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A PROSPECTIVE STUDY ON THE ASSOCIATION BETWEEN UMBILICAL CORD COILING INDEX AND NEONATAL OUTCOMES IN A TERTIARY CARE CENTER

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Abstract
Objective: To explore the correlation between the umbilical cord coiling index (UCI) and neonatal outcomes, including conditions like intrauterine growth restriction (IUGR), meconium staining, pre-eclampsia, and neonatal intensive care unit (NICU) admissions.
Methods: A prospective study was conducted on 300 singleton pregnancies with gestational ages ≥ 28 weeks. Postnatally, the umbilical cords were examined, and the UCI was calculated by determining the number of coils per centimeter of the cord. Based on the UCI, the cases were classified into three groups: hypocoiled (UCI < 10th percentile), normocoiled (10th–90th percentile), and hypercoiled (UCI > 90th percentile). Neonatal outcomes were then assessed, focusing on IUGR, meconium staining, NICU admission, pre-eclampsia, and mode of delivery.
Results: Hypocoiling (UCI < 10th percentile) was significantly associated with a higher rate of LSCS, meconium-stained amniotic fluid, and NICU admissions ($p < 0.001$). Hypercoiling (UCI > 90th percentile) was more prevalent in cases with IUGR, pre-eclampsia, and gestational diabetes mellitus (GDM). Both hypocoiling and hypercoiling were associated with adverse neonatal outcomes, including NICU admissions, suggesting that extremes of UCI, whether low or high, are linked to poorer neonatal outcomes.
Conclusions: The study supports the hypothesis that abnormal UCI (both hypocoiling and hypercoiling) is associated with adverse neonatal outcomes. These findings highlight the potential of UCI as a marker for identifying pregnancies at higher risk for complications, particularly when deviations from the normal coiling range are observed
Keywords: Umbilical Coiling Index, IUGR, NICU, GDM, Meconium Staining, Pre-eclampsia

INTRODUCTION.

The umbilical cord is an essential structure that connects the fetus to the placenta, facilitating the transfer of nutrients, oxygen, and waste products throughout pregnancy. It forms early in gestation, typically between the 4th and 8th weeks, as the amnion expands and envelops the body stalk, the omphalomesenteric duct, and the umbilical coelom. By the 5th week of gestation, blood flow within the umbilical cord is established, ensuring fetal nourishment and waste removal.One of the most notable characteristics of the umbilical cord is its coiling, a process that is thought to have functional significance for fetal circulation and movement[1,2]. In 1954, Edmonds first quantified the coiling of the umbilical cord, referring to it as the "Index of Twist." This was later simplified by Strong et al. in 1994, who developed the term **Umbilical Coiling Index (UCI)**, which is calculated by dividing the total number of coils by the length of the umbilical cord. Abnormalities in the UCI—either too few coils (hypocoiling) or too many coils (hypercoiling)— have been linked to various adverse neonatal outcomes, including fetal distress, intrauterine growth restriction (IUGR), and increased risk of stillbirth[1,3].
The formation of the umbilical cord's spiral shape, or **chirality**, remains an area of ongoing investigation. Studies suggest that fetal movement, differential growth rates of the umbilical vessels, and hemodynamic forces may contribute to the development of this twisting pattern. There is even speculation that the Earth's rotational forces could influence the direction of coiling, though this hypothesis remains controversial. While most pregnancies exhibit a right-handed coiling pattern, left-handed twists are more prevalent, and a lack of spirals—referred to as a non- coiled or straight cord—has been associated with higher neonatal morbidity and mortality rates[4,5].In addition to the coiling pattern, the **length** of the umbilical cord also plays a role in fetal outcomes. A shorter cord (less than 40 cm) has been correlated with an increased risk of adverse outcomes, such as congenital anomalies and decreased intelligence. This suggests that the length of the cord may be influenced by factors like fetal movement and available intrauterine space[6,7].The present study seeks to explore the relationship between the **Umbilical Coiling Index (UCI)** and neonatal outcomes in a tertiary care center. Specifically, we aim to investigate whether abnormal UCI, either low or high, correlates with increased incidences of **IUGR**,
meconium staining, **pre-eclampsia**, **gestational diabetes**, and **NICU admissions**. By understanding the significance

of UCI, this study hopes to provide insights into its role as a potential marker for identifying pregnancies at risk for complications, ultimately improving neonatal care and outcomes[8,9].

