



Umbilical Artery Doppler Indices Difference and Umbilical Cord Length: An Observational Study

Nesreen Fathy Ahmed Eisa; Moustafa Mahmoud Abdel Kawi;
Mohamed Samir Sweed, Eman AbdElSalam NasrELDin

¹ Radiodiagnosis Department, Faculty of Medicine, Helwan University, Egypt.

² Obstetrics and Gynecology Department, Faculty of Medicine, Ain Shams University, Egypt.

Corresponding authors: Nesreen F.A. Eisa , email: nesrina.nf89@gmail.com

ABSTRACT

The umbilical cord (UC) is responsible for transporting nutrients and oxygen through the fetal circulatory system. Abnormal UC length has been linked to adverse pregnancy outcomes. Doppler evaluation of the UA is a cheap, safe, and practical approach and does not require any special equipment. However, there is no defined method for measuring or predicting the length of the UC in the fetal period so far. This study investigates whether Doppler indices difference between placental and fetal ends of the UA is related to UC length or not. **Patients and Methods:** 120 singleton pregnant women at term candidate for elective cesarean section were recruited from the outpatient clinic of both Helwan University Hospital and Ain Shams University Maternity Hospital. Women who were recommended for study were examined by Doppler ultrasound on umbilical artery at fetal end, placental end and free loop for about seven minutes then Doppler indices were saved to be compared of the length of the umbilical cord after delivery, outcome complications, gestational age at delivery and (sex, weight, Apgar score) of the fetus. **Results:** In our study, there was significant negative correlation between umbilical cord length and umbilical artery S/D and RI at placental end. While there was no significant correlation between umbilical cord length and Doppler indices at fetal end and free loop. Also, there was statistically non-significant correlation between umbilical cord length and umbilical artery PSV, PI or EDV at placental end. There was statistically non-significant correlation between difference in PSV, EDV, PI, SD or RI and umbilical cord length. Our study showed 2 groups of umbilical cord length: group for the long cords and the other for the normal umbilical cords as no short chord was found in measurements. There was statistically significant difference of Doppler indices between two groups as regard PSV ratio at placental end which was significantly higher in patients with long umbilical cord and PI in fetal end which was higher in normal length cords. **Conclusion:** there is no significant correlation between difference in Doppler indices and umbilical cord length. PSV, EDV, S/D, PI and RI have highest value at fetal end which decrease at free loop and low level at placental end. PSV at placental end is higher in patients with long cords. There is high significant negative correlation between umbilical cord length and APGAR score.

Keyword: Doppler indices, umbilical cord length, placental end, fetal end, free loop.

Introduction

The umbilical cord (UC) is responsible for transporting nutrients and oxygen through the fetal circulatory system; therefore, it is very important for both the development of the fetus and the fetal and neonatal wellbeing (1).

At term fetuses, the UC is about 50–60 cm in length. A long cord is defined as >100 cm and a short cord as < 30 cm (2). Abnormal UC length has been linked to adverse pregnancy outcomes. Short cords have been associated with a delay in second stage of labor, inversion of uterus, birth asphyxia, cord herniation, irregular fetal heart rate, placental abruption, rupture of UC, and finally neonatal complications. Controversially, long UC may lead to cord prolapse, torsion, true knot entanglement around the fetus, and delivery complications (3,4). UC length is thus a significant factor when assessing fetal risk (5). The umbilical arteries are the most commonly examined vessels in the assessment of fetal circulation. They provide information on the fetoplacental capillary bed; where resistance is increased, investigation of the UAs allows early detection of risk to the fetus (5).

Doppler evaluation of the UA is a cheap, safe, and practical approach and does not require any special equipment (6). It is relatively easy to carry out even in the later weeks of pregnancy thanks to the length and variable course of the UC. Due to the flexibility of the cord, vessels can usually be examined at the appropriate angle for good quality spectral curves (5).

The umbilical artery (UA) is the longest blood vessel in the human fetus and the UA Doppler indexes are known to vary along the length of the UC (7,8).

When considered that the UC is a closed vessel segment which has one side at placenta and the other side at fetus, the difference of Doppler indexes which measured on both sides of UC may be related with UC length. However, there is no defined method for measuring or predicting the length of the UC in the fetal period so far (6). Antenatal estimation of cord length is extremely difficult (5).

