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Original Article

Sonographic measurement of the umbilical cord and fetal anthropometric parameters

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Abstract

Objective: To determine reference ranges for the diameter and the cross-sectional area of the umbilical cord during pregnancy and to determine if umbilical cord morphometry is related to fetal size. *Methods*: A prospective cross-sectional study was designed to assess the sonographic cross-sectional diameter and area of the umbilical cord. The sonographic umbilical cord measurements were obtained in a plane adjacent to the insertion of the cord into the fetal abdomen. Nomograms for the umbilical cord diameter and area were computed. Fetal biometry included: biparietal diameter, abdominal circumference, and femur length. Polynomial regression analysis was conducted. *Results*: Five hundred and fifty seven patients were included into the study. The regression equation for the umbilical cord diameter (y) according to gestational age (x) was $y=-10.0563+1.4265x+0.0194x^2$ and for the umbilical cord area (y') was $y'=91.6-3.3x+0.03x^2-0.00007x^3$. A significant relationship was found between umbilical cord measurements and fetal anthropometric parameters. *Conclusion*: Reference ranges for umbilical cord diameter and area have been generated. The sonographic diameter and cross-sectional area of the umbilical cord increase as a function of gestational age and both diameter and area correlate with fetal size.

Keywords: Umbilical cord; Nomograms; Fetal biometry

1. Introduction

Traditionally, the prenatal sonographic investigation of the umbilical cord has been limited to the assessment of the number of vessels and to the evaluation of the impedance to blood flow by Doppler waveform analysis [1–5].

Little is known about the prenatal morphometry of the umbilical cord and whether a relation exists between the umbilical cord size and the pregnancy course or the perinatal outcome. Changes in the amount of Wharton's jelly have been described in several conditions such as hypertensive disorders [6], dismaturity [7], and fetal distress [7]. Absence of Wharton's jelly around the umbilical cord has also been found in cases of perinatal mortality [8]. However, this findings were the results of pathologic studies or case reports.

Moreover, a lower Wharton's jelly content in the umbilical cord of growth retarded newborns in comparison to eutrophic infant has been shown by computerized microscope morphometry [9]. Weissman and Jakobi [10] reported that fetuses of patients with gestational diabetes mellitus have larger umbilical cord at ultrasound than fetuses of nondiabetic patients. In addition, a significantly smaller mean umbilical cord diameter in patients with antepartum variable decelerations compared with those

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without has been described [11]. Finally, we have recently reported that fetuses with a ''lean'' umbilical cord have an increased risk of being small for gestational age at birth and of having signs of distress at the time of delivery [12].

Large prospective studies assessing the morphometry of the umbilical cord in uncomplicated pregnancies and evaluating its relationship with the anthropometric fetal parameters are rare in the literature [13–15].

The purposes of this study were: 1) to generate nomograms for the diameter and cross-sectional area of the umbilical cord during pregnancy and 2) to determine if umbilical cord area is related to fetal size.

2. Material and methods

A prospective cross-sectional study was designed to assess the sonographic diameter and cross-sectional area of the umbilical cord during pregnancy. Eligibility criteria were: 1) singleton gestation, 2) gestational age above 10 weeks, 3) intact membranes, 4) normal umbilical artery Doppler flow velocimetry, and 5) known gestational age. Exclusion criteria were: 1) congenital and chromosomal abnormalities, 2) pregnancy complications (i.e. diabetes, hypertensive disorders), 3) estimated fetal weight below the 10th or above the 90th percentile for gestational age at the time of ultrasound [16] and 4) amniotic fluid index <5 cm or >25 cm [17]. Gestational age was determined by a reliable recollection of the last menstrual period confirmed by an ultrasonographic examination within 20 weeks of gestation. Each patient was included only once. The sonographic cross-sectional area as well as the greatest diameter of the umbilical cord were measured in a plane adjacent to the insertion of the fetal abdomen. The diameter of the umbilical cord was measured as outer-to-outer border. The cross-sectional area of the umbilical cord was computed using the software of the ultrasound machine. Intra- and interobserver variability were 4.3% and 5.1% respectively [18]. Umbilical arteries Doppler flow velocity waveforms were recorded during fetal apnea and, when at least three consecutive waveforms showing a consistent pattern were obtained, the pulsatility index was calculated. Fetal anthropometric parameters including biparietal diameter (BPD), abdominal circumference (AC), and femur length (FL) were measured in all fetuses above 12 weeks of gestation and the estimated fetal weight calculated [16]. Amniotic fluid index was calculated as previously described [17]. All ultrasound examination were performed with a Toshiba SSH-140A unit (Toshiba Corporation, Medical Systems Division, Tokyo, Japan) equipped with a 3.75 MHz transducer. Pulsed Doppler interrogation of the umbilical arteries was conducted operating at power output of <100 mW/cm^2 spatial peak temporal average and with a 100 Hz high pass filter. All placentas were weighed at the time of delivery.

