Original Research Article

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Role of Umbilical Cord Cross Sectional Area (UCCSA) in Prediction of Neonatal Birth Weight

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Abstract

Background: It has been well known that foetal size at birth influences the maternal and perinatal outcome. Birth of small for gestational age (SGA) is associated with high rates of admission to neonatal intensive unit (NICU) for problems such as hypoxia, respiratory distress, whereas birth of large for gestational age (LGA) may cause more obstetric trauma during vaginal births and both conditions lead to high rates of operative abdominal delivery. Recent investigations have shown that single estimation of Umbilical Cord Cross Sectional Area (UCCSA) can reasonably predict foetal weight ranges. *Objective:* To correlate fetal UCCSAobtained at the time of third trimester scan with neonatal birth weight. *Design:* Prospective observational study over a period of two years. *Setting:* Department of Obstetrics and Gynaecology, Kasturba Medical College, Manipal, Karnataka, India *Population:* Two hundred and fifty women from 34 weeks gestational age who have delivered within 2 weeks of UCCSA. *Methods:* Women from 34 weeks' gestation, who presented for sonographic examination and who delivered within 2 weeks of the examination, were included in the study. The UCCSA was measured in a free loop of the umbilical cord. Linear regression analysis was used to correlate umbilical cord cross sectional area with neonatal birth weight. *Results:* It was observed that proportion of cases with a lean umbilical cord was significantly higher in the group of small for gestational age group (60.7%) compared with other group (4.5%). A large umbilical cord was found in 65.2% of macrosomic babies compared with 4.4% in non-macrosomic infants. All these association were found to be statistically significant ($p<0.005$). *Conclusion:* There is a positive correlation between UCCSA and birth weight. As UCCSA increases, there is an increase in mean birth weight.

Keywords: Umbilical Cord Cross Sectional Area (UCCSA); Small for Gestational Age (SGA); Macrosomia; Neonatal Birth Weight.

Introduction

Accurate prediction of fetal weight has been of great interest as it helps the obstetricianto decide whether or not to deliver the fetus and also on the mode of delivery. It has alsobecome increasingly important, especially in preventing mishaps of prematurity, foeto pelvic disproportions, induction of labour in high risk pregnancies before term and in detection of foetal growth restriction. Missing the diagnosis of foetal macrosomia may result in traumatic vaginal deliveries which can compromise both maternal and neonatal health.

The traditional birth weight estimation incorporates standard biometric parameters such as biparietal diameter, head circumference, abdominal circumference and femur length, but the formula used to estimated foetal weight using these parameters is now more than 30 years old [1]. There are several attempts in the past to improvise the foetal weight estimation using parameters such as foetal abdominal fat, mid-thigh fat distribution, subscapular fat etc.[2,3,4]. Investigators have also tried limb incorporating volume estimations using three dimensional ultrasound technologies to predict birth weight [5]. However in spite of these efforts foetal weight estimation has an error of 10% when compared to birth weight after delivery and this may be due to the fact that there is great biological, ethnical, regional variations that influence the foetal body weight composition and traditional biometric assessment appears to have reached limits of its predicting abilities.

Umbilical cord is a vital component that links the mother and the foetus and can be used to evaluate pregnancy outcomes. Presently umbilical cord is mainly assessed by colour Doppler in evaluation of blood flow patterns to decide timing of delivery mainly in growth compromised foetuses [6]. Foetal growth restriction can occur in abnormalities of the umbilical cord, like single umbilical artery and velamentous cord insertion [7]. Umbilical cord morphometry such as number of vessels, Wharton jelly content, cord thrombosis, varices etc., is mainly evaluated after the birth by pathologists to correlate adverse maternal and foetal events [8].