This study investigates whether Doppler indices difference between placental and fetal ends of the UA is related to UC length or not.

Patients and methods:

A prospective observational study was conducted at Helwan University Hospital and Ain Shams University Maternity Hospital from June 2021 to June 2022 on 120 singleton pregnant women at term candidate for elective cesarean section.

All recruited women were subjected to:

- A thorough history and examination: History was taken (eg. for detection of smoking and medical history for pre-existing diseases) then clinical examination was done to exclude any diseases such as preeclampsia, after that revision of the previous ultrasound for detection of fetal anomalies, oligohydramnios, intrauterine growth retardation, placental abruption, umbilical cord abnormalities (true knot, nuchal cord.... etc).

A color Doppler unit (SAMSUNG MEDISON CO, LTD, Korea MODEL H60 or TOSHIBA Aplio 400, Toshiba medical systems, Japan) with a 3.5-MHz convex probe was used to perform all ultrasonographic measurements.

Gestational age was confirmed based on fetal measurements and the date of last menstruation.

An umbilical artery Doppler ultrasound at; fetal end, free loop and placental end was done during her visit in the third trimester, time of examination was estimated to be 10 to 15 minutes. Doppler indices (Systole/diastole (S/D) rate, resistance index (RI), and pulsatility index (PI), peak systolic velocity (PSV), and end-diastolic velocity (EDV) were calculated for each site of UA and compared to the length of umbilical cord after delivery.

Following delivery, the entire UC was measured in centimeters from the placental end (PE) of the cord to the umbilical stump on the baby. The outcome of pregnancy was noted including complications, gestational age at delivery, fetal Sex, birth weight, and APGAR score.

Statistical analysis:

Data collected and analyzed using Microsoft Excel software. Data were then imported into Statistical Package for the Social Sciences (SPSS version 20.0) software for analysis. According to the type of data qualitative represent as number and percentage, quantitative continues group represent by mean $\pm$ SD. Differences between quantitative independent multiple by ANOVA. ROC curve are done. P value was set at <0.05 for significant results & <0.001 for high significant result.

Results

The present study showed clinico-demographic characteristics of the studied women. The age of women ranged from 18 to 42 years with mean age 27.92 ± 5.83 years. The mean BMI was 29.4 ± 4.17 Kg/m². The gravidity ranged from 1.0 to 6.0 with median 3 with IQR (2-4). The gestational age calculated by LMP ranged from 37 to 41 weeks with median 38 weeks and IQR (38-39) weeks while the gestational age calculated by US ranged from 36 to 41 weeks with median 38 weeks and IQR (38-39) weeks (**Table 1**).

Regarding umbilical artery indices detected by Doppler at the fetal end, the mean PSV and EDV were 46.53 ± 10.48 and 20.49 ± 5.44 respectively. The mean S/D, RI and PI were 2.35 ± 0.4 , 0.56 ± 0.07 and 0.89 ± 0.29 respectively (**Table 2**).

Regarding umbilical artery indices at free loop detected by Doppler, the mean PSV and EDV were 44.68 ± 9.62 and 20.23 ± 5.46 respectively. The mean S/D, RI and PI was 2.26 ± 0.51 , 0.55 ± 0.07 and 0.8 ± 0.18 respectively (**Table 3**).

Regarding umbilical artery indices at placental end detected by Doppler, the mean PSV and EDV were 38.8 ± 10.52 and 18.38 ± 5.19 respectively. The mean S/D, RI and PI were 2.09 ± 0.37 , 0.51 ± 0.08 and 0.74 ± 0.16 respectively (**Table 4**).

The mean $\pm$ SD of umbilical cord length was 57.53 ± 10.41 cm and ranged from 30 cm to 84 cm (**Table 5**).

Neonatal outcome concerning newborn sexes (54.2% males and 45.8% females) with mean birth weight was 3220.42 ± 475.96 grams. The mean Apgar score at 1 minute was 8.34 ± 0.9 and ranged from 7 to 10 while the mean Apgar score at 5 minutes was 9.73 ± 0.63 and ranged from 8 to 10 (**Table 6**).

There was no significant correlation between umbilical cord length and Doppler indices at fetal end including PSV, EDV, S/D, RI as well as PI ($P>0.05$) (**Table 7**).

