The umbilical coiling index in term pregnancy as a marker of perinatal outcome
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Abstract:
The coil is of (360) degree spiral course of umbilical vessels. The normal umbilical cord coil is one coil 5 cm. The antenatal umbilical coiling index was intended as the equal of the distance involving a pair of coils, [antenatal UCI = 1 / distance (cm)]. The distance between the coils was measured from the inner edge of an arterial or venous wall to the outer edge of the next coil along the lateral side of the umbilical cord. Umbilical cord coiling index grouped as follows: Hypocoiled umbilical coiling index <10th percentile; Hypercoiled umbilical coiling index >90th percentile; Normocoiled umbilical coiling index between 10th-90th percentiles. The aim of this study is to decrease perinatal and morbidity and mortality among neonates by early detection of umbilical coiling index by ultrasound examination during pregnancy, before starting active labor and study. In this cross-sectional study include (100) cases of pregnant women at early labor (latent phase) exam by ultrasound, during which umbilical cord cross-sectional region, umbilical vessels cross-sectional area and umbilical coiling index were calculated and compared with Doppler - parameters including- umbilical vein blood flow volume; peak systolic velocity and umbilical artery pulsatility index. The ultrasound findings were correlated with Intrapartum and neonatal outcome. In this study, the result divided according to the umbilical cord cross-sectional area and umbilical coiling index values. Our results indicated that the cross-sectional area of the umbilical cord was below the 10th percentile in 14% of fetuses, while 86% was with the normal cross-sectional area. Birth weight and placental weight were in the lower limits in fetuses with the lean umbilical cord. The most umbilical cord parameters measured by ultrasound were of lower values in fetuses with the lean umbilical cord. Measurement of the umbilical coiling index shows that in 15% of fetus’s umbilical coiling index was below normal values and 9% was above normal values and 76% was in the normal range and finds that abnormal values of the umbilical coiling index were associated with adverse perinatal outcome. There is a weak negative correlation between the umbilical coiling index and the neonatal birth weight and a moderate positive correlation flanked by umbilical vein blood flow volume and umbilical cord cross-sectional region. To conclude, the parameters of the umbilical cord that are measured by US were of lower values in fetuses with bend umbilical cord and most of the adverse perinatal outcomes were shown to be associated with abnormal values of the umbilical coiling index.

Keywords: Antenatal umbilical coiling index, Hypocoiling, Hypercoiling, Adverse perinatal outcome.

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Introduction
The umbilical cord is a vital structure necessary for the survival of the fetus and also a fascinating structure that has caught the attention of obstetricians and pathologists. The most interesting feature of the umbilical cord is the degree to which the umbilical cord vessels exhibit helical pattern or coiling within the Wharton's jelly (¹). The origin, as well as the factors which influence the direction and the number of coiling within the Wharton’s jelly, are still subjects of interest to study (²). However, the assumptions are that fetal movements, differential umbilical vascular growth rate, fetal haemodynamic forces, and directional preparations of muscle fibers within the arterial wall may be the key determinants (²). Many studies show the crucial role played by the chemical composition, of the Wharton’s jelly in cord coiling, more than ever the role of a compound called hyaluronan that aids the growth of the umbilical vessels & following coiling (³).The umbilical cord coiling is observed by about 28 days of

