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Gross patterns of umbilical cord coiling: Correlations with placental histology and stillbirth

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ABSTRACT

Introduction: The purpose of this study was to define gross patterns of umbilical cord hypercoiling and determine correlations with histological features in the placenta and/or perinatal outcomes such as stillbirth.

Methods: Gross images of placentas with hypercoiled umbilical cords (>3 coils/10 cm) were assigned a major umbilical coiling pattern and the direction (right or left) of the coiling. Definitions of 4 gross coiling patterns were established: undulating, rope, segmented, and linked, each with progressively deeper indentations in cord diameter. Outcome variables obtained from placental pathology reports and maternal medical records included histological abnormalities indicative of significant chronic fetal vascular obstruction, such as fetal vascular thrombi, avascular villi, villous stromal-vascular karyorrhexis, and fetal thrombotic vasculopathy, and stillbirth.

Results: 318 placentas/umbilical cords met inclusion criteria. The rope pattern was the most common (52%), followed by the undulating (26%), segmented (19%) and linked (3%) patterns. The segmented and linked gross coiling patterns were significantly correlated with histologic evidence of chronic fetal vascular obstruction and stillbirth, when compared with the rope and undulating patterns. Cords with right twists were also significantly correlated with histologic evidence of chronic fetal vascular obstruction and stillbirth when compared with cords with left twists. The number of cord coils per 10 cm did not correlate with any of the outcome variables.

Conclusions: Among hypercoiled umbilical cords, specific gross patterns of coiling can be recognized, and patterns with the most significant indentation or pinching of the cord diameter are associated with histological evidence of chronic fetal vascular obstruction and stillbirth.

1. Introduction

The umbilical cord is the vital link between the fetus and placenta which carries oxygenated blood to the fetus via the umbilical vein and removes deoxygenated blood via the umbilical arteries. One of the most characteristic gross features of the umbilical cord is its helical coiling pattern. On average, the umbilical cord has about one coil every 5 cm as defined by the Umbilical Coiling Index (UCI) [1]. Hypercoiled umbilical cords with a coiling index greater than 0.3 coils/cm are not uncommon, with incidence reported between 6 and 21% of pregnancies [2,3]. Pregnancies with hypercoiled umbilical cords have increased incidence of pregnancy complications [2–4], and adverse outcomes, such as fetal demise [3].

Due to the relatively high incidence of umbilical cord hypercoiling and to personal, clinical observations that not all hypercoiled cords are associated with evidence of fetal vascular obstruction and/or poor outcome, we hypothesized that beyond the number of coils in the umbilical cord, other specific gross features of the hypercoiled umbilical cord may contribute to deleterious effects on the fetus. In other words, UCI alone may not be entirely informative about the potential of the umbilical cord anatomy to contribute to an adverse outcome. To our knowledge, the gross patterns of umbilical cord hypercoiling and their effect on fetal outcome have not been well-studied. The purpose of the present study was to define and describe the gross patterns of umbilical cord hypercoiling and to determine if there are any
specific coiling patterns that correlate with evidence of chronic fetal vascular obstruction in the placenta and/or stillbirth.

2. Methods

Placentas are submitted to the Pathology Department at Northwestern Memorial Hospital/Prentice Women’s Hospital based on criteria established by a multidisciplinary group of clinicians. Criteria are based on College of American Pathologist guidelines [5] and include: gross abnormality of the placenta, stillbirth, intrauterine growth restriction, preterm delivery less than 34 weeks gestation, severe pre-eclampsia, clinical suspicion of infection or abortion, maternal malignancy, and compromised clinical course of the neonate. As part of the routine examination of placentas at our institution, all placentas received in pathology are photographed, and the umbilical cord coils are counted and recorded as the number of 360° coils per 10 cm segment. A diagnosis of hypercoiled umbilical cord was made based on the gross description indicating that the umbilical cord had more than three coils per 10 cm segment. After Institutional review board approval, we searched the pathology database between January 2009 and December 2010 for placentas with a diagnosis of hypercoiled umbilical cord. Gross digital images of all singleton cases were collected and examined. Placental images which did not include the umbilical cord or where the umbilical cord was partially obscured or too short for analysis (< 10 cm) were excluded. Based on previous observations by the authors, a priori definitions of the gross patterns of coiling were established. Coiling was divided into 4 major patterns: undulating, rope, segmented, and linked patterns (Fig. 1). The undulating pattern was defined as a cord with a serpentine or loose S-shape to the coils without significant indentations between the coils. The rope pattern was characterized by relatively tight coils but with a generally preserved/straight external surface to the cord, similar to the appearance of a rope. The segmented umbilical cord showed coils with indentations involving < 50% of the diameter of the cord between each coil, and the linked pattern displayed deeper indentations (>50% of the cord diameter) between each coil (Fig. 2).

