Ultrasound Assessment of Umbilical Cord Morphology in the First Trimester: A Feasibility Study

Rajit Narayan\textsuperscript{a} Rahmah Saaid\textsuperscript{a,d} Lars Pedersen\textsuperscript{c} Jon Hyett\textsuperscript{a,b}

\textsuperscript{a}Department of Maternal Fetal Medicine, RPA Women and Babies, Royal Prince Alfred Hospital, and \textsuperscript{b}Discipline of Obstetrics, Gynaecology and Neonatology, Faculty of Medicine, University of Sydney, Sydney, N.S.W., Australia; \textsuperscript{c}Department of Obstetrics and Gynecology, Institute of Clinical Medicine, Aarhus University, Aarhus, Denmark; \textsuperscript{d}Department of Obstetrics and Gynaecology, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia

**Key Words**

Umbilical cord morphology · Umbilical cord coiling · Sepulveda classification system

**Abstract**

**Objective:** The aim of this study was to determine whether morphology and measurement of the umbilical cord could be accurately assessed at the time of the 11- to 13\textsuperscript{th} -week scan.

**Methods:** We conducted a prospective study of 100 consecutive women with singleton pregnancies at 11–13\textsuperscript{th} weeks’ gestation who were seen for routine aneuploidy screening. Transabdominal ultrasound scans were performed, and the distance between two adjacent coils of the umbilical artery was measured in a free loop of umbilical cord. The antenatal umbilical coiling index (aUCI) was calculated as the inverse of this measurement (aUCI = 1/intercoil distance in cm). The maximum diameter of the umbilical vein was measured. Umbilical venous blood flow velocity was obtained using standard Doppler technique. Interobserver variability was assessed. A subjective assessment of the cord was performed using the Sepulveda system of classification to compare the reproducibility of the observations between two observers.

**Results:** The intended measurements could be obtained in all cases. The aUCI was found to decrease with advancing gestation, while the umbilical venous diameter increased with gestation. The umbilical venous blood flow velocity also increased with gestation. Interobserver consistency in the objective measurement of the aUCI was poor (kappa 0.146). However, the Sepulveda classification system was found to be applicable and reproducible at this period of gestation (kappa 0.601).

**Conclusions:** Umbilical cord morphology can be consistently studied in the first trimester. A subjective method of evaluation of the morphology may be a more reproducible technique until measurement strategies are refined and operator experience developed.

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**Introduction**

An integrated assessment of maternal demographics and biophysical and biochemical parameters at 11–13\textsuperscript{th} weeks can be used to identify pregnancies at risk of preterm delivery, preeclampsia, fetal growth restriction and stillbirth [1–3]. It has been suggested that screening at this period of gestation should form the basis of obstetric care [4]. Whilst the identification of pregnancies destined to be affected by adverse outcomes is important, there is a significant false positive rate, and due to the low prevalence of these outcomes, the positive predictive value of screening remains poor. This could potentially be improved by including other factors in the process of risk assessment.
In addition to assessing fetal and maternal components, it is possible to identify placental and cord anomalies that are associated with poor obstetric outcome. The umbilical cord may be hyper- or hypocoiled, and both these features have been associated with outcomes such as aneuploidy, preterm labour, growth restriction, fetal distress in labour, low APGAR scores and intrauterine fetal demise [5–9]. Normal coiling has been defined both at pathological and ultrasound examination, and parameters for hyper- and hypocoiling have been described [10]. Similarly there is data linking cord thickness and umbilical venous blood flow volume to fetal birth weight [11, 12]. Most published data on umbilical cord assessment focuses on pregnancies screened at ≥15 weeks’ gestation.

The aim of this study was to determine whether biophysical characteristics of the umbilical cord can be accurately assessed at the time of the 11- to 13+6-week scan. If so, these could help improve predictive modeling when combined with markers used in the current risk assessment algorithm.

**Materials and Methods**

This prospective observational study was conducted within the Fetal Medicine Unit at Royal Prince Alfred Hospital, a tertiary teaching hospital in Sydney, N.S.W., Australia. Ethics approval for the study was obtained from the hospital’s Research and Ethics Committee (RPA Ethics protocol No. X12-0167 and HREC/12/RPAH/270). A total of 100 consecutive women with singleton pregnancies who presented between January and August 2013 for combined first-trimester screening between 11 and 13+6 weeks’ gestation were included in the study. Written informed consent was obtained in all cases. Multiple pregnancies and pregnancies found to be affected by intrauterine fetal death or structural fetal anomalies were excluded from the assessment. Pregnancies found to have a two-vessel cord were also excluded. All ultrasound scans were carried out using a Voluson E8 machine with a 3D 4- to 8-MHz transabdominal probe (GE Healthcare, North Ryde, N.S.W., Australia). Scans were performed by a single sonologist (R.N.) who was accredited for first-trimester screening.