There was no significant correlation between umbilical cord length and Doppler indices at free loop including PSV, EDV, S/D, RI as well as PI ($P>0.05$) (**Table 8**).

There was significant negative correlation between umbilical cord length and umbilical artery S/D and RI at placental end (**Figure 1 & 2**).

There is significant difference between Doppler indices at placental end, free loop and fetal end. PSV, EDV, SD, PI and RI have highest value at fetal end which decreases in free loop and low level is at placental end (**Figure 3**).

There is statistically non-significant correlation between difference in PSV, EDV, PI, SD or RI and umbilical cord length (**Table 9**).

There was a high significant negative correlation between umbilical cord length and APGAR score at 5 minutes (**Figure 4**).

As short cords were defined as < 30 cm and long cords > 70 cm in length (**9**). Umbilical cord length of our studied cases ranged from 30 to 84 cm, so there was no short cords and we divided the cases into: **Group (A)** cases with normal umbilical cord length (n= 103, 85.8%), **Group (B)** cases with long umbilical cord length (n= 17, 14.2%).

There was no statistically significant difference between the two group regarding age, BMI, gravidity and gestational age (p>0.05) (**Table 10**).

Table 1: Demographic and clinical characteristics of the studied cases.

Parameters		Studied patients (n= 120)
Age (years)	Mean± SD	27.92 ± 5.83
	Range	18.0 – 42.0
BMI (Kg/m ²)	Mean± SD	29.4 ± 4.17
	Range	21.0 – 35.0
Gravidity	Median (IQR)	3(2 – 4)
	Range	1.0 – 6.0
Gestational age by LMP (weeks)	Median (IQR)	38(38 – 39)
	Range	37 – 41
Gestational age by US (weeks)	Median (IQR)	38(38 – 39)
	Range	37.0 – 41.0

SD= standard deviation, n: number,

Table 2: Umbilical artery Doppler indices at the fetal end among the studied cases.

	Studied cases (n= 120)			
	Mean	± SD	Min.	Max.
PSV	46.53	10.48	23.99	69.8
EDV	20.49	5.44	11.4	37.80
S/D	2.35	0.4	1.6	3.37
RI	0.56	0.07	0.41	0.70
PI	0.89	0.29	0.52	2.14

Table 3: UA Doppler indices at free loop among the studied cases.

	Studied cases (n= 120)			
	Mean	± SD	Min.	Max.
PSV	44.68	9.62	21.2	60.8
EDV	20.23	5.46	7.70	30.90
S/D	2.26	0.51	0.50	4.4
RI	0.55	0.07	0.36	0.77
PI	0.8	0.18	0.45	1.7

Table 4: UA Doppler indices at placental end among the studied cases.

	Studied cases (n= 120)			
	Mean	± SD	Min.	Max.
PSV	38.8	10.52	15.5	64.2
EDV	18.34	5.19	8.5	30.40
S/D	2.09	0.37	1.6	3.4
RI	0.51	0.08	0.38	0.71
PI	0.74	0.16	0.48	1.24

SD= standard deviation, n: number,

Table 5: Mean of ± SD of umbilical cord length in the studied cases.

Parameters	Studied patients (n= 120)	
Umbilical cord length (cm)	Mean± SD	57.53 ± 10.41
	Range	30.0 – 84.0

SD= standard deviation,

Table 6: Distribution of studied cases regarding neonatal outcome.

Parameters		Studied cases (n= 120)	
		n	%
Sex of newborn	Female	55	45.8%
	Male	65	54.2%
Birth weight (gram)	Mean± SD	3220.42 ± 475.96	
	Range	2500.0 – 4000.0	
Apgar score (at 1 Min.)	Mean± SD	8.34 ± 0.9	
	Range	7.0 – 10.0	
Apgar score (at 5 Min.)	Mean± SD	9.73 ± 0.63	
	Range	8.0 – 10.0	

n: number, %: percentage, SD= standard deviation,

Table 7: Correlation between umbilical cord length and UA Doppler indices at fetal end.

	Umbilical cord length	
	r	P- value
PSV	-0.015	0.87
EDV	0.078	0.397
S/D	-0.091	0.323
RI	-0.103	0.264
PI	-0.171	0.062

r: Pearson correlation coefficient

Table 8: Correlation between umbilical cord length and UA Doppler indices at free loop.