Gross photographs of placenta and umbilical cord were then reviewed by the authors blinded to any clinical or other pathologic data. For each case, a major umbilical coiling pattern and the direction, counterclockwise (left) or clockwise (right), of the coiling was assigned. If a second, minor coiling pattern (involving less than 50% of the cord length) was present, that pattern was also recorded. Cord insertion was recorded and considered abnormal if marginal or velamentous. Placental pathology reports finalized by a single pathologist (LE) were reviewed for all cases.

Routine histologic sampling included at least two sections of umbilical cord, at least one section of the membrane roll, three sections of the parenchyma with maternal surface, and two full-thickness sections of parenchyma. Histologic abnormalities indicative of significant chronic fetal vascular obstruction such as choriocarcinoma or stem villous vascular thrombi, avascular villi, and villous stromal-vascular karyorrhexis were recorded. Criteria for the histologic lesions was based upon definitions created by the Society for Pediatric Pathology, perinatal section, fetal vascular obstruction nosology committee [6]. Fetal vessel thrombi were defined by the presence of occlusive or non-occlusive blood clots in chorionic or stem villous vessels. The blood clots were characterized histologically by fibrin strands and adherence to the endothelium. Avascular villi were defined as any focus of terminal villi showing a total loss of villous capillaries with bland hyaline fibrosis of the villous stroma. Villous stromal-vascular karyorrhexis was defined as terminal villi showing karyorrhexis of fetal cells within the villous and capillary degenerative changes. A diagnosis of severe fetal vascular obstruction, consistent with fetal thrombotic vasculopathy (FTV) was recorded in cases with >15 avascular villi per slide = fetal thrombosis [6]. Clinical pregnancy data such as maternal age, gravidity, parity, maternal medical complications, and gestational age was obtained from review of the maternal medical record. The immediate outcome of the pregnancy, live birth or stillbirth, was recorded.

All data were entered into a coded database to protect patient confidentiality. Umbilical cord coiling patterns were correlated with gross and histologic placental characteristics and outcome using Chi-square analysis for categorical variables and student’s t-test or one way analysis of variance (ANOVA) for continuous variables. All statistical analyses were performed using IBM® SPSS® Statistics, version 20. P-value < 0.05 was considered to indicate statistically significant correlations.

3. Results

Our search of the Surgical Pathology database at Northwestern Memorial Hospital/Prentice Women’s Hospital returned 392 placental cases with hypercoiled umbilical cords. A total of 74 cases were excluded based on the above exclusion criteria, leaving 318 cases qualifying for analysis. The gestational age of the patients ranged from 19 weeks to 42 completed weeks of gestation with a mean of 37.3 ± 4.0 weeks. The remaining clinical characteristics of these 318 pregnancies are shown in Table 1.

The most common umbilical cord coiling pattern identified was the rope pattern which was seen in 164 cases or 52% of the umbilical cords analyzed. The second most common pattern was the undulating pattern seen in 82 cases or 26% of the total group. The segmented and linked patterns were less common, with 60 cases showing the segmented pattern, and only 12 cases with the linked pattern. See Table 2. There was no significant difference in the average UCI or number of coils per 10 cm length of cord between the rope, segmented, and linked patterns. However, cords with the undulating pattern had significantly fewer coils per 10 cm segment of cord. Abnormal umbilical cord insertion, either marginal or velamentous, was seen in all coiling groups, and there was no significant difference in frequency of abnormal cord insertion among the groups. See Table 2.

Stillbirth was identified in 18 cases and occurred across all cord coiling groups, but was by far most frequently associated with the linked pattern of coiling, occurring in nearly half (5/12, 42%) of cases showing that coiling pattern. In addition, 56% of the stillbirths had either the segmented or linked pattern of umbilical cord coiling. FTV was present in 7/18 (39%) of the placentas associated with stillbirth, but 12/18 (67%) showed some element of fetal vascular obstructive pathology in the form of fetal vascular thrombi or avascular villi. Therefore, only one third of the stillbirths were not
associated with histologic evidence of fetal vascular obstruction. Umbilical cords with the linked pattern were associated with the highest frequency of lesions associated with chronic fetal vascular flow obstruction such as fetal vascular thrombi, avascular villi, villous stromal-vascular karyorrhexis, and FTV, followed closely by the segmented pattern. See Table 2.