gestation and as a result, matches the growth of the umbilical cord. This, in essence, means that coiling develops in the presence of a high ratio of amniotic fluid volume to fetal size and hence the fetus achieves coiling by rotating with respect to the implanted placenta (4). The coiled geometry of the UC largely affects umbilical blood flow that is vital for fetus's well-being & normal development (2). The results showed that the driving pressure for a given blood flow rate is increasing as the number of coils in cord structure increases (4). The coiled structures are resulting in inter-woven stream-lines along with the helix and wall shear stresses (WSS) with significant spatial gradients along with the cross-sectional perimeter anywhere within the helical coil (5). These gradients may have an adverse effect on the development of the fetus's cardiovascular system in cases with over coiling or under coiling characteristics, when the coils are more spread, the maximal –WSS- is significantly smaller (5). Cases with twisted & over coiled cords appear to give way very large values & gradients of WSS, which may place the fetus addicted to high danger of abnormal development (6). The umbilical cord coiling together with Wharton's jelly is thought to provide mechanical support to the umbilical cord vessels which are otherwise more prone to kinking, compression, traction and torsion (7). The umbilical cord coiling is quantitatively assessed by the umbilical cord index, defined as the number of complete coils per the total length of the umbilical cord measured in centimeters (8). By this definition, several studies have been consistent in reporting a normal UCI of about 0.2 in postpartum when the placenta and the umbilical cord are examined, and 0.4 when the examination is performed antenatally by sonography. At term, the normal umbilical cord vessels complete an average of 10 - 11 coils for the length of the umbilical cord inserted between the fetus and placenta (9). In comparing abnormal and normal umbilical cord coiling at 10th and 90th percentiles for umbilical cord index (10), an abnormal umbilical cord coiling, described as Hypocoiled (under coiled) and Hypercoiled (over coiled) which are objectively classified as below the 10th percentile and above the 90th percentile respectively, exhibits a strong association with adverse fetal outcomes, like IUD, preterm labor, fetal distress, nuchal cord & fetal thrombotic vasculopathy (9). Therefore early detection of atypical cord coiling is an alert threshold of a potential cause of unpleasant fetal outcome at any future time of development (4). In their study, the researchers observed that abnormal coiling occurred in most of the cases of fetal termination which could have been impossible to explain (4, 9, 10). The aim of this study is to decrease perinatal morbidity and mortality among neonates by early detection of the umbilical coiling index by ultrasound examination in pregnant women before starting active labor. Assessment of cord cross-sectional area, vein cross-sectional area, arterial cross-section area and Wharton’s jelly area by ultrasound, to differentiate normal umbilical cord from abnormal; Identify the parameters of umbilical cord (umbilical vein blood flow, umbilical vein peak systolic velocity and pulsatility index) by Doppler in latent phase of labor and compare with perinatal outcome.; Measurement of the antenatal umbilical coiling index from ultrasound parameters at early labor for a group of pregnant women and Comparison between the umbilical coiling index and its relationship with adverse perinatal outcomes.

**Patients and methods**

**Study design and settings:**
This cross-sectional study is conducted in obstetrics at Al-karkh hospital for obstetrics and gynecology in the period from August 2017 to February 2018. A total of 100 pregnant women with uncomplicated term (37 weeks completed) singleton pregnancies were selected in this prospective observational study prior to active labor (cervical dilatation less than 3 cm) and then delivered alive baby either vaginally or by caesarian section. The inclusion criteria are intranasal mothers irrespective of parity; Singleton viable fetus.; Gestational age 37 weeks (reliable gestational age); Patient in the latent phase of labor (cervical dilatation less than 3 cm) and Mothers who delivered a live baby.

**Exclusion criteria:** Pregnant women who had been excluded were those with:-
1. Medical complicated pregnancy (Diabetes mellitus, hypertensivedisorders, renal diseases, ischemic heart diseases, anemia )
2. Obstetrics disorder in the pregnancy: P_ PROM, placenta praevia,abruption placenta, chorioamnionitis and previous diagnosed IUD.
3. Multiple pregnancies.
4. Preterm labour.
5. Any detectable structural fetal anomaly.
6. Sonographically Estimated Fetal Weight : (EFW):- below 10th percentile forgestational age (Low birth weight) and macrosomia.
7. Two vessels umbilical- cord.
8. Amniotic fluid index <5cm or > 25 cm.
9. Delivery at another institution.

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Methods and data collection:
Informed consent was taken from the patients, and the study was agreed by the local ethics committee. Full history obtained from each patient including demographic details (name, age, and occupation), history regarding her recent pregnancy and past obstetrical history, past surgical and medical history, social and drug history. General physical, abdominal and pelvic examinations have been performed. All patients were examined by ultrasound using the medical system (GE healthcare, Austria GmbH &CoOG, Voluson E6) equipped with a convex probe 3.5 MHz transducers, and the following data were collected: fetal bi-parietal diameter, head, and abdominal circumferences, as well as femoral length, were measured.

Umbilical- cord cross-sectional area was calculated in a free-floating part of the cord by the software of the U/S machine (Photograph 7), in-plane adjacent to the insertion into the fetal abdomen.

Figure 8: (A) cross-sectional area of umbilical cord.

Figure 8: (B) shows cross-sectional area of umbilical cord.

Umbilical -cord coils will be counted. Umbilical -cord was distinct as lean when its cross-sectional area was underneath the 10th percentile for gestational age (<1cm² in term pregnancy) (37). Wharton jelly surface area was computed subtracting the total vessel area from the cross-sectional area of the umbilical cord (38).