UA at free loop	Umbilical cord length	
	r	P- value
PSV	0.032	0.762
EDV	-0.039	0.673
S/D	-0.077	0.401

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RI	0.038	0.681
PI	-0.005	0.959

r: Pearson correlation coefficient

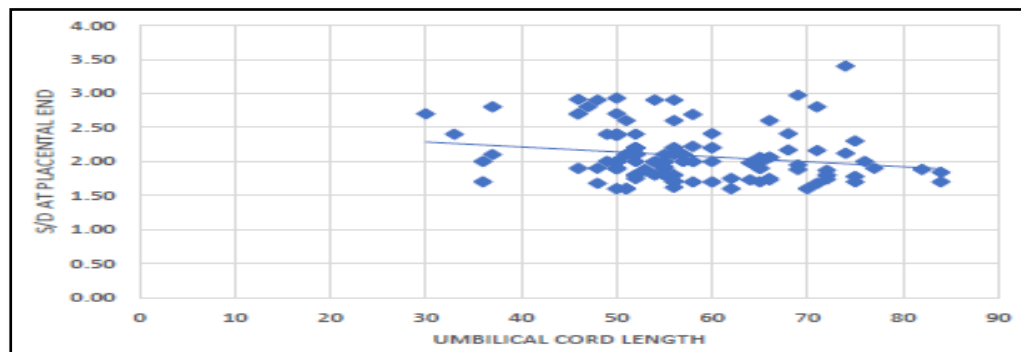


Figure (1): Scatter dot graph showing significant negative correlation between umbilical cord length and UA S/D at placental end.

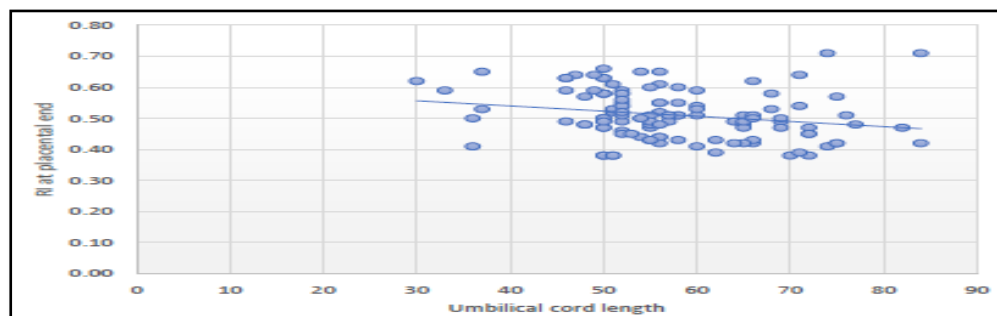


Figure (2): Scatter dot graph showing significant negative correlation between umbilical cord length and UA RI at placental end.

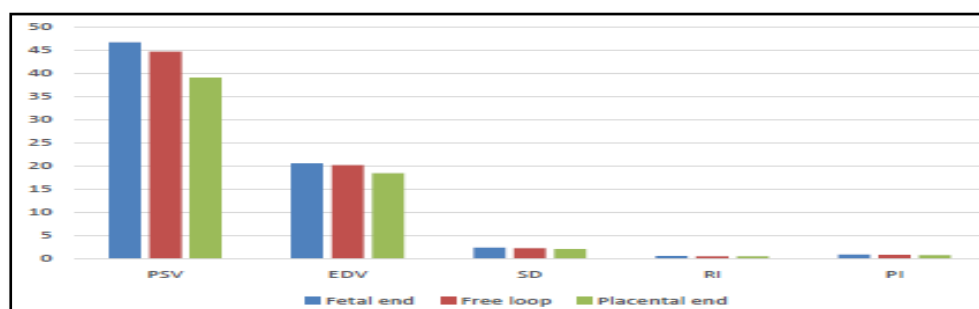


Figure (3): Multiple bar chart showing umbilical cord Doppler indices at fetal end, free loop and placental end

Table 9: Correlation between difference between placental and fetal ends Doppler measurements and umbilical cord length among studied patients:

Difference	<i>r</i>	<i>p</i>
PSV	0.083	0.367
EDV	-0.03	0.78
SD	-0.042	0.645
RI	-0.113	0.219
PI	0.054	0.562

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r Spearman rank correlation coefficient * $p < 0.05$ is statistically significant

