover, there was a non-significant relationship between the umbilical coiling index and the Doppler flow parameters of umbilical arteries.

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Introduction

The definitive umbilical cord is outcome of the formation of three umbilical vessels that are lodged in Wharton's jelly (the mesoderm of the connecting stalk), which is then covered by an amniotic membrane sheath [1]. The umbilical cord consists of one vein and two adjacent arteries. These three vessels are embedded in a helical form within the umbilical cord [2]. The typical umbilical cord is approximately 50-60 cm in length during term gestation, and between the placental and fetal attachment sites, its veins form an average of 10–11 spirals or coils [3]. As umbilical vessels are not parallel to one another, the vein is twisted to variable degrees by umbilical arteries, typically on the left side. As the length of the cord increases and gestational age progresses, given the set number of twisting, the coiling index decreases [4].

The origin of umbilical coiling is not clear. Fetal movements, variable umbilical vascular development rates, and fetal hemodynamic forces are among the hypotheses [5]. However, the fundamental genetic cause of umbilical coiling remains unknown. Counseling on the possibility of issues resulting from aberrant coiling will be significantly impacted by knowing whether there is a genetic basis for umbilical cord coiling [6]. A higher incidence of fetal discomfort, genetic abnormalities, and even fetal death is linked to an aberrant vascular route inside the umbilical cord [7].

It is evident that coiling is a natural feature of the umbilical cord and must have a positive impact. In fact, coiling gives the cord turgor, increasing its flexibility while also increasing its resistance to compression, creating a stronger structure [8]. Without affecting the cord's elasticity, coiling could shield the umbilical cord from external pressures such as tension, stretching, torsion, entanglement and compression [9].

Regarding the use of the umbilical coiling index to assess the umbilical cord, it has been established that umbilical cords with lower coiling are linked to many fetal abnormalities such as abnormal heart rate of the fetus, entanglement of the nuchal cord, and abnormal insertion of the umbilical cord. Moreover, fetal discomfort, hypoxia and a single artery in the umbilical cord are all linked to an umbilical cord having a higher number of coiling [10]. Doppler ultrasound may reveal abnormal blood flow patterns in the fetal circulation that could point to a poor prognosis. False positive Doppler ultrasonography results could also result in unfavorable consequences from inappropriate interventions, such as preterm birth. According to recent research, Doppler ultrasound on the umbilical arteries during high-risk pregnancies may save perinatal fatalities and necessitate fewer obstetric interventions[11].

Variation in coiling is referred as a risk-identifying prenatal marker for fetuses. In that context, the majority of research on umbilical coiling index (UCI) has been done after birth. However, prenatal ultrasonography can be used to calculate UCI [12]. The umbilical cord is visible for most of the gestation and can be seen shortly after the fetal pole is seen. Due to the well-established association between a single umbilical artery and a poor pregnancy outcome, umbilical cord examination was typically restricted to the assessment of the number of cord vessels only. Sonographic examinations can identify a variety of other abnormalities in the umbilical cord that have significant prognostic implications for neonatal morbidity and mortality [13].

The reciprocal of the distance between two umbilical cord coils is used to calculate the prenatal UCI [14]. Measurements of UCI taken before and after birth have shown strong correlation. During the antepartum period, the sonographic umbilical coiling index mean value is around 0.44 ± 0.11, and around 0.28 ± 0.08 after delivery. Only few studies have evaluated the blood flow characteristics of umbilical cord

coiling in connection with Doppler ultrasound. It has been observed that there is a substantial link between blood flow in the umbilical vein and the coiling index but there is no link between coiling and arterial flow patterns in both umbilical arteries [15].

In terms of vascular placental function, flow in the umbilical vein may also have a greater physiological relevance than flow in umbilical arteries, which influences the amount of nutrients and oxygen that reach the fetus. Umbilical coiling is mostly assessed using the coiling index. The umbilical vein does not usually coil to the same extent as the umbilical artery. The coiling index may not be appropriate for the precise evaluation of coiling in the umbilical cord when there are varying numbers of coils in the umbilical arteries and veins [10]. According to some observations, less umbilical coiling results in less umbilical vein blood flow, which increases the cord's vulnerability to external compression [9].

This study quantified antenatal umbilical cord coiling sonographically, and investigated whether a relationship exists between the umbilical coiling index and umbilical vessels' Doppler parameters. If the umbilical coiling index is found to have an effect on umbilical vessel Doppler parameters, then this can be used as an additional parameter for the assessment of fetal wellbeing.