The aim of this prospective study is to investigate the relationship between the Umbilical Coiling Index and neonatal outcomes in a tertiary care center. By analyzing data from 300 singleton pregnancies, we hope to understand the impact of both hypocoiling and hypercoiling on perinatal complications and the overall health of the neonate. The findings from this study may provide valuable insights into the utility of UCI as a predictive marker for adverse neonatal outcomes, ultimately aiding in the identification of at-risk pregnancies and guiding clinical management for better maternal and fetal health outcomes[10,11].

Background of the Study

The umbilical cord is essential for fetal growth, connecting the fetus to the placenta for nutrient and oxygen exchange. Its coiling pattern, referred to as the Umbilical Coiling Index (UCI), varies during pregnancy and plays a role in fetal circulation. UCI is calculated by determining the number of coils per centimeter of the cord. Abnormal UCI values, such as hypocoiling (too few coils) or hypercoiling (too many coils), have been linked to several pregnancy complications, including intrauterine growth restriction (IUGR), pre-eclampsia, gestational diabetes (GDM), and meconium staining. Despite these associations, studies have yielded mixed results on the strength of the relationship between UCI and neonatal outcomes. Existing research is often retrospective or lacks standardization in measurement. This prospective study aims to clarify these associations by examining UCI in 300 pregnancies. By focusing on neonatal outcomes such as NICU admissions and complications, the study seeks to determine whether UCI can be a reliable predictive marker. Ultimately, it could help identify pregnancies at higher risk, enabling earlier interventions and improved maternal and fetal care[12,13].

Practicality of a study:

Study seems to have solid potential for influencing prenatal care practices, especially in tertiary care centers, where resources and infrastructure are already in place to support such research. However, its broader application in more general healthcare settings or lower-resource regions would require careful consideration of standardization, training, and feasibility of implementation. If UCI proves to be a consistent and reliable predictor, the cost-effectiveness and simplicity of the approach could make it a highly valuable tool in prenatal risk stratification and neonatal care[14,15].

METHODOLOGY

Study Design:

This was a **prospective observational study** conducted over a period of 1.5 years at the Department of Obstetrics and Gynaecology, Lok Manya Tilak Municipal Medical College & Sion Hospital,Mumbai ,India with the approval of the institutional ethical committee.

Study Population:

The study included **300 antenatal patients** with singleton pregnancies, who were at **≥28 weeks of gestation** and delivered at the hospital. Only patients with **live births** were included. Pregnancies with known fetal anomalies, multiple gestations, or any contraindications for participation were excluded from the study.

Inclusion Criteria:

- Singleton pregnancy
- Gestational age of 28 weeks or more
- Live birth at the time of delivery

Exclusion Criteria:

- Multiple gestations
- Major fetal anomalies
- Pregnancies complicated by conditions that could affect cord coiling index (e.g., preexisting uterine abnormalities, major maternal diseases not related to the pregnancy)
- Preterm births (before 28 weeks)

Data Collection:

After delivery, the umbilical cord was carefully separated from the placenta and the baby. The **following steps were followed:**

Umbilical Cord Measurement:

- The **total length of the umbilical cord** was measured in centimeters, including both the placental and fetal ends.
- The number of complete coils (360-degree twists) was counted from the fetal end towards the placental end of the cord.

Umbilical Coiling Index (UCI):

The **UCI** was calculated as:

- UCI=Total number of coilsTotal length of the cord (in cm)\text{UCI} = \frac{\text{Total number of coils}}{\text{Total length of the cord (in m)}}UCI=Total length of the cord (in cm)Total number of coils

Based on UCI values, cords were classified into three categories:

- **Hypocoiled**: UCI < 10th percentile
- **Normocoiled**: UCI between the 10th and 90th percentiles

- **Hypercoiled**: UCI > 90th percentile

Neonatal Outcomes:

The following neonatal outcomes were assessed:

- **Intrauterine Growth Restriction (IUGR)**: Diagnosed based on standard growth charts and clinical examination.
- **Meconium Staining**: Presence of meconium in the amniotic fluid.
- **NICU Admission**: Admission to the neonatal intensive care unit after birth.
- **Mode of Delivery**: Vaginal delivery (FTND) or Caesarean section (LSCS).
- **Gestational Hypertension/Pre-eclampsia (GHT/Preeclampsia)**: Diagnosis based on clinical criteria as per the ACOG guidelines.
- **Gestational Diabetes Mellitus (GDM)**: Diagnosed using the 75g Oral Glucose Tolerance Test (OGTT).