Postnatally paediatricians are potentially aware that thin and lean umbilical cord is associated with small and growth restricted neonates leading to either intrauterine death or still birth [9]. A lean umbilical cord is reported to be associated with SGA neonates. Researchers have found significant differencesin mean gestational age, mode of delivery, birth weight, andadverse perinatal outcome between foetuses with umbilicalcord thickness below the 5th centile (lean umbilical cord)vs. those with umbilical cord thickness above the 5th centile(non-lean cord) in the first and early second trimesters ofgestation [10,11]. On the contrary large umbilical cord area is associated with macrosomic babies [12]. Hence, a quick, easy and reliable method of predicting fetal weight ranges in utero keeping umbilical cord as a bench mark would in fact be a boon to an obstetrician. With modern ultrasound techniques it has now become possible to study umbilical cord morphometry with reasonable and acceptable accuracy.

The purpose of this study was to determine whether there is a correlation between sonographic measurements of UCCSAand actual birth weight. The potential benefit of proving such a correlation may be in future may improve the accuracy of birth weight prediction for better obstetric management.

Materials and Methods

This prospective observational study was conducted in a referral medical college hospital in Coastal Karnataka over a period of two years. The participants included 250 pregnant women after 34 weeks of gestation, who were followed up with two weekly scans till they delivered. An implied consent wasobtained from all women who were participating in thestudy. Institutional ethicalcommittee and hospital authorities gave necessaryclearance to conduct the study. Following were the inclusion and exclusion criteria requirements for the participant to fulfil the goal of the study.

Inclusion Criteria

1. Singleton pregnancies
2. Gestational age at and above 34 weeks
3. Presence of three vessel umbilical cord
4. Intact membranes

Exclusion Criteria

1. Multiple pregnancies
2. Intrauterine death
3. Presence of fetal anomalies
4. Prelabour Rupture of membranes (PROM)

Calculation of gestational age was based on reliable recollection of the last menstrual period and confirmed or modified by ultrasound within the first 14 weeks of gestation. All pregnancies had an ultrasound evaluationusing Philips HD11XE ultrasound equipment with acapability of B-mode and colour Doppler scanning.

The measurement of the UCCSA was done in a free loop of umbilical cord with trans abdominal probe being perpendicular to the cord length as much as possible. To get clear images, we saw to the point that umbilical cord section was surrounded by good amount of liquor amni. The area of interest was further zoomed (Figure 1) and the circumference of the umbilical cord was traced as accurately as possible using machine calliper and software of the ultrasound machine automatically calculated the cross sectional area in mm^2.

A large umbilical cord was defined when its sonographic cross sectional area was above the 90^{th} percentile.A lean umbilical cord was defined when its sonographic cross sectional area was less than 10^{th} percentile.

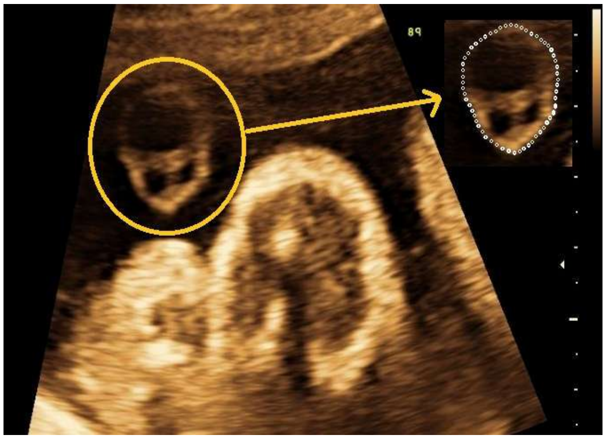

Fig. 1: Identification of free loop of umbilical cord and placement of curser around the cord section

The outcome measured was birth weight. Newborn was measured immediately after birth. Macrosomia was defined as birth weight >90th percentile in the study group.Small for gestational age was defined as a birth weight below the 10th percentile in the study group.

Sample Size Estimation

Morteza T et al. studied the relationship of sonographic measurements of umbilical cord thickness with neonatal weight [13]. A statistically significant correlation was observed between lean umbilical cord and low birth weight (LBW), with sensitivity of 57.9%. We calculated sample size requirement using following formula based on sensitivity rates.