Since the linked and segmented patterns both showed some degree of umbilical cord indentation, while the undulating and rope patterns did not, we dichotomized the four patterns into two broader presentations of cord coiling: “segmented + linked” and the “rope + undulating” categories. These two categories were reanalyzed for the same outcome variables. The segmented + linked patterns of umbilical cord coiling showed significant correlations with fetal thrombi, avascular villi, villous stromal-vascular karyorrhexis, fetal thrombotic vasculopathy, and stillbirth when compared with the rope and undulating patterns. See Table 3.

257 of the cords presented with a left-handed twist while 61 of them presented with a right-handed twist. Right-handed coiling correlated with a higher percentage of the histologic markers of chronic fetal vascular obstruction (fetal thrombi, avascular villi, villous stromal-vascular karyorrhexis, and FTV) and stillbirth than left coiling. See Table 4. There were no significant differences in the incidence of abnormal cord insertion between the two coiling directions. The spectrum of gross coiling patterns also differed significantly between cords that coiled to the right versus the left. See Fig. 3. The most common coiling pattern in left hypercoiled cords was the rope pattern (60%), while only 15% of the right hypercoiled cords displayed the rope pattern. In contrast, the segmented pattern was most frequent in right hypercoiled cords.

![Fig. 2. Placental images representing the four gross umbilical cord coiling patterns. A. Undulating pattern, B. Rope pattern, C. Segmented pattern, D. Linked pattern.](image)

<table>
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<th>Parameter</th>
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<th>SD</th>
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<td>6.0</td>
<td>17–50</td>
<td>23</td>
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<td>Black 51</td>
<td>Hispanic 40</td>
<td>Asian 18</td>
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<td>Parity</td>
<td>Median 2</td>
<td>Range 1–10</td>
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<tr>
<td>Gestational age</td>
<td>Average 37.3</td>
<td>SD 4.0</td>
<td>Range 19–42</td>
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<tr>
<td>Alcohol</td>
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<td>No 317</td>
<td>No 316</td>
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<tr>
<td>Drugs (THC only)</td>
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<td>No 277</td>
<td>No 305</td>
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<td>No 305</td>
<td>No 309</td>
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<td>Yes 9</td>
<td>No 309</td>
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<td>Mild 8</td>
<td>Severe 19</td>
<td>Superimposed 7</td>
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<td>No 313</td>
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<td>No 307</td>
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<td>Labor</td>
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<td>No 54</td>
<td>No 284</td>
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<td>Route of delivery</td>
<td>NSVD 162</td>
<td>Assisted vaginal 27</td>
<td>Cesarean section 129</td>
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<td>Birth weight</td>
<td>Average 2878.29</td>
<td>SD 845.8</td>
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<tr>
<td>Placental weight</td>
<td>Average 421.23</td>
<td>SD 122.11</td>
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<tr>
<td>Sex</td>
<td>Female 140</td>
<td>Male 177</td>
<td>Ambiguous 1</td>
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</tr>
</tbody>
</table>

NSVD – Normal Spontaneous Vaginal Delivery, SD – standard deviation, THC – Tetrahydrocannabinol.
Correlation of coil twist direction and outcomes.