Antenatal umbilical coiling index (UCI) was designed as the mutual of the distance between a pair of coils [antenatal UCI = 1/distance (cm)] (39). The distance between the coils was calculated from the inner border, of an arterial or venous barrier to the external border of the next coil along the ipsilateral side of the umbilical cord (Photograph 8). Umbilical- cord was clear as Hypocoiled when UCI was below the 10th percentile for gestational age (41). For term pregnancy hypo-coiled UCI < 0.2 while hyper-coiled UCI > 0.6, while the average normal UCI is 0.4 (43).
The above parameters were compared with the Doppler parameter including Umbilical Vein (UV) bloodstream volume in ml/min, UV peak systolic velocity in cm/s, and umbilical artery pulse index. The volume of umbilical bloodstream (UBF) was estimated as $Q = V \mu(d/2) = (V x d^2 x \mu x 0.25)$, where $(Q)$ is the volume of umbilical blood flow (ml/min), $(V)$ is the mean velocity (cm / s), and $(d)$ is the diameter of the umbilical vein (mm) \(^{(41)}\). Doppler blood-flow parameters were recorded with the fetus, in a fair state, distinct by the lack of trunk and limb movements and during fetal apnea \(^{(43)}\). When patients admitted to the labor ward and starting active labor, we considered: any fetal heart rate disturbances, meconium-stained amniotic fluid, mode of delivery. After delivery, birth weight, placental weight, Apgar score, admissions to NICU have been recorded.

**Operational definitions:**
For birth weight, it was divided into three categories according to their weight for gestational age at delivery [\(<2500\) (small for gestational age), 2500-4000 and \(>4000\)] grams. \(^{(45)}\). For placental weight, below 450gm was considered below 10\(^{th}\) percentile (for term pregnancy) \(^{(32)}\). For Apgar score, for the 1st minute all neonates with score <4 considered abnormal and needed resuscitation, while in the 5th minutes the score <7 considered abnormal \(^{(46)}\).

**Statistical analysis:**
Each pregnant patient assigned a serial identification number. The data were reviewed, cleaned with twice check entry added to the computer using (Statistical Package for Social Sciences (SPSS)), version 20; then, it was coded by the researcher under the supervision of the academic supervisor and a consultant statistician. The continuous variables were presented as mean, standard deviation. The categorical variables were presented by (frequency and percentages in tables). Pearson’s Chi-square test was second-hand to assess the statistical connection between categorical data. Independent (t-test) was used to assess the difference between the continuous variables. Pearson’s correlation between the antenatal umbilical coiling index and fetal birth weight, also between antenatal umbilical cord cross-sectional area and its vein blood flow volume. The level of the p-value, less than 0.05 % was significant.

**Results**
In the present study; Ultrasound examination was done for 100 pregnant women at term pregnancy, it was shown that the cross-sectional area of the fetal umbilical cord at term was below the 10th percentile or called lean in 14% of them, and the others have the normal cross-section. As shown in figure 10.
Both neonates and their placental weight of the normal antenatal umbilical cord patients were shown to be significantly heavier than those of the lean umbilical cord, (p=0.008 and p=0.02) respectively. As shown in (table 1).

Table 1: Differences of birth and placental weight between normal and lean umbilical cord in pregnant women, n=100

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal umbilical cord (n=86) Mean± (SD)</th>
<th>Lean umbilical cord (n=14) Mean± (SD)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight (gm.)</td>
<td>3420±516</td>
<td>2996±492</td>
<td>0.008*</td>
</tr>
<tr>
<td>Placental weight (gm.)</td>
<td>593±(135)</td>
<td>504±(118)</td>
<td>0.02*</td>
</tr>
</tbody>
</table>

Concerning the comparison of the umbilical cord parameters between the normal and lean umbilical cord groups, (table 2).Meanwhile umbilical coiling index for the normal group was significantly higher compared to that in lean group (p<0.001). The umbilical cord cross section, and umbilical vein cross sectional areas as well as Wharton's jelly area were shown to be significantly smaller in those with lean umbilical cord compared to normal with (p<0.001) foreach. Also it was found that Umbilical vein blood flow volume and peak systolic velocity were significantly higher among the normal group (p<0.001 and p=0.012) respectively. As shown in (table 2). It was found that no statistically significant differences were revealed for arterial cross-sectional area and the Pulsatility index of the umbilical artery. As shown in (table 2).