Material and Methods

A cross-sectional study was conducted at a major Health Services Hospital. Forty-eight scheduled pregnant women who regularly visited the Obstetric Department for prenatal checkups between 28 and 42 weeks of gestation were included in this study. Gestational age was determined in relation to the estimated date of confinement, in accordance with the last menstrual period. Otherwise, the earliest ultrasound examination's anticipated date of confinement was used.

The inclusion criteria were met by multiparous women with singleton, normal pregnancy at 28 to 42 weeks of gestational age. Exclusion criteria was were any fetal anomaly, maternal diabetes, maternal hypertension, small or large gestational age, oligohydramnios and polyhydramnios. Each patient was included only once. The institutional review board of a large university evaluated and approved this study.

All ultrasound examinations were performed using a Toshiba Xario prime ultrasound machine with a 6-MHz transabdominal convex transducer. Patients were selected according to the inclusion and exclusion criteria and informed consent was obtained. Patients were placed in the supine position according to scanning requirements. Scanning was performed in transverse and longitudinal planes as required. Gestational age was recorded based on the last menstrual period or the earliest ultrasound examination's anticipated date of confinement. A standard 3rd trimester obstetrical ultrasound examination was performed to rule out any abnormality.

Parameters were noted in the free loop of the umbilical cord. To calculate the umbilical coiling index, the distance between the umbilical coils was measured from the inner edge of an arterial or venous wall to the outer edge of the next coil along the ipsilateral side of the umbilical cord. The angle of insonation between the umbilical cord vessels and the Doppler beam was less than 30◦ in order to obtain as accurate blood flow velocity recordings as possible. The antenatal UCI was calculated as the reciprocal of the distance between a pair of coils (antenatal UCI = 1/distance in cm).

The correlation was primarily made between Doppler indices and umbilical coiling index values, regardless of their coiling patterns. Coiling patterns, including normocoiled, hypercoiled and hypocoiled, were also calculated. The umbilical coiling index was considered low if below the 10th percentile and high if above the 90th percentile, and the values for the 10^{th} and 90th percentiles were calculated for each parameter using the patient data collected in the study. The direction of the umbilical cord helix was noted. A left helix was indicated by arteries that were oriented like the left limb of the letter V on a sonogram with the cord held vertically. The right helix was indicated by those that were angled like the right limb of the V. Then, Doppler ultrasound of umbilical arteries was performed in the sagittal plane to record Doppler parameters including PSV (peak systolic velocity) and RI (resistive index). All blood flow parameters were averaged from the values obtained in each umbilical artery for each pa-

Fig. 1. *Ultrasound image of a normocoiled umbilical cord with an antenatal umbilical coiling index (UCI) of 0.43 and intercoil distance of 2.3 cm along the cord axis.*

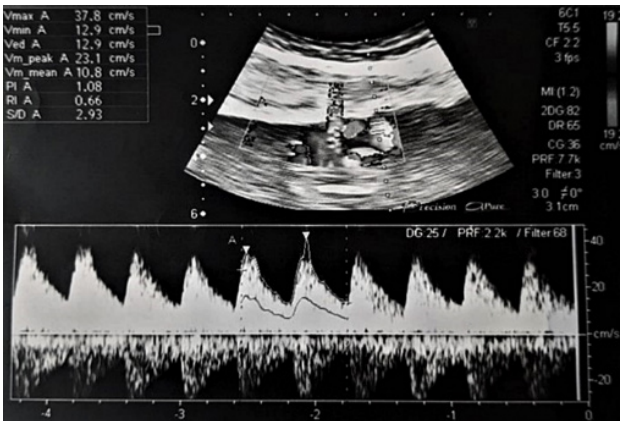

Fig. 2. *Spectral Doppler of the umbilical artery, obtained with pulsed-wave Doppler. The resultant peak systolic velocity (PSV) was 37.8 cm/s and resistive index (RI) was 0.66 .*

tient. After that, the mean velocity in the umbilical vein was recorded. Umbilical vein diameter was also obtained for each patient in transverse section on grey scale ultrasound, and blood flow rate through the umbilical vein was calculated according to the formula: Volume flow = Vm × CSA (mL/m), Vm is the mean umbilical vein velocity (cm/s) and CSA is the cross sectional area. CSA is obtained as πr^2 (or its equivalent, D^2 x 0.785), assuming that the vessel is circular in cross-section.