Table 4

<table>
<thead>
<tr>
<th>Coiling pattern</th>
<th>Frequency N (%)</th>
<th>Abnormal cord insertion N (%)</th>
<th># of coils per 10 cm mean SD N (%)</th>
<th>Fetal thrombi N (%)</th>
<th>Avascular villi N (%)</th>
<th>Villous stromal-vascular karyorrhexis N (%)</th>
<th>Fetal thrombotic vasculopathy N (%)</th>
<th>Stillbirth N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undulating</td>
<td>82 (26)</td>
<td>14 (17)</td>
<td>4.64 ± 1.05</td>
<td>20 (24)</td>
<td>14 (17)</td>
<td>5 (6)</td>
<td>6 (7)</td>
<td>5 (6)</td>
</tr>
<tr>
<td>Rope</td>
<td>164 (52)</td>
<td>28 (17)</td>
<td>5.34 ± 1.7</td>
<td>28 (17)</td>
<td>25 (15)</td>
<td>2 (1)</td>
<td>8 (5)</td>
<td>3 (2)</td>
</tr>
<tr>
<td>Segmented</td>
<td>60 (19)</td>
<td>10 (17)</td>
<td>5.43 ± 1.5</td>
<td>19 (32)</td>
<td>19 (32)</td>
<td>5 (8)</td>
<td>8 (13)</td>
<td>5 (8)</td>
</tr>
<tr>
<td>Linked</td>
<td>12 (3)</td>
<td>1 (8)</td>
<td>5.50 ± 1.5</td>
<td>6 (50)</td>
<td>5 (42)</td>
<td>2 (17)</td>
<td>3 (25)</td>
<td>5 (42)</td>
</tr>
<tr>
<td>Rope + Linked</td>
<td>246 (77)</td>
<td>42 (17)</td>
<td>4.8 (20)</td>
<td>39 (16)</td>
<td>7 (3)</td>
<td>14 (6)</td>
<td>8 (3)</td>
<td></td>
</tr>
<tr>
<td>Linked + Unlink</td>
<td>72 (16)</td>
<td>11 (16)</td>
<td>30 (35)</td>
<td>24 (33)</td>
<td>10 (70)</td>
<td>11 (15)</td>
<td>0.007</td>
<td>10 (14)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.963**</td>
<td>0.003</td>
<td>0.13*</td>
<td>0.005**</td>
<td>0.0027**</td>
<td>0.000**</td>
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</tr>
</tbody>
</table>

For categorical variables: Pearson Chi-square* or Fisher’s exact**; For continuous variable: One way ANOVA.

4. Discussion

To our knowledge this is the first study to define and examine the significance to specific gross patterns of umbilical cord hypercoiling and correlate the patterns with placental histologic findings of chronic fetal vascular obstruction and stillbirth. Cord coiling was recorded first by Berengarius in the 1500s, and studied intermittently through the early 1900s [7]. Edmonds did an exceptional job of summarizing this literature in 1954 [8], describing the spirals of the cord, setting forth an index for determining their intensity (“index of twist”), and enumerating many of the vital questions concerning gross cord patterning. However, it was not until the early 1990s that the description and documentation of umbilical cord coiling became a routine part of the placental examination. In 1993 Strong noted that uncoiled cords were associated with unfavorable fetal outcomes such as intrauterine death, preterm delivery, repetitive intrapartum fetal heart rate decelerations, operative delivery for fetal distress, meconium staining, and anatomical-karyotypic abnormalities [9]. Then a year later, he defined the Umbilical Coiling Index (UCI) with the normal range of coiling as 0.1–0.3 coils/cm umbilical cord [1]. His initial study showed that umbilical cords outside the normal range of coiling, either hypo- or hypercoiled were associated with significantly greater incidence of moderate or severe variable fetal heart rate decelerations [1].

The significance of umbilical cord hypercoiling (>0.3 coils/cm or >3 coils/10 cm) has continued to be examined by several authors, and a hypercoiled umbilical cord has been found to be associated with several adverse pregnancy outcomes including cocaine usage and preterm delivery [4], fetal demise, fetal intolerance to labor [3], oligohydramnios, meconium and fetal distress [2]. However, these associations are not universally true of all hypercoiled umbilical cords, and further examination of which particular patterns of hypercoiling are more likely to be associated with immediate neonatal adverse outcomes, such as stillbirth, has not been performed. Our study is the first to define four distinct gross patterns of umbilical cord hypercoiling in clinical placental specimens and to show that the two patterns with the most indentation between the coils, the segmented and linked patterns, are associated with histologic evidence of chronic fetal vascular obstruction/FTV in the placenta and stillbirth. The major implication of this finding is that the specific coiling pattern seen in the umbilical cord may predict the degree and/or severity of fetal blood flow restriction.