Statistical analysis: Statistical analysis was performed using Stat view 4.1 (Abacus Concepts Inc, Berkeley, CA). The mean and standard deviation for umbilical cord diameter and area were calculated in biweekly intervals. The 10th, 50th and 90th centile for gestational age for the measurements were also calculated. Polynomial regression analysis was performed to identify the regression curves that best fitted the data point. Spearman rank correlation was used to assess the correlation between umbilical cord measurements and fetal antrophometric parameters. Statistical significance was considered achieved when P was less than 0.05.

3. Results

During the study period, 557 patients met the inclusion criteria. Patients characteristics are presented in Table 1. The measurements of the umbilical cord diameter and area are presented in Table 2. The 10th, 50th and 90th percentile for gestational age of the umbilical cord diameter and area are displayed in Figs. 1 and 2, respectively. The sonographic umbilical cord diameter and cross-sectional area increase as a function of gestational age. The regression equation for the umbilical cord diameter (y) according to gestational age (x) was $y=-10.0563+1.4265x+0.0194x^2$ and for the umbilical cord area (y') was $y'=91.6-3.3x+0.03x^2-0.00007x^3$. A significant relationship was found between umbilical cord measurements and fetal anthropometric parameters (diameter and BPD: $r=0.69$, $P<0.01$; diameter and AC: $r=0.59$, $P<0.01$; diameter and FL: 0.6, $P<0.01$; area and BPD: $r=0.47$, $P<0.01$; area and AC: $r=0.45$, $P<0.01$; area and FL: $r=0.46$, $P<0.01$). A significant correlation has also been found between the antenatal umbilical cord cross-sectional area and placental weight ($r=0.78$, $P<0.01$) and birth weight ($r=0.37$, $P<0.01$).

4. Discussion

A MEDLINE search of the literature from 1966 onward was performed to identify nomograms of the umbilical cord diameter and area. Additional articles were searched by cross-referencing. The present study provides nomograms for the umbilical cord diameter derived from the

Table 1
Clinical characteristics of patients whose umbilical cord measurements were used to construct nomograms

Characteristics	$n=557$
Maternal age (y) (mean±SD)	28.3±4.6
Gestational age at delivery (wk) (mean±SD)	39.6±0.8
Nulliparous (n)	223 (40%)
Cesarean deliveries (n)	88 (15.8%)
Birthweight (g) (mean±SD)	3415±465
Placental weight (g) (mean±SD)	582±119

Table 2
Umbilical cord diameter and area according to gestational age

Week of gestation (weeks+days)	Cases (n)	Umbilical cord diameter		Umbilical cord area	
		Mean (mm)	SD (mm)	Mean (mm^2)	SD (mm^2)
10+0–10+6	6	3.19	0.40	8.11	2.06
11+0–11+6	8	3.65	0.41	11.40	4.87
12+0–12+6	8	3.68	0.53	11.70	3.16
13+0–13+6	12	4.37	0.43	15.10	2.77
14+0–14+6	13	5.10	0.39	20.50	3.00
15+0–15+6	15	5.95	0.73	26.62	7.35
16+0–16+6	24	6.47	0.81	33.04	10.58
17+0–17+6	21	7.23	0.79	38.96	9.81
18+0–18+6	18	7.87	0.74	49.12	12.90
19+0–19+6	25	8.68	1.07	55.39	15.07
20+0–20+6	20	9.47	1.48	65.01	18.13
21+0–21+6	18	10.73	1.55	80.54	21.04
22+0–22+6	23	10.93	1.58	87.45	22.96
23+0–23+6	12	12.23	1.62	104.54	22.23
24+0–24+6	20	13.14	1.72	127.88	24.33
25+0–25+6	20	13.44	1.74	128.00	27.32
26+0–26+6	18	14.34	1.80	139.03	38.44
27+0–27+6	15	14.06	1.99	143.02	44.99
28+0–28+6	13	14.34	2.07	143.40	40.95
29+0–29+6	22	16.25	2.01	186.36	49.26
30+0–30+6	23	16.24	2.12	186.65	44.56
31+0–31+6	21	16.45	2.21	187.50	43.17
32+0–32+6	21	16.59	2.42	187.95	51.66
33+0–33+6	22	16.72	2.49	189.98	48.20
34+0–34+6	24	16.72	2.57	192.53	49.15
35+0–35+6	21	16.27	2.67	182.65	47.04
36+0–36+6	20	16.53	2.30	181.70	42.02
37+0–37+6	22	16.01	1.99	181.56	42.48
38+0–38+6	18	15.85	1.82	163.07	39.30
39+0–39+6	17	14.48	1.60	149.44	37.11
40+0–40+6	9	15.59	1.41	146.77	35.66
41+0–42+0	8	14.42	1.50	139.07	24.64