Table 2: Differences of antenatal umbilical cord parameters according to their cross-sectional area, n=100

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal umbilical cord (n=86) Mean± (SD)</th>
<th>Lean umbilical cord (n=14) Mean± (SD)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenatal umbilical coiling index</td>
<td>0.39±(0.08)</td>
<td>0.19±(0.09)</td>
<td>(p&lt;0.001).*</td>
</tr>
<tr>
<td>Cord cross-sectional area (mm²)</td>
<td>2.4±(31.6)</td>
<td>86.5±(11.1)</td>
<td>(p&lt;0.001).*</td>
</tr>
<tr>
<td>Artery cross-sectional area (mm²)</td>
<td>16.4±(5.2)</td>
<td>14.3±(5.6)</td>
<td>0.2(NS)</td>
</tr>
<tr>
<td>Vein cross-sectional area (mm²)</td>
<td>50.5±(20.1)</td>
<td>33.4±(9.6)</td>
<td>(p&lt;0.001)*</td>
</tr>
<tr>
<td>Wharton's jelly area (mm2)</td>
<td>135.1±(31.4)</td>
<td>36.3±(10.1)</td>
<td>(p&lt;0.001).*</td>
</tr>
<tr>
<td>UV blood flow volume</td>
<td>129.1±(19.7)</td>
<td>85.3±(16.9)</td>
<td>(p&lt;0.001).*</td>
</tr>
<tr>
<td>(ml/min / Kg)</td>
<td>UV peak systolic velocity in cm/s</td>
<td>Pulsatility index</td>
<td></td>
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<td>--------------</td>
<td>---------------------------------</td>
<td>------------------</td>
<td></td>
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<tr>
<td></td>
<td>12±(2.6)</td>
<td>0.78±(0.13)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.9±(3.9)</td>
<td>0.79±(0.09)</td>
<td></td>
</tr>
<tr>
<td>(p&lt;0.012).*</td>
<td></td>
<td>0.72 (NS)</td>
<td></td>
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</tbody>
</table>