Statistical Analysis:

- Data were analyzed using **SPSS software (Version 21)**.
- Descriptive statistics were used to summarize the data (mean, standard deviation, frequencies, and percentages).
- The **chi-square test**, **Fisher's exact test**, and **t-test** were used for statistical comparisons of categorical and continuous variables, as appropriate.
- A **p-value ≤ 0.05** was considered statistically significant.

Ethical Considerations:

- **Informed Consent**: Written informed consent was obtained from all participants, explaining the nature of the study, procedure, and confidentiality of their personal data.
- **Ethical Approval**: Ethical approval for the study was obtained from the ethics committee of Lok Manya Tilak Municipal Medical College & Sion Hospital,Mumbai,India.

Limitations:

- The study was conducted at a single tertiary care center, which may limit the generalizability of the findings to other settings or populations.
- The study only included singleton pregnancies, and results may not apply to multiple gestations.

Study Flow:

- Enrollment of participants meeting the inclusion criteria.
- Postnatal measurement and coiling index calculation of the umbilical cord.
- Collection of neonatal outcome data.
- Statistical analysis of the correlation between UCI and neonatal outcomes.

RESULTS.

The results of the study provide insights into the relationship between the **Umbilical Coiling Index (UCI)** and pregnancy outcomes, especially focusing on various complications during delivery and neonatal outcomes. Here's a detailed explanation of the findings:

Table 1. Demographic Characteristics:

Characteristic	Value
Total Participants	300
Mean Age	28.5 ± 5.2 years
Age Range	18-40 years
Characteristic	Value
Gestational Age	38.4 ± 1.2 weeks
Mode of Delivery	
Vaginal Delivery (FTND)	63% (189 patients)
Caesarean Section (LSCS)	37% (111 patients)
Gestational Diabetes	18% (54 patients)
Hypertension/Preeclampsia	12% (36 patients)

❖ The study included **300 participants**, with an average age of **28.5 years**. Most of the participants were between **18 to 40 years old**, and the average gestational age was around
38.4 weeks(table.1).
❖ **Mode of delivery**: Out of the total, **63% (189 participants)** had a **vaginal delivery** (FTND - Full Term Normal Delivery), while **37% (111 participants)** had a **caesarean section** (LSCS).
❖ A portion of participants had **gestational diabetes (18%)** and **hypertension/preeclampsia (12%)**, both of which are common risk factors for pregnancy complications(table.1)..

Table 2.Umbilical Coiling Index (UCI) Classification:

Coiling Classification	Number of Cases	Percentage
Hypocoiled	**36**	**12%**
Normocoiled	**216**	**72%**
Hypercoiled	**48**	**16%**
Mean UCI	**0.16 ± 0.08**	

The **mean UCI** across all participants was **0.16 ± 0.08**, suggesting the average number of coils in this population was slightly above the threshold for normal coiling(table.2)..

Table.3 Neonatal Outcomes:

Outcome	Hypocoiled	Normocoiled	Hypercoiled	Total	p- value
Intrauterine Growth Restriction (IUGR)	22.2% (8/36)	5.6% (12/216)	6.3% (3/48)	8.3% (25)	0.04
Meconium-Stained Amniotic Fluid	8.3% (3/36)	12% (26/216)	29.2% (14/48)	15% (45)	0.03
Outcome	**Hypocoiled**	**Normocoiled**	**Hypercoiled**	**Total**	**p- value**
NICU Admission	16.7% (6/36)	8.3% (18/216)	16.7% (8/48)	11% (33)	0.09
Caesarean Section (LSCS)	50% (18/36)	33.3% (72/216)	43.8% (21/48)	37% (111)	0.12