Experimental models of umbilical blood flow have been employed to study the effects of umbilical cord coiling on blood flow. Using a model of standardized encirclement force on the umbilical cord, Georgiou et al. demonstrated a significant inverse relationship between umbilical cord coiling and minimum weight required to occlude venous perfusion [10]. This could be interpreted to imply that the hypercoiled umbilical cord is associated with decreased pressure needed to occlude the umbilical vein, and thus could place the fetus at greater risk for a fatal cord accident. In addition, using a computational model to study the effects of umbilical cord coiling on arterial blood flow, Kaplan et al. showed that the number of coils did not have a significant effect on wall shear stresses, but that wider spreading of the coils reduced wall shear stresses [11]. This is consistent with our observations that the undulating pattern, with its wider spreading of coils, had less thrombosis than the linked and segmented patterns of coiling. Significant, chronic umbilical cord compression or elevated wall shear stresses can produce stasis of fetal blood flow, thrombosis in fetal vessels, multifocal avascular villi (FTV), and ultimately fetal...
death. Our data support the finding that beyond the number of coils, the gross pattern of coiling may affect the degree of fetal blood flow restriction. Specifically, our most important observation is that the segmented and linked patterns of umbilical cord hypercoiling are more highly associated with placental histologic features of chronic umbilical cord obstruction and stillbirth than the patterns with less restriction in diameter between the coils.

In general, left umbilical cord twisting is more frequent than right umbilical cord twisting with a reported ratio of 5–7:1 [12,13], but in our study of exclusively hypercoiled umbilical cords the ratio is approximately 4:1, suggesting hypercoiled cords may represent an enriched population of the right coiling pattern. Our results show that in the setting of a hypercoiled cord, right umbilical cord twisting is more frequently associated with histologic changes of chronic fetal vascular obstruction and stillbirth than left umbilical cord coiling. Baergen has also shown that long umbilical cords frequently have right twisting [14]. Right umbilical cord twisting may be less common in the general population because the right umbilical artery is typically larger than the left umbilical artery, and this discrepancy creates rotational torque to the left. Therefore, right umbilical cord twisting may indicate a developmental abnormality [14]. Our results demonstrate that for the coiling patterns with significant indentation, and perhaps the greatest coiling torque, this developmental abnormality is associated with the highest degrees of fetal vascular obstruction and stillbirth. This is not surprising, as severe fetal vascular pathology as seen in FTV has been associated with several adverse outcomes including stillbirth [15–19]. Our study further strengthens the link between gross umbilical cord abnormalities and stillbirth, especially when umbilical cord hypercoiling is associated with significant restriction of umbilical cord diameter between the coils.

The factors that determine umbilical cord coiling are largely unknown, but several theories exist including fetal movement, torsion by the embryo, differential vascular growth rates, fetal hemodynamic forces, structure of the muscle of the umbilical vessels, and genetic factors [7,13,14]. It is generally believed that umbilical cord coiling is established early in gestation. Twisting of the cord can be appreciated as early as the 9th week of gestation [4,13], and increases only insignificantly in the third trimester [13]. Studies demonstrating the utility of ultrasound in prenatal diagnosis of umbilical cord coiling are conflicting. For instance, Pedranic and colleagues demonstrated a strong correlation between second trimester UCI as determined by one observer and postnatal UCI, with reliable intra-observer reproducibility [20]. Similarly, another study that determined antenatal UCI within 24 h of delivery also found that ultrasound UCI correlates well with UCI after birth [21]. In contrast, another study failed to show a good correlation, although antenatal UCI measurement in this study was performed by three separate investigators with no analysis of inter- or intra-observer variability [22]. In addition, some studies have linked umbilical cord coiling with umbilical arterial flow characteristics [23], while others suggest that the coiling primarily correlates with umbilical venous Doppler indices [21]. These discrepant results may be related to the methodology by which antenatal umbilical cord coiling is assessed, and in total, suggest that not only is a standardized ultrasonographic technique for coiling required, but that establishment of uniform technique in assessing gross patterns of coiling is also necessary.

In conclusion, this is the first study to define four different grossly recognizable patterns of umbilical cord hypercoiling in clinical placental specimens and to correlate the segmented and linked patterns (characterized by the greatest constriction of cord diameter between the coils) with histologic evidence of chronic fetal vascular obstruction and one of the poorest pregnancy outcomes, stillbirth. Further studies to examine the histologic and physical properties of the umbilical vessels in the segmented and linked pattern of hypercoiling may shed more light on the underlying defect in this important developmental umbilical cord abnormality. Further investigation is also needed to determine if these coiling patterns can be recognized antenatally to identify fetuses at risk for adverse outcome.

References