$N= [Z^2_{1-\alpha/2} \times Sn \times (1-Sn)] / [L^2 \times P^\alpha]$

where in

N= number of patients

$Z_{1-\alpha/2}$ = 1.96 (standard normal deviate value that divides the central 95% of z distribution from 5% in the tails)

Sn = reported sensitivity (52.9%, i.e., 0.529).

L= absolute precision desired on either side (half width of the confidence interval of the confidence interval) of sensitivity/specificity (10% i.e., 0.1)

P^α = Prevalence of lean cord (10%, i.e., 0.1)

The sample size calculation based on sensitivity was 93, however we decided to recruit 250 patients which is likely to improve the power of study significantly.

Statistical Analysis

Statistical analysis was done using Statistical Package for Social Sciences 16.0 (SPSS Inc. Chicago, Illinois, USA). All statistical tests for significance of differences were done at a level of 5% using two-tailed t-test. The comparison of outcome among the study group was done by Chi-square test and Pearson correlation wherever applicable. A *P value* of < 0.05 was considered statistically significant.

Results

A total of 250 antenatal women were recruited for the study, of which 150 (60%) were primigravida and 100 (40%)were multigravida. 86.8% women were between 20 to 30 years of age, whereas 13.2% women were older.The mean UCCSAwas 203.6mm^2 with a standard deviation of 47.5mm^2. The UCCSA was in the range of 107-290 mm^2.

The 10th and the 90th percentile values were 145 and 286 mm^2 respectively. Hence UCCSA< 145 mm^2 were categorized as lean cord and those with UCCSA> 286 mm^2 were categorized as large cord (Table 1). Those between 145 and 286 mm^2 were categorized as normal cord. 79.2% of the women had a normal cord.

The mean birth weight of the neonates at the time of birthwas 2943 grams with astandard deviation of 413 grams. The birth weight was in the range of 1740 – 4180 grams.The 10th and the 90th percentile values

Table 1: Categories of UCCSA

Type of Umbilical cord	UCCSA (mm²)	N = 250	%
Lean	<145	27	10.80
Large	>286	25	10.00
Normal	145- 286	198	79. 20

were 2400 and 3499 grams respectively. Hence cases with birth weight < 2400 grams were categorized as small for gestational age (SGA) infants and those with birth weight > 3499 grams were categorised as macrosomic infants.

There were a total of 28 (11.2%) women in the SGA group, 23 (9.2%) in the macrosomic group and 199 (79.6%) in the normal birth weight group (Table 2).

The UCCSA values were further divided into 8 groups at intervals of 25 mm^2 and comparison of means of neonatal birth weight in each group was further analysed using ANOVA.

Table 2: Categories of birth weight

Birth Weight Classifier	Birth weight (grams)	N = 250	%
SGA	< 2400	28	11.20
Macrosomia	>3499	23	09.20
Normal	2400 - 3499	199	79.60

Table 3 shows mean neonatal weight and standard deviation in each group. It was found that as the UCCSA range increased, there was gradual increase in the neonatal birth weight and this was statistically significant (p <0.01).

Figure 2 shows Box and Whisker plot analysis showing relationship between neonatal birth weight and UCCSA groups showing fivenumber summary i.e., minimum, first quartile, median, third quartile, and maximum in a graphical representation. It can be visually seen that lower order UCCSA groups had lower values and higher order UCCSA groups had higher values, again indicating that neonatal birth weight increases as the UCCSA range increases. Table 4 shows precisely the various values of Box and Whisker plot statistics. Figure 3 shows scatter plot of UCCSA in *X* axis and neonatal birth weight in *Y* axis. Curve fitting analysis was done to know which type of growth curve explains the relationship between these two variables by comparing R values (Table 5). Both exponential and polynomial functions explained the relationship accurately, compared to linear fit.