SD, Standard deviation of the mean.

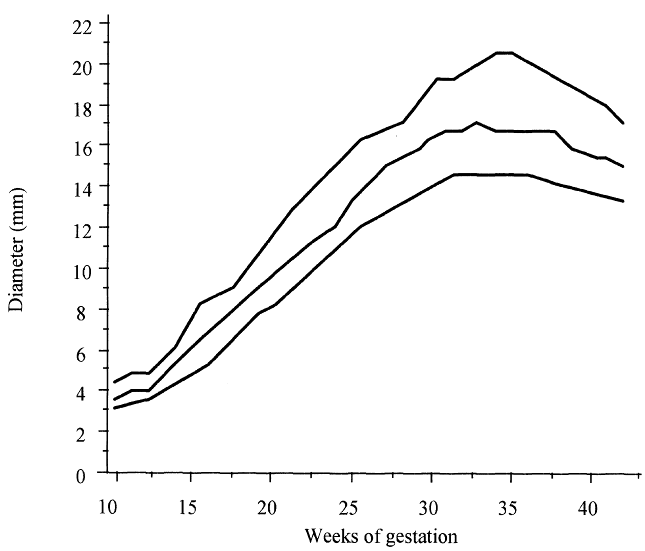

Fig. 1. Umbilical cord diameter according to gestational age. The lines represent the 10th, 50th and 90th percentiles.

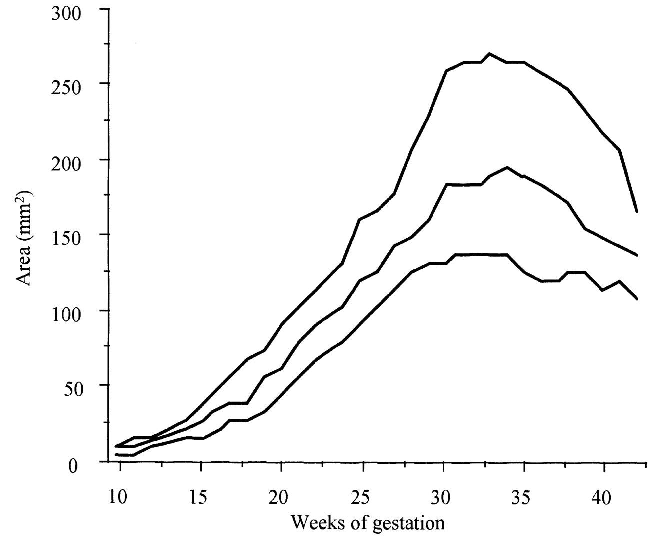

Fig. 2. Umbilical cord area according to gestational age. The lines represent the 10th, 50th and 90th percentiles.

largest study population and the first nomogram for the ultrasonographic evaluation of the umbilical cord area.

The first observation of this study is that there is a progressive increase of the umbilical cord diameter and cross-sectional area up to 32 weeks of gestation followed by a reduction of umbilical cord size. This is in agreement with the study by Weissman et al. [19] who reported nomograms of the umbilical cord diameter and vessels. These authors extrapolated the surface area of Wharton's jelly at each gestational age and found that there is a reduction of Wharton's jelly toward the end of the pregnancy. This is in keeping with previous reports in which a decreased umbilical cord water content has been noted with increase in gestational age [20].