Statistical analysis was performed using SPSS v.26. Quantitative variables such as gestational age, umbilical coiling index, PSV, RI, vein diameter, mean velocity and flow rate were presented as mean ± SD. Qualitative variables, including coiling pattern and helix direction, were presented using frequency and percentages. The Pearson correlation coefficient test was applied to assess the relationship between antenatal umbilical coiling index values and Doppler parameters of umbilical cord vessels. P-value ≤ 0.05 was considered significant.

Results

In this study, 48 women were included (mean age 27.1 years, standard deviation 2.98 years). The patients' ages ranged from 23 to 35 years, with the majority of the patients falling within one standard deviation of the mean; therefore, this age distribution was comparatively typical. The study concentrated on the third trimester and found a range of 28 weeks to 37 weeks in terms of gestational age. With a standard deviation of 2.4 weeks, the mean gestational age was 31.4 weeks. It was clear from the distribution of the modest dispersion of gestational age around the mean that the sample was diverse.

The antenatal sonographic UCI was calculated as the reciprocal of the distance between a pair of coils (Fig. 1). The mean UCI was found to be 0.42 ± 0.1. The values of UCI ranged from 0.24 to 0.62. The 10th and 90th percentiles of the antenatal UCI were used to stratify the coiling index into three categories: hypercoiled, normocoiled, and hypocoiled. The primary correlation was observed between the UCI and Doppler parameters, regardless of the coiling pattern categorization. The 10th and 90th percentiles of calculated UCI came to be 0.27 and 0.57 respectively . Based on the UCI 10th percentile value, 4 (8%) umbilical cords with UCI ≤ 0.27 were hypocoiled cords. While taking the UCI 90th percentile value, 5 (10%) umbilical cords with UCI ≥ 0.57 were hypercoiled. Apart from these patterns, 39 (82%) umbilical cords were normocoiled; based on UCI, normocoiled umbilical cords ranged from 0.28 to 0.56 (Table 1). The coiling direction of umbilical cord helix was divided into right and left, based on its helical structure twist direction. Out of 48 umbilical cords, 40 (83%) cords had left sided coiling. Only 8 (17%) umbilical cords were coiled to the right side.

Fig. 3. *The diameter of the umbilical vein was measured to be 8.7 mm in a transverse section.*

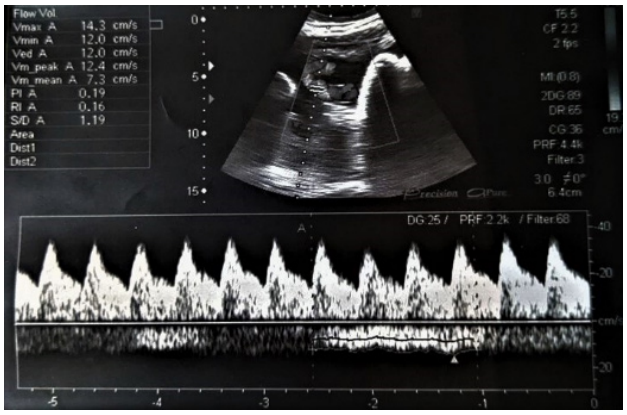

Fig. 4. *Spectral Doppler of the umbilical vein shows a mean blood flow velocity of 7.3 cm/s.*

Umbilical artery Doppler indices were recorded in the free loop of the umbilical cord. Pearson correlation coefficient test was performed to check the correlation of umbilical coiling index with Doppler indices of umbilical arteries. The mean peak systolic velocity was found to be 47.5 ± 3.7 cm/s (Fig. 2). There was a non-significant correlation between the coiling index and PSV of the umbilical artery (P=0.169). According to the Pearson correlation test, the correlation was weak and positive (r=0.202). The mean resistive index was found to be 0.59 ± 0.04. There was a non-significant correlation between the coiling index and RI of the umbilical artery (P=0.905). According to the Pearson correlation test, the correlation was very weak and positive (r=0.018) (Table 2).