In our study proportion of cases with a lean umbilical cord was significantly higher in the group of small for gestational group (60.7%) compared with other group (4.5%). This difference was statistically significant (Table 6).

Similarly proportion of cases with a large umbilical cord was significantly higher in the group of macrosomic (65.2%) compared with non macrosomic infants (4.4%). This difference was also statistically significant (Table 7).

Table 3: Correlation between UCCSA groups and neonatal birth weight

UCCSA Groups	UCCSA Range (mm²)	n (%)	Mean BW (gm)	SD (gm)
1	100 - 125	9 (3.6%)	2000	177
2	126 - 150	25 (10.0%)	2460	180
3	151 - 175	41 (16.4%)	2642	227
4	176 - 200	58 (23.2%)	2883	159
5	201 - 225	46 (18.4%)	3051	147
6	226 - 250	21 (8.4%)	3218	182
7	251 - 275	18 (7.2%)	3384	225
8	276 - 300	32 (12.8%)	3498	274

P value <0.01 (Anova), F= 123, Highly Significant

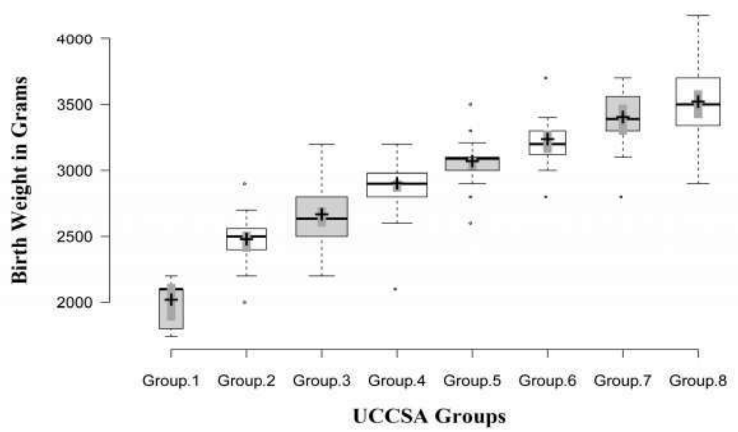

Fig. 2: Relationship between birthh weight & UCCSA using Box and Whisker plot analysis

Table 4: Box and Whisker Plot Statistics of eight UCCSA groups

Parameters	Group1	Group2	Group3	Group4	Group5	Group6	Group7	Group8
Upper whisker	2200	2700	3200	3200	3210	3400	3700	4180
3rd quartile	2100	2560	2800	2980	3100	3300	3560	3700
Median	2100	2500	2635	2900	3090	3200	3390	3500
1st quartile	1800	2400	2500	2800	3000	3120	3300	3340
Lower whisker	1740	2200	2200	2600	2900	3000	3100	2900
n	9	25	42	58	46	21	18	31
Mean	2000	2460	2642	2883	3051	3218	3384	3498

n=no. of data points (patients in each group)