A growing body of experimental and clinical evidence suggests a metabolically active role for the umbilical cord.

Vizza et al. [21] reported that the collagen fibrillar network of the Wharton's jelly, studied by scanning electron microscopy, shows the presence of a wide system interconnected cavities consisting of canalicular-like structures as well as cavernous and perivascular spaces. The authors postulated that this system of cavities might play a mechanical role allowing the storing of the ground substance of the jelly and its diffusion during twisting or compression. Considering that the Wharton's jelly lack of a proper vasculature, this system of cavities may have an important role facilitating the diffusion throughout the jelly of water and trophic metabolities either from or to the umbilical vessels and the amniotic fluid. Moreover, it has been reported that the varied appearance of the umbilical cord at term can be related to its water content and that the difference are mainly confined to the Wharton's jelly [22]. In addition, pathologic studies have shown that the cells of Wharton's jelly, which appear to possess contractility comparable to that of smooth muscle cells, may participate in the regulation of umbilical blood flow [23]. Indeed, a tendency toward a linear relationship between the Wharton's jelly area after delivery and the degree of alteration of the umbilical Doppler immediately before birth have been observed in growth retarded fetuses [9]. It has been proposed that the cells of Wharton's jelly may participate in the regulation of umbilical blood flow and that, at least in some case, the reduction in fetal growth could be the consequence of Wharton's jelly diminution leading to vascular hypoplasia of the umbilical vessels [9,23]. This is in keeping with the finding, recently reported by our group, that a ''lean'' umbilical cord at ultrasound is associated with an increased risk of having a small for gestational age infant [12].

Waissman and Jakobi [10] reported that fetuses of patients with gestational diabetes have larger umbilical cords than fetuses of nondiabetic patients and that this is mainly due to a higher content of Wharton's jelly. These authors found an alteration in the distribution of Wharton's jelly fibers with large empty spaces among them and speculated that this could cause accumulation of fluid and plasma proteins within the Wharton's jelly, resulting in an increased surface area. This modification was already present at 24 weeks' gestation suggesting that the involvement of the umbilical cord in fetuses of diabetic mothers is a phenomenon that occurs early in pregnancy. Of note, Hill et al. [24] reported that 60% of fetuses with an intrauterine fetal demise had the cord length more than 2 standard deviation below the expected value for menstrual age during the first trimester of pregnancy.

Silver et al. [11] found, in prolonged pregnancy, a consistent trend of increased peripartum morbidity when either amniotic fluid volume or umbilical cord diameter was below the population mean. A significant correlation was also observed between water content in both the cord and amniotic fluid. This is in agreement with our data (unpublished) which demonstrate that the proportion of fetuses with a ''lean'' umbilical cord [12] is higher among patients who has oligohydramnios at the time of delivery than among those with normal amniotic fluid (60% versus 8.7%, $P<0.01$].

The second observation of this study is that there is a correlation between both umbilical cord diameter and area and fetal anthropometric parameters. This finding is in accordance with that of Gill and Jarjoura [25] who reported that infants born to women with higher prepregnancy weight, male infant and those who are heavier at birth have an advantage with regard to the quantity of Wharton's jelly wrapped around their umbilical cord vessels. Moreover, a correlation between Wharton's jelly content, umbilical cord diameter and estimated fetal weight has been reported in non macrosomic fetuses of mothers diagnosed to have gestational diabetes [10].

In vitro measurements of the umbilical cord demonstrated that the cord diameter observed at ultrasonography reflects the actual quantity of Wharton's jelly [6]. However, we believe that the antenatal measurement of the umbilical cord area is probably a simpler and better parameter than umbilical cord diameter determination to quantify the amount of Wharton's jelly because it has been demonstrated that in case of segmental thinning of the umbilical cord the greater reduction of Wharton's jelly occurs especially around the umbilical arteries [7,8]. Thus, considering that the cross-sectional shape of the umbilical cord may be not perfectly circular, minimal reduction of Wharton's jelly without modification of the arterial lumen could be underestimated with the solely evaluation of the umbilical cord diameter.

Since the umbilical cord area is easy to measure and now are available nomograms, we suggest that the measurement of the cross-sectional area should be part of a routine sonographic evaluation during pregnancy and that, in case of abnormal size of the umbilical cord, a careful monitoring of the pregnancy should be undertaken.

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