During ultrasound examination, a free loop of cord was identified and magnified to obtain a sharp image suitable for measurement. The distance from the outer margin of an umbilical artery in its coil to the corresponding margin of the vessel in its next coil was measured (fig. 1).

The antenatal umbilical coiling index (aUCI) was calculated as the inverse of this measurement (aUCI = 1/intercoil distance measured in cm). Two publications have described the measurement of aUCI using a similar technique, but used colour Doppler to outline the umbilical vessels [13, 14]. In our experience this compromises accuracy, as either ‘bleeding’ of colour beyond the confines of the vessels at low pulse repetition frequency settings or ‘dropout’ of colour at high pulse repetition frequency settings leads to under- or overestimation of the aUCI. The diameter of the umbilical vein was measured as the widest distance between the opposing walls of the vein. Calipers for measurement were placed on the echogenic boundary of the vessel, using the same principle as that described for nuchal translucency measurement (fig. 1, 2) [15].

The velocity of venous blood flow in the loop of the cord was then measured in centimetres/second using standard Doppler principles (the umbilical vein was sounded in the free loop of the cord with the pulse Doppler gate no wider than 0.6 mm and the angle of insonation no greater than 30°; fig. 3).

Subjective evaluation of the cord morphology was performed using a previously described classification system that categorises umbilical cords into 3 types depending on the pattern and tightness of the coiling [16]. In type 1, the umbilical vein and arteries course together in a straight line, with no coiling of the arteries around the vein. In type 2, the umbilical arteries coil around the vein, which is predominantly straight or undulating. In type 3, the vein and arteries course together in a helical fashion and are tightly intertwined (table 1).
A second investigator (R.S.), who was blinded to these observations, then made offline measurements of the intercoil distance and the umbilical venous diameter and categorised the umbilical cords subjectively. A pilot study of 20 cases had been conducted prior to the start of this study to refine the measurement strategy and ensure uniformity in measurement between the two observers.

**Statistical Analysis**

Normality of the measurements was assessed by the Shapiro-Wilk test and by visually inspecting the data before and after log transformation. Linear regression analysis was used to estimate the association between two variables. All statistical analyses were performed with Statistical Package for Social Science (SPSS), Mac version 21.0, IBM Corp., Chicago, Ill., USA.

**Results**

One hundred patients were enrolled in the study. The mean maternal age was 33 years (SD 4.09), the mean gestational age 12.3 weeks (SD 0.6), and the crown rump length 65 mm (SD 7.3). The umbilical cord measurement set was completed in all cases. The umbilical vein diameter was normally distributed (Shapiro-Wilk significance level 0.97). Both aUCI and umbilical venous blood flow velocity had to be log-transformed to achieve normal distribution (Shapiro-Wilk significance levels 0.93 and 0.72, respectively). There was no association between venous diameter, aUCI or venous blood flow velocity with maternal age.

**Antenatal Umbilical Coiling Index**

The aUCI ranged from 0.51 to 1.81, with a mean of 1.02 (SD 0.24). There was a statistically significant trend towards reduction in the aUCI with advancing gestation (fig. 4a).

**Umbilical Vein Diameter**

The umbilical vein diameter ranged from 0.8 to 1.7 mm, with a mean of 1.28 mm (SD 0.17). There was a statistically significant trend towards an increase in the diameter of the vein with advancing gestation (fig. 4b).

**Umbilical Venous Blood Flow Velocity**

The umbilical venous blood flow velocity ranged from 5.9 to 12.7 cm/s, with a mean of 8.5 cm/s (SD 1.38). Umbilical venous blood flow velocity was also significantly associated with advancing gestation (fig. 4c).

Flow through the umbilical vein was reduced in fetuses with a higher aUCI (more tightly coiled cord), but this association was not significant (p = 0.1; fig. 5a). Flow through the umbilical vein also appeared to be associated with the diameter of this vessel, but this was not significant (p = 0.07; fig. 5b).

**Interobserver Consistency**

While all parameters could be measured in every case, the kappa statistic for the intercoil distance and therefore for aUCI estimation was 0.146, suggesting poor interobserver consistency (p < 0.001).

**Subjective Classification**

Two operators assessed umbilical cord coiling and categorised the cords into 3 groups. Thirteen cords were categorised as type 1, 56 as type 2 and 31 as type 3. The mean aUCI in these 3 categories were 0.72, 0.99 and 1.19, respectively (table 2), and there was a significant difference between these groups (p < 0.001; fig. 6). The kappa statistic for the Sepulveda class estimation was 0.601, suggesting interobserver consistency (p < 0.001).