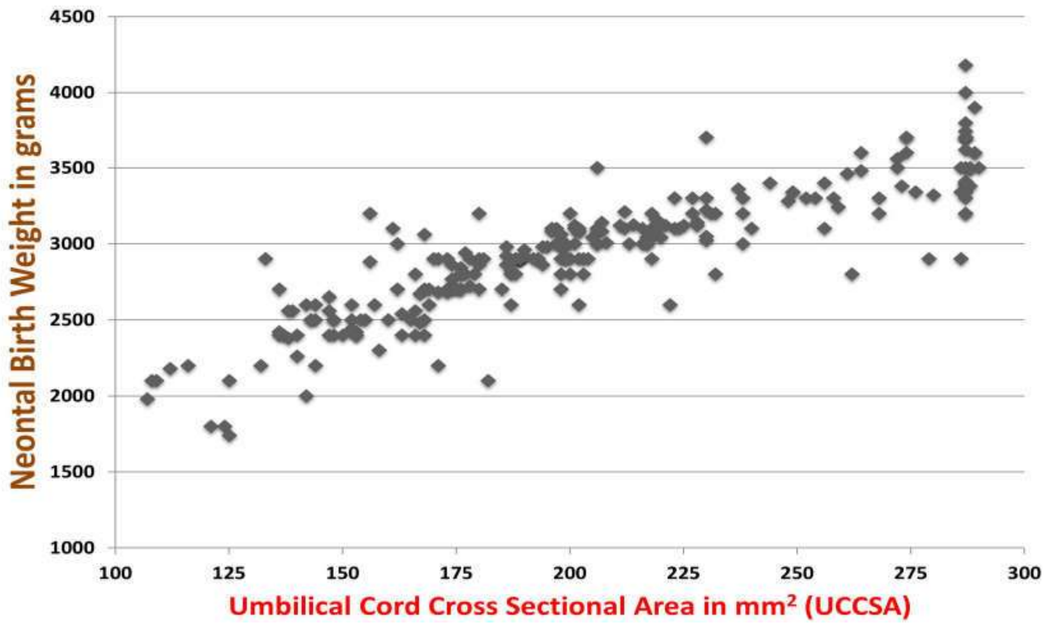

Fig. 3: Scatter plot showing UCCSA in X axis and BW in Y axis

Table 5: Relationship between neonatal birth weight and UCCSA

Type of Association	Formula	Coefficients of formula				Coefficient of Correlation (R)
		a	b	c	d	
A. Polynomial	y=a+bx+cx^2+dx^3	-2.742	2.492	-0.06353	0.00006846	0.9055
B. Exponential	y=a(1-exp(-bx)	4328.8	0.005775	-	-	0.9054
C. Linear	y=a+bx	1293.6	8.079	-	-	0.8773

y=dependent variable (birth weight in grams), x=independent variable (UCCSA in mm^2)

Table 6: Comparison of lean umbilical cord with Small for Gestational Age (SGA)

UCCSA (mm^2)	Birth weight <2400g n (%)	Birth weight ≥ 2400 g n (%)	P Value*
< 144	17 (60.7)	10 (4.5)	<0.001
≥ 144	11 (39.3)	212 (95.5)	

*Chi Square test Test

Table 7: Comparison of lean umbilical cord with Small for Gestational Age (SGA)

UCCSA (mm^2)	Birth weight > 3499 g n (%)	Birth weight ≤ 3499 g n (%)	P Value*
>286	15 (65.2)	10 (4.4)	<0.001
≤ 286	08 (34.8)	217 (95.6)	

**Chi Square test*Test

Discussion

The umbilical cord is the major link that providescommunication between the placenta and the foetus. It contains porous Wharton's jelly which acts like a protective cushion for its contents, i.e. two umbilical arteries and one umbilical vein, preventing them from getting compressed and there by maintaining blood flow to the foetus [14].

There is a progressive increase of the umbilical cord diameter and cross-sectional area up to 34 weeks of gestation. Weissman et al. extensively studied diameters of umbilical cord and its vessels from 8 weeks of gestation till term and they found that these measurements are directly correlated to gestational age only up to 34 weeks of gestation and there after umbilical cord parameters remain static till term [15]. The variations in cord area seen after 34 weeks is essentially a function of foetal weight, meaning leaner the umbilical cord, smaller is the foetus and vice versa, the thicker the cord, larger is the baby. This is the reason why we recruited our patients only after 34 weeks of gestation.