Umbilical vein Doppler indices were recorded in the free loop of the umbilical cord. Pearson correlation coefficient test was performed to check the correlation of umbilical coiling index with the Doppler indices of umbilical vein. The mean diameter of umbilical vein was found to be 6.2 mm with a standard deviation of ± 1.05 (Fig. 3). The mean velocity in umbilical vein was calculated and it was 7.2 ± 0.76 cm/s (Fig. 4). There was a significant correlation between the coiling index of cord and the mean velocity (Vm) of umbilical vein (P=0.002). According to the Pearson correlation test, the correlation was moderate and positive (r=0.432). It showed that the Vm was higher in cases having more coiling of the umbilical cord. The mean blood flow rate was found to be 231.08 ± 80.83 mL/m. There was a significant correlation between the coiling index of the umbilical cord and the umbilical vein blood flow rate (P=0.00). According to the Pearson correlation test, that correlation was strong and positive (r=0.668) (Table 3). This means that the blood flow rate in the umbilical vein tended to increase in cases with a higher umbilical coiling index.

Discussion

This research aimed to find any relationship between the coiling of umbilical cord vessels and their blood flow indices, when studied using Doppler ultrasonography. The antenatal quantification of umbilical cord coiling can be performed using ultrasonography. In this perspective, Degani *et al.* conducted a prospective study on forty-five patients and sonographically evaluated umbilical cord coiling patterns. The coiling patterns were compared at 24 hour prior to delivery and after delivery. The results showed that ultrasonography could be successfully used in accurately predicting the coiling pattern of the umbilical cord using quantification by UCI [15].

In this study, the mean coiling index was quantified by taking a reciprocal of the distance between one pair of coils in the umbilical cord on colour Doppler ultrasound. The calculated mean UCI was found to be 0.42 ± 0.1 during the third trimester of pregnancy. Regarding UCI, Degani *et al.* conducted a study on 45 women, who had singleton pregnancies at term between 38 and 41 weeks. These wom-

Table 1. Coiling Patterns of Umbilical Cord		
Coiling Pattern	**UCI**	**Percentage**
Hypercoiled	≥ 0.57	8%
Hypocoiled	≤ 0.27	10%
Normocoiled	0.28 – 0.56	82%

Table 2. Umbilical Artery Doppler Indices and Correlation with UCI			
Parameter	**Mean ± SD**	**P value**	**Pearson Correlation coefficient (r)**
PSV	47.5 ± 3.7 cm/s	0.169	0.202
RI	0.59 ± 0.04	0.905	0.018

UCI = Umbilical Coiling Index

Table 3. Umbilical Vein Doppler Indices and Correlation with UCI			
Parameter	**Mean ± SD**	**P value**	**Pearson Correlation coefficient (r)**
Vm	7.2 ± 0.76 cm/s	0.002	0.432
Flow Rate	231.08 ± 80.83 mL/m	0.00	0.668

UCI = Umbilical Coiling Index

en were examined with obstetric ultrasound exam within 24 hours prior to delivery to assess the coiling pattern of the umbilical cord. The mean coiling index of these cases was 0.44 ± 0.11. Then, the coiling index was calculated after birth and it came to be ranging between 0.28 ± 0.08. They found that the antenatal coiling index predicted the postnatal coiling index [15]. Another study highlighted that minor variations in UCI can also occur, because of differences in demographics, gestational ages, inclusion of abnormal pregnancies, maternal diabetes, etc. [16]. Similar to our study, most authors recognised hypocoiled cords as cords with coiling index ≤ 10th percentile, whereas hypercoiled cords were defined as cords with coiling index ≥ 90th percentile of their calculated coiling index values [17,3]. Other authors simply calculated the mean of coiling index of their patients, but the cut off values of some other investigation studies were used for hypocoiling and hypercoiling patterns of the umbilical cord [18,19]. In this study, the left sided direction of helices predominated in 80% of the cases, whereas right-sided helices were present in only 20% of the cases. In a similar study, Degani *et al.* found the predominance of left-handed helices in 73% and right-handed helices only in 15% of cases. Additionally, a mixed direction of helices was present in 12% of cases [15].

In the current study, umbilical artery PSV and coiling index of cord had a non-significant correlation. That correlation was weak and positive, which means that when UCI increased, PSV was also increased but these both had a weak relationship. Similarly, in a prospective study, Degani *et al.* sonographically evaluated antenatal umbilical coiling patterns 24 hours prior to and after delivery. Flow parameters were measured the on by Doppler in the vein of the umbilical cord and in the umbilical arteries. It appeared that, non-significant correlation was observed between the umbilical artery velocities and cord coiling patterns in these cases [15]. Given that this was an active process, it was doubtful that the umbilical coiling index would have