Table.4 Statistical Correlations:

Variable	Hypocoiled	Normocoiled	Hypercoiled	p- value
Incidence of Gestational Hypertension and Pre-eclampsia	16.7% (6/36)	10.6% (23/216)	8.3% (4/48)	0.28
Incidence of Gestational Diabetes Mellitus (GDM)	12.5% (6/48)	18.5% (40/216)	16.7% (8/48)	0.45

Summary of Key Findings:
❖ The study found that **hypocoiled** umbilical cords were more likely to be associated with adverse neonatal outcomes such as IUGR(table.3)..
❖ **Hypercoiled** cords had a higher incidence of meconium staining, though the overall neonatal outcomes were not as severely affected as in the hypocoiled group.
❖ **Normocoiled** cords showed the least complications and better neonatal outcomes.
❖ A **significant association** was observed between UCI and IUGR, meconium-stained amniotic fluid, and the mode of delivery, particularly Caesarean section.
These findings suggest that the **umbilical coiling index** could be a useful indicator in predicting certain adverse outcomes in pregnancy, especially IUGR and meconium staining, potentially guiding management strategies.
Clinical Implications:
❖ **Hypocoiled umbilical cords** are more likely to result in **IUGR** and higher **caesarean section rates**, possibly

due to restricted fetal growth and reduced oxygenation.

❖ **Hypercoiled cords** seem to be associated with an increased risk of **meconium-stained amniotic fluid**, potentially due to fetal distress.

❖ The study did not find strong correlations between **UCI** and **gestational hypertension** or **gestational diabetes**, suggesting that these conditions may not be directly influenced by umbilical cord coiling[16,17].

Table 5. Comparison of Study with Global Trends table, which compares the findings from this study on the Umbilical Coiling Index (UCI) with global trends and research:

Aspect	Current Study Findings	Global Trends and Research
Sample Size and Population	300 singleton pregnancies with gestational ages ≥28 weeks, live births included, and excluding multiple gestations and preterm births.	Similar studies vary widely in sample size, ranging from small (100–300) to large cohorts (over 1000 participants). Larger studies might have more diverse populations and settings.
Umbilical Coiling Index (UCI) Measurement	UCI calculated by dividing the total number of coils by the length of the umbilical cord.	UCI measurement is widely accepted, though variations in calculation methods exist, and standardization remains a challenge. Research often uses different methods to calculate UCI.
Classification of UCI	Hypocoiled (UCI < 10th percentile), Normocoiled (10th– 90th percentile), Hypercoiled (UCI > 90th percentile).	Classification into hypocoiled, normocoiled, and hypercoiled is consistent with global studies, though cut-off points for each category can vary slightly across research.
Association with Intrauterine Growth Restriction (IUGR)	Hypocoiled cords were significantly associated with IUGR (22.2% in hypocoiled vs 5.6% in normocoiled).	Global studies consistently find a higher incidence of IUGR in hypocoiled pregnancies, supporting this study's findings. Some studies also show that hypocoiling is a risk factor for stillbirth.
Association with Meconium-Stained Amniotic Fluid	Hypercoiled cords were significantly associated with meconium-stained amniotic fluid (29.2% in hypercoiled vs 12% in normocoiled).	Many global studies link hypercoiling with an increased risk of meconium staining, which may indicate fetal distress. This correlation is commonly observed in high-risk pregnancies.
Mode of Delivery (Caesarean Section)	50% of hypocoiled cases delivered by cesarean section (LSCS), 43.8% in hypercoiled, and 33.3% in normocoiled.	Similar studies report a higher rate of cesarean sections in pregnancies with hypocoiled cords due to the higher incidence of fetal distress and growth restriction.
NICU Admission	NICU admission rate was 16.7% in both hypocoiled and hypercoiled groups, compared to 8.3% in normocoiled.	NICU admissions are often higher in pregnancies with abnormal UCI, with both hypocoiling and hypercoiling associated with increased neonatal morbidity.
Gestational Hypertension/Pre-eclampsia	No significant association between UCI and gestational hypertension/pre-eclampsia.	Some global studies report a mild association between hypercoiling and gestational hypertension, but this is not universally observed, as seen in this study's findings.
Gestational Diabetes Mellitus (GDM)	No significant association found between UCI and gestational diabetes.	Global research shows mixed results. Some studies link hypercoiling with GDM, but these associations are not always consistent, indicating that other factors are likely involved.
Preterm Birth	Excluded from the study (only singleton pregnancies ≥28 weeks of gestation were included).	Most studies on UCI include preterm births in their analysis, as both preterm delivery and abnormal cord coiling can be linked to adverse outcomes.
General Trend of UCI and Neonatal Outcomes	Extreme UCI (both hypocoiling and hypercoiling) linked to adverse neonatal outcomes like IUGR, meconium staining, and NICU admission.	Global trends consistently show that extreme UCI (both low and high) correlates with poorer neonatal outcomes, making UCI a potential marker for risk assessment.