In our study proportion of cases with a lean umbilical cord was significantly higher in the group of small for gestational group (60.7%), compared with other group (4.5%). Morteza T et al. studied the relationship of sonographic measurements of umbilical cord thickness, cross-sectional area, and coiling index with pregnancy outcome (low birth weight, meconium staining) [13]. A total of 223 singleton pregnant women were studied after 20 weeks of gestation. In these patients, the diameter, cross-sectional area, and coiling index were measured in a free loop of umbilical cord. A statistically significant correlation was observed between small umbilical cord thickness and cross-sectional area and low birth weight (LBW) and meconium staining, with sensitivity of 52.9% and 57.9%, specificity of 95.0% and 94.4%, positive predictive value of 52.6% and 52.0%, and negative predictive value of 95.0% and 95.0% respectively. Also noted was significant correlation between small umbilical cord thickness and cross-sectional area with meconium staining ($p<0.001$).

Ghezzi F et al investigated the role of altered in umbilical cord vessel morphometry in assessing adverse perinatal outcome among fetuses especially when associated with lean umbilical cord on sonography [16]. They enrolled 160 fetuses with a sonographically lean umbilical cord (cross-sectional area below the 10^{th} percentile for gestational age) after 20 weeks of gestation. Outcome variables investigated were perinatal death, admission to the neonatal intensive care unit, intrauterine growth restriction, and 5-minute Apgar score. It was found that the proportions of perinatal death (1/96 versus 6/64, $p < 0.05$) and admission to the neonatal intensive care unit (17/96 versus 22/64, $p < 0.05$) was significantly higher among fetuses with an umbilical area below or equal to the 10^{th} percentile for gestational age than among those with an umbilical area greater than the 10^{th} percentile. They concluded that among fetuses with a sonographically lean umbilical cord, a significant relationship exists between an umbilical area below or equal to the 10^{th}percentile and an adverse neonatal outcome.

Al Heshimi studied relationship between umbilical cord circumference and birth weight in fifty singleton gravidae between 32 - 42 weeks who were admitted in labor and delivered within 12-24 hours [17]. Ultrasound measurement of umbilical cord circumference was obtained from cross sectional three vessel view of a free loop. Umbilical cord circumference correlated with birth weight, ($r = 0.8$, $p <0.001$). A simple regression equation was formulated which could give an estimation of fetal weight (Birth weight (gm) = C2 + 35 C (mm), where C is the umbilical cord circumference).

We observed that proportion of cases with a large umbilical cord was significantly higher in the group of macrosomic (65.2%) compared with non macrosomic infants (4.4%). Cromi and associates with the objective of determining relationship between a large cross-sectional area of the umbilical cord and fetal macrosomia, studied 1026 consecutive singleton pregnancies with duration of gestation beyond 34 weeks [12]. They measured cross-sectional areas of the umbilical cord, the umbilical vessels and the Wharton's jelly in a free loop of the umbilical cord using ultrasound. The proportion of cases with a large umbilical cord was significantly higher in the group of macrosomic compared with non-macrosomic infants (54.7% vs. 8.7%, $p < 0.0001$). The sensitivity, specificity and positive and negative predictive values of a sonographic large umbilical cord were 54.7%, 91.3%, 25.4%, and 97.4%, respectively. The combination of abdominal circumference > 95^{th}centile and large cord predicted 100% of macrosomic infants.

Henan and coworkers studied whether addition of UCCSA to Hadlock formula improves birth weight prediction [18]. They found that cross sectional area of umbilical cord was more accurate in predicting birth weight than fetal anthropometric parameters such as biparietal diameter, head circumference, abdominal circumference and femur length. These findings indicate that more soft tissue parameters for example, cord area, Wharton jelly content, foetal fat distribution should be comprehensively assessed in evaluating extremes of foetal weight ranges; small for gestational age as well as foetal macrosomia.

Conclusion

There is a positive correlation between umbilical cord cross sectional area and birth weight. As umbilical cord cross sectional area increases, there is increase in mean birth weight. Sonographic assessment of umbilical cord area may improve the prediction of fetal growth restriction and macrosomia.

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Conflict of interest: None.

Ethical approval: The study was approved bytheInstitutional Scientific Committee.

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