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**Table 1.** Sonographic classification of antenatal coiling of the umbilical cord according to Sepulveda et al. [16]

<table>
<thead>
<tr>
<th>Sepulveda class</th>
<th>Umbilical vein</th>
<th>Umbilical arteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Straight</td>
<td>Straight</td>
</tr>
<tr>
<td>Type 2</td>
<td>Straight</td>
<td>Coiled around vein</td>
</tr>
<tr>
<td>Type 3</td>
<td>No straight segment, helically intertwined with arteries</td>
<td>Helically intertwined with vein</td>
</tr>
</tbody>
</table>

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Fig. 3. Measurement of umbilical venous blood flow velocity (in cm/s).
Fig. 4. **a** Correlation between aUCI and fetal crown rump length (CRL): $aUCI = -0.011 \times CRL + 1.76, R^2 = 0.12, p < 0.001$. **b** Correlation between umbilical vein diameter and fetal CRL: diameter $= 0.669 + (0.009 \times CRL), R^2 = 0.15, p < 0.001$. **c** Correlation between umbilical venous blood flow velocity and fetal CRL: velocity $= 3.36 + (0.079 \times CRL), R^2 = 0.17, p < 0.001$.

Fig. 5. Non-significant correlations. **a** Slower venous blood flow in more tightly coiled cords (not statistically significant). **b** Faster venous blood flow in thicker umbilical veins (not statistically significant).
Discussion

This study has shown that it is possible to develop a technique for the assessment of umbilical cord coiling in the first trimester of pregnancy and that this can be applied to all cases. The diameter of the umbilical vein increases, and the spiraling umbilical arteries become less tightly coiled with advancing gestation. The velocity of umbilical vein flow also increases with advancing gestation, suggesting that the processes of morphological development of the cord and functional flow through the placenta continue to change through the first trimester.

A number of groups have reported the pattern and tightness of umbilical cord coiling, as well as the caliber of umbilical vessels and blood flow volumes, but most of these data have been generated in the second trimester of pregnancy. Our data support the previous findings, at later gestations, who have documented that the aUCI reduces with advancing gestation, through to birth [12, 17]. Predanic et al. [17] for instance estimated that the aUCI reduces by 50% from 20 weeks’ gestation to postnatal UCI. This supports the theory that the number of coils in the umbilical cord is established at a very early stage of pregnancy, and as the cord lengthens with advancing gestation, the aUCI is reduced.

The umbilical cord starts coiling around the 8th week of gestation, and it has been postulated that the final number of coils is attained by about 9 weeks’ gestation [18]. What causes the umbilical cord to coil around itself is uncertain. In view of the absence of concordance in monozygotic twins, the helical nature of the cord is possibly controlled by factors which may be partly genetic and partly environmental. For example, maternal diabetes, obesity and hypertension are associated with non-coiled cords [19, 20].

The poor level of interobserver consistency is most likely due to the difficulties in defining the echogenic markers that determine the end points of a single arterial coil. First-trimester quantification of the aUCI may be improved by recording dual images showing grey scale (for measurement) and colour (for interpretation of the vessel site). The level of interobserver variability in a subjective assessment (classifying the cord into 3 types) was good, and this may be more readily applied. Our results from the subjective classification of cord coiling are broadly similar to those of Sepulveda et al. [16]. There were a higher proportion of cords that appeared to be hypo-coiled at 12 weeks (13 vs. 6.5%) and a smaller proportion of cords that were hypercoiled (31 vs. 38%), but these differences are relatively small numerically and may merely reflect the process of development (the Sepulveda dataset was collected at 22 weeks’ gestation).

Previous studies, at 20 weeks’ gestation, have suggested that hypercoiled cords are associated with greater volumes and rates of flow through the umbilical veins [12, 21]. It was postulated that this was due to the increase in pulsatility of the neighbouring umbilical arteries, which would be stronger in more tightly coiled cords. We could not reproduce this finding, but found that cords with a lower aUCI had higher flow velocities through the umbilical veins. We believe this is most likely explained by the fact that cords with lower aUCI tended to be wider. An alternative explanation could be that cords with lower aUCI tended to be straighter, hence exerting lower resistance on venous blood flow, leading to flows with greater velocities.

<table>
<thead>
<tr>
<th>Sepulveda class</th>
<th>Number of instances (n = 100)</th>
<th>Mean aUCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>13</td>
<td>0.72</td>
</tr>
<tr>
<td>Type 2</td>
<td>56</td>
<td>0.99</td>
</tr>
<tr>
<td>Type 3</td>
<td>31</td>
<td>1.19</td>
</tr>
</tbody>
</table>

**Fig. 6.** Correlation between Sepulveda class and aUCI.

**Table 2.** aUCI versus Sepulveda classification
This study has demonstrated that it is possible to assess cord coiling at the time of the routine 11- to 13+6-week scan. We have developed normograms that can be used to define coils that are hypo- and hypercoiled, but further work is needed to reduce interobserver variability in measurement. Another limitation of the study is that the research protocol did not include longitudinal follow-up through gestation, so the evolution of the cord anatomy over time was not studied. Subjective evaluation and categorization of cords into 3 groups is, however, easy and reproducible. We now propose to assess the value of the aUCI and its surrogate, the Sepulveda class of cord coiling, in predicting adverse pregnancy outcome.

**Disclosure Statement**

The authors declare no conflicts of interest.

**References**


Narayan/Saad/Pedersen/Hyett

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