a significant impact on the normal flow in umbilical arteries. The coiling index did not significantly affect arterial Doppler measurements, according to the literature [9]. A recent review emphasized that the level of umbilical coiling in umbilical cord did not significantly influence the arterial Doppler measurements, including PSV. Moreover, the findings of another research also supported the results of the current study, but with a strong relationship between variables [14]. In that, Predanic *et al.* demonstrated a significant positive correlation between PSV of umbilical arteries and coiling index. This significance occurred because of the small number of cases in the hypercoiled and hypocoiled groups, so their normocoiled group was the most influencing group. It was apparent that unlike others, they relied on this coiling pattern grouping for correlating PSV. Additionally, the gestational age of their cases was early (18-23 weeks) in comparison to the current study [20]. As described earlier, another study proposed that a minor variation in the coiling pattern could occur due to different gestational ages . These might be the possible reason for significance in that study [16].

In the current study, there was a non-significant correlation between the UCI and RI of umbilical arteries. Although the correlation was positive, it was very weak. This means that with an increase in UCI, the resistive index of umbilical artery was also increased, but both had a very weak and non-significant relationship. Similarly, in a prospective study, there was no significant correlation between UCI and umbilical arteries' flow characteristics of on Doppler ultrasound, including the resistive index [15]. Moreover, another study also found a correlation between UCI and resistive index. However, that correlation was significant and inversely related. The mean resistive index values decreased with increase in the antenatal umbilical coiling index. Apparently, a major difference was that the mean gestational age of samples in that study was early in second trimester, compared to this study [20]. Regardless of that study, in a comprehensive review, Laat *et al*. suggested that cord coiling does not significantly affect the resistive index in umbilical arteries [14].

In the current study, the mean velocity of the umbilical vein and the UCI had a significant correlation. This correlation was found to be moderate and positive. It showed that when the UCI increased, then mean velocity of the umbilical vein also increased significantly. Similarly, a study investigated 45 near term gestations. On investigating the relationship between mean velocity of the umbilical vein and coiling index of the umbilical cord, a significant linear trend was found r=0.47 (P=<0.006). It showed that an increase in UCI tends to promote blood flow velocity within the umbilical vein. In aberrant situations, the relationship between umbilical coiling and umbilical vein velocities may be relevant. The fact that decreased coiling was linked to lower umbilical vein flow indices may assist in explaining the unfavourable outcome that has been linked to a significantly lower coiling index. Additionally,a pulsatile pattern of the umbilical vein velocity waveforms was linked to increased coiling of the umbilical cord [15].

In this study, there was a significant correlation between the coiling index of umbilical cord and blood flow rate in the umbilical vein. This correlation was strong and positive. This significant direct relationship showed that the blood flow rate within the umbilical vein tended to increase in cases with higher UCI. Similarly, a study by Predanic *et al.* assessed the coiling index of cord and blood flow variables within the umbilical vein during a fetal sonographic anatomical survey in the second trimester. They noted a significant correlation between the cord coiling and the flow in the umbilical vein; an increase in cord coiling had a strong association with an increase in blood flow rate within the umbilical vein (P=0.032) [20]. This phenomenon could be supported by the pulsometer effect. Assuming that the pulsation of both umbilical arteries and the umbilical vein occur in opposite directions, the arterial pressure pulsations can serve as a pulsometer or piston that would eventually promote venous blood flow in the umbilical vein [21]. During pulsations, the arteries in the cord lengthen. Due to the narrowing of the arteries and resulting expansion of the vein, the vein experiences a relative drop in pressure. Venous blood is pumped forward in this manner. The more coils, the greater the impact of the arteries' pressure pulses on the vein, and thus, the greater the

rise in venous flow [22]. In another prospective study, Degani *et al.* evaluated coiling patterns of the human umbilical cord on ultrasonography, a day before and after delivery. Blood flow parameters were measured on Doppler ultrasound in the umbilical cord vein and arteries. They found a direct proportional relation between umbilical venous blood flow and coiling index of umbilical cord (r=0.59, P<0.001) [14]. In a study on umbilical venous flow patterns, Nakai *et al.* also found a similar relation between blood flow within the umbilical vein and umbilical coiling. They found that a decrease in umbilical cord coiling was associated with a reduction of blood flow indices in the umbilical vein [23].

Conclusion

The antenatal UCI can be assessed on ultrasonography and there is a significant relationship between the Doppler flow parameters of the umbilical vein and the umbilical coiling index. It showed that umbilical coiling does promote venous blood flow in the umbilical vein. Moreover, there is a non-significant relationship between the UCI and Doppler flow parameters of the umbilical arteries. **R**

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