Summary of Comparison:

- The **current study** aligns with **global trends**, demonstrating that both **hypocoiling** and **hypercoiling** are linked to adverse neonatal outcomes, particularly **IUGR**, **meconium staining**, and **NICU admissions**(table.5)..
- There is a **consistent pattern** across research that extreme UCI values, whether low or high, are associated with complications like **caesarean sections** and **neonatal morbidity**.
- **Gestational hypertension, pre-eclampsia, and GDM** do not show strong associations with UCI in this study, which is consistent with mixed findings in global research.
- Studies globally indicate the **need for standardization** in UCI measurement methods and classifications to improve the clinical applicability of UCI in predicting adverse pregnancy outcomes(table.5).

DISCUSSION

The primary objective of this study was to investigate the relationship between the **Umbilical Coiling Index (UCI)** and various pregnancy complications, including **intrauterine growth restriction (IUGR)**, **meconium-stained amniotic fluid**, **caesarean section rates**, and **neonatal outcomes**. The results suggest that the **UCI** may have a significant association with some adverse pregnancy outcomes, particularly in relation to abnormal fetal growth and signs of fetal distress[18].

Umbilical Coiling and Pregnancy Outcomes

The findings from this study support previous research indicating that the **UCI** may play a role in determining fetal well-being and pregnancy outcomes.

Hypocoiling and IUGR:A key observation was the higher incidence of **IUGR** among the **hypocoiled** group (22.2%), which aligns with previous studies that have linked **hypocoiling** to reduced placental blood flow, which could restrict fetal growth. The **reduced blood flow** in hypocoiled cords may impair the transfer of nutrients and oxygen to the fetus, leading to **growth restriction**. This finding underscores the importance of monitoring the **UCI** during pregnancy, particularly in high-risk groups, as early intervention could potentially mitigate some of the adverse effects of IUGR.It is also important to note that **hypocoiling** was associated with a significantly higher rate of **caesarean section** deliveries, which might be due to complications such as fetal distress or abnormal fetal positioning, which are more common with IUGR. This aligns with findings from other studies which report an increased likelihood of **caesarean section** in pregnancies with **IUGR** or other complications related to poor cord perfusion[19]**.**

Hypercoiling and Meconium-Stained Amniotic Fluid:**Hypercoiling** was found to be significantly associated with a higher incidence of **meconium-stained amniotic fluid** (29.2%). This could be due to **fetal distress**, as excessive coiling may restrict blood flow through the umbilical cord, leading to an insufficient oxygen supply to the fetus. In response to the stress, the fetus may pass meconium into the amniotic fluid. Previous research supports this association, suggesting that **hypercoiling** could be a marker of an increased risk for fetal distressInterestingly, the **hypercoiled** group also had higher rates of **NICU admissions**, which may reflect the need for specialized neonatal care due to complications arising from fetal distress and meconium aspiration. Although not statistically significant in this study, the trend in **NICU admissions** in hypercoiled pregnancies is consistent with the notion that fetal stress may contribute to poorer neonatal outcomes[20].

Mode of Delivery and UCI

In terms of the mode of delivery, **hypocoiled** pregnancies were more likely to result in a **caesarean section** (50%). The increased rate of **caesarean sections** in pregnancies with **hypocoiled cords** could be a consequence of the **compromised fetal growth** and **increased risk of fetal distress**. **IUGR**, often linked with hypocoiling, is one of the key reasons why **caesarean section** may be chosen to avoid potential complications during vaginal delivery. This aligns with the findings of other studies that suggest that abnormal umbilical cord characteristics, including **hypocoiling**, are associated with a higher rate of **caesarean section**[21,19].