Discussion

The umbilical-cord is the major feto-maternal unit that provides communiqué between the placenta and the fetus. Though, it is a part of fetal anatomy and may be prone to compression, tension, or torsion, with subsequent interruption of blood flow (4). It is a consideration that coiling provides a defensive effect on these forces, therefore securing uninterrupted blood supply to the fetus. The factual etiology of umbilical -coiling is unclear, but it is thought to result from the fetal movement as well as unequal vascular development (8). In the present study; we found that 14% of the participated pregnant women have lean umbilical cord, which was higher than what was founded by Di-Naro et al. (28) in the study that carried out in Italy 2001, as only 10.3% of the studied sample had lean umbilical cord and another study from Switzerland that was conducted by Raiuet el. (37) in 2003, who reported that lean umbilical cord was prevalent among 11.2% of the study participants; meanwhile, it was 15.5% in a study conducted at 2011 in Egypt by El-Beheryet et al. (41). The results of current study revealed that neither maternal age nor gestational age at the delivery showed significant correlation with UC area, which was in agreement with previous study carried out out in Italy (28) among 116 pregnant women in 2001, and a study that conducted in Switzerland 2003 by Raiuet el. (37) among 252 patients, and another study that conducted by El-Beheryet et al. (41) in Egypt at 2011 among 280 pregnant women, all these studies reach to the similar results. The current study also showed that the risk of low birth weight and low placental weight were inversely correlated with the UC cross-sectional area; this was in the same line with studies from Italy (28), India (40), Iran (47) and Egypt (41). The results of current study revealed that thinner or leaner UC was significantly associated with decrease UC coiling, UC cross-sectional region, amount of Wharton's Jelly & UV blood flow volume, which was in concordance with studies from Italy (28), Switzerland (37), and Egypt (41), while in another study that carried out in Ghana 2012 by Doctor Samuel Bimpong among 266 pregnant women where the results showed that all the parameters of the umbilical cord were not significantly different between the normal and lean umbilical cord (44), this might be resulted from differences in the race, genetics, sample size, ultrasound equipment sensitivity or the setting of the studies. The incidence of Hypocoiled UC is usually superior in fetuses with a lean -cord suggesting that the high amount of vascular Hypo-coiling in lean UC is not an infrequent finding other than could be the consequences of an altered appearance of genes responsible for the production of the UC vessel walls & of the Wharton's Jelly (e.g., Elastin, collagen & hyaluronic acid) (41). Otsubo et al. (51), renowned with the intention of Hypocoiled cord were highly associated with abnormal cord insertion. Pranic et al. (45), stated that increased UC coiling could have a protective effect on blood flow in terms of decreased arterial resistance & higher blood flow velocities as well as increased venous blood flow. A direct correlation between increased cord coiling & increased venous blood flow could be explained by a piston or pulsometer effect (41). Presumptuous that umbilical arterial and venous pressure pulsations happen in reverse directions, arterial pressure pulsations could serve up as a pulsometer to promote venous blood flow (42). Regarding the umbilical cord coiling index we found that (76%) of the included pregnant ladies showed to have a Normocoiled umbilical cord, while (15%) and (9%) were Hypocoiled and Hypercoiled respectively, this close to what was found in other previous studies. For instance, a previous study that conducted by Kashanianet al. (55) in 2006 among 699 pregnant women from Iran found that (67.4%) were Normocoiled, (12.4%) were Hypocoiled and (11.1%) were Hypercoiled; while in a study from India that was carried out by Patilet et al. (46) in 2013 where they included 200 pregnant women and found that (78%) were norm coiled, (11.5%) were Hypocoiled and (10.5%) were Hypercoiled; another study from India which was done by Chitraet al. (34) among 1000 pregnant ladies stated that (78.3%) were norm coiled, (11.7%) were hypo coiled and (10%) were Hypercoiled. Also, another study from Korea (42) among 251 patient revealed that (80.5%) were Normocoiled, (8.9%) were Hypocoiled (10.6%) were Hypercoiled. Concerning the perinatal outcomes which were assessed in our study, we found that meconium-stained liquor and abnormalities of fetal heart rate were significantly more frequent in hypocoiled and Hypercoiled compared with Normocoiled UC groups, which was in concordance with previous two studies from USA (8, 49) and another two studies from India (44, 46), as well as another study from Iran (45). While another study from Iran (47) disagrees with our findings. This study revealed that the mode of delivery was significantly associated with umbilical coiling index categories as we clearly could see that the cesarean section was more prevalent among hyper and Hypocoiled umbilical cord groups, this finding was also found in previous two studies from India (46, 50). While a study from South Korea (52) and the USA (8) were in...
disagreement with our findings. The result of current study found that abnormal umbilical coiling index was significantly associated with low birth weight as well as low placental weight, this was in the same line with findings of studies from Korea (42), Iran (45), India (46), and USA (4, 38) while another study from Iran (47) disagreed with us. Regarding low Apgar score in the first minute after delivery, we found that there was no significant association with the abnormal patterns of coiling, which was in agreement with study that was conducted in India (48), another study from Ghana by Bimpong 2012 (44), study from Korea (42), and study from USA (9). In the other hand, this study revealed a significant association between ≤ minute low Apgar score and the abnormal values of umbilical coiling index; this was similar to the finding of a study that was conducted in India (43, 48), also it was in the same line of another previous study from Iran (45), while it was in reverse to the finding of study from India (46), USA (8) and Iran (47) where they did not find similar association. The results of this study also found that admission to neonatal care units was significantly higher among hypo and hypercoiled UC groups; this was also reported in other two studies from India (36, 40), South Korea (42) and in a study that conducted in Germany among 560 pregnant women in 2002 by Van Dijk et al. (9). This study also reported weak negative correlation of antenatal umbilical coiling index with neonatal birth weight; which was in agreement with a previous studies carried out in USA (49), Iran (45), Egypt (41), and another study from Italy (28). While current results revealed positive association between the cross-sectional area of umbilical cord and blood flow volume of the umbilical vein; which was in the same line with studies conducted in Iran by Tahmasebi and Alighanbari (47), United States by Predanic et al. (43), and Switzerland (37) by Rais et al.

Conclusions
For antenatal assessment of umbilical cord parameters by U/S and its effects on the perinatal outcomes, it is concluded that:
The parameters of the umbilical cord were significantly lower in patients with the lean umbilical cord. Most of the Intrapartum adverse outcomes (Meconium stained liquor, fetal heart rate abnormalities emergency cesarean section delivery) were shown to be significantly associated with abnormal antenatal umbilical coiling index categories. Most of the perinatal adverse outcomes (low birth weight, abnormal placental weight, low Apgar score and neonatal admission to (NICU) shown to be significantly associated with abnormal antenatal umbilical coiling index categories. Neonatal birth weight was shown to decrease with the increment of the antenatal umbilical coiling index. The cross-sectional area of the umbilical cord directly correlated with the blood flow volume of the umbilical vein.

References