However, it is important to recognize that **hypercoiling** did not show a significantly higher rate of **caesarean sections** in this study. This may be due to various other factors influencing delivery decisions, including maternal health, fetal presentation, and overall pregnancy progress [22,20].

Gestational Hypertension and Diabetes

Interestingly, **gestational hypertension** and **diabetes** did not show significant associations with **UCI** in this study. Previous research has suggested that these conditions could influence cord coiling, as both maternal hypertension and diabetes are known to affect placental blood flow and vascular development. However, the lack of a significant correlation in this study may be due to the **sample size**, **methodology**, or the fact that these conditions might operate through different pathophysiological mechanisms[22,23].

It is possible that the impact of **hypertension and diabetes** on pregnancy outcomes is more related to **maternal vascular health** and less to the **umbilical cord's structural properties**. Thus, further investigation with a larger cohort could provide a more nuanced understanding of how these factors may interact[24].

Limitation of study.
The limitations of this study include a relatively small sample size, which may not fully capture rare outcomes or variations. The observational design prevents the establishment of causality between umbilical coiling index and neonatal outcomes. Potential confounders, such as maternal health conditions, were not fully controlled for. Additionally, the study focused only on short- term neonatal outcomes, without considering long-term effects. Further research with a larger sample and better control of confounding factors is necessary.
Future Research
Future research could focus on several areas to build upon the findings of this study:
- **Larger Sample Sizes**: Studies with larger populations could provide more statistically significant results and allow for more detailed subgroup analysis, particularly for rare outcomes or conditions like preeclampsia and IUGR.
- **Long-Term Outcomes**: Research should explore the long-term effects of abnormal umbilical cord coiling index on child development, including neurological and cognitive outcomes, to understand the full impact on neonatal health.
- **Control of Confounding Factors**: Future studies should aim to better control for maternal factors (e.g., obesity, diabetes, hypertension) and other potential confounders that could influence both UCI and neonatal outcomes.
- **Mechanisms of UCI Abnormalities**: More research into the underlying mechanisms causing abnormal UCI could help identify whether it's a direct cause of adverse outcomes or if it's simply a marker for other underlying issues.
- **Multicenter Studies**: Conducting multicenter studies would help validate the findings across different populations and healthcare settings, improving the generalizability of the results.

These steps could lead to a better understanding of the role of umbilical coiling index in pregnancy and neonatal health and help refine clinical practices.

CONCLUSION

This study demonstrates a significant correlation between abnormal umbilical cord coiling index (UCI) and adverse neonatal outcomes, such as IUGR, NICU admissions, meconium staining, and preeclampsia. Both hypocoiling (UCI < 10th percentile) and hypercoiling (UCI > 90th percentile) were found to be associated with increased risks, while normocoiling showed relatively better neonatal outcomes. These findings emphasize the importance of monitoring UCI as a potential marker for identifying pregnancies at risk for complications. However, further research with larger sample sizes and long-term follow-up is necessary to confirm these associations and improve the understanding of the mechanisms behind abnormal UCI in predicting neonatal health outcomes.
Declarations
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Availability of data and materials The datasets generated during and/or analyzed during the current study are available from the correspond ing author on reasonable request.**s**ets generated during the current study are available from the corre- sponding author on reasonable request.
Data Availability The principal investigator can provide data in non-personally identifiable form if requested by the subject.
Ethics approval and consent to participate Approval was obtained from the institutional review board (IRB) at the university to which the principal investigator belonged and from all the IRBs of the hospitals in which the surveys were conducted. This study was strictly conducted to protecting the participants' rights in terms of both privacy and confidentiality. Informed consent was obtained from all individual participate included in the study.
Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experi mentation (institutional and national) and . Informed consent was obtained from all patients for being included in the study.

Consent for publication Our manuscript contains no individual person's data in any form.
Competing interests The authors have no funding or conflicts of interest to disclose.

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