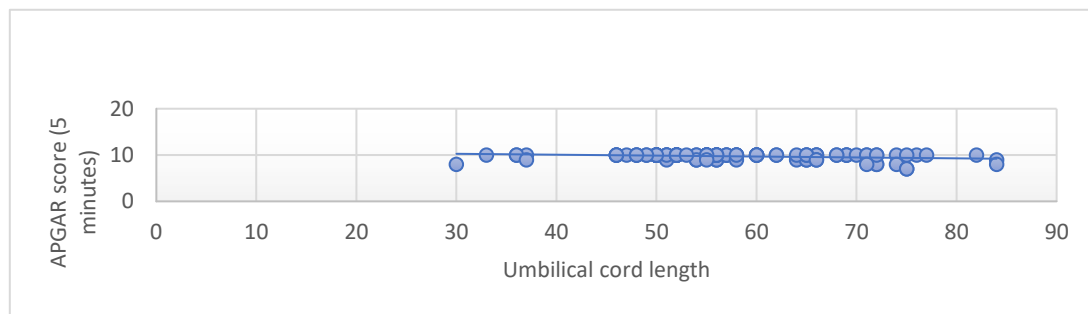


Figure (4): Scatter dot graph showing significant negative correlation between umbilical cord length and APGAR score at 5 minutes.

Group B had significantly longer umbilical cord length compared to group A ($p < 0.001$) (**Table 11**). Umbilical artery indices at fetal end among the two groups. There was statistically significant difference between the two groups regarding PI which was higher in group A. There was no statistically significant difference between the two groups regarding PSV, EDV, RI and S/D ratio ($p > 0.05$) (**Table 12**). Umbilical artery indices at free loop among the two groups. there is statistically non-significant difference between groups regarding PSV, EDV, S/D, RI and PI ($p > 0.05$) (**Table 13**).

There is statistically significant difference between groups regarding PSV ratio which is significantly higher in patients with long umbilical cord. There was no statistically significant difference between the two groups regarding S/D ratio, EDV, RI and PI ($p > 0.05$) (**Figure 5**). There is significant difference between Doppler indices at placental end, free loop and fetal end. PSV, EDV, SD, PI and RI have highest value at fetal end which decreases in free loop and low level is at placental end (**Table 14**).

There is significant difference between Doppler indices at placental end, free loop and fetal end. EDV, SD, and RI have highest value at fetal end which decreases in free loop and low level is at placental end. PSV, and PI have highest value at free loop which decreases in fetal end and low level is at placental end (**Table 15**). There is non-significant correlation between difference in PSV, EDV, SD, PI or RI and umbilical cord length among normal cord group (**Table 16**). There is non-significant correlation between difference in PSV, EDV, SD, PI or RI and umbilical cord length among long cord group (**Table 17**). Neonatal outcome among the two groups. APGAR score at 5 minutes was significantly higher in group A. There was no statistically significant difference between the two groups regarding sex of newborn, birth weight & APGAR at 1st minute or birth weight (**Figure 6**).

Table 10: Comparison between the two groups regarding demographic characteristics.

		Group A (n = 103)	Group B (n = 17)	P-value
Age (years)	Mean $\pm$ SD	28.06 $\pm$ 6.01	27.06 $\pm$ 4.71	0.515
BMI (Kg/m ²)	Mean $\pm$ SD	29.46 $\pm$ 4.21	29.06 $\pm$ 4.05	0.718
Gravidity	Median (IQR)	3 (2-4)	2 (2-4)	0.248
Gestational age by LMP (weeks)	Median (IQR)	38 (38-39)	39 (37-40)	0.522
Gestational age by US (weeks)	Median (IQR)	38 (38-39)	37 (37- 40)	0.983

t independent sample *t* test

Table 11: Comparison between the two groups regarding umbilical cord length.

		Group A (n = 107)	Group B (n = 13)	t	P-value
Umbilical cord length	Mean± SD	54.61 ± 7.94	75.18 ± 4.35	-15.664	<0.001**
	Range	35.0 – 70.0	71.0 – 84.0		

t independent sample t test **p≤0.001 is statistically highly significant

Table 12: Comparison between the two groups regarding umbilical artery Doppler indices at fetal end.

	Group		p
	Group A	Group B	
	Mean ± SD	Mean ± SD	
PSV	46.59± 10.46	46.14 ± 10.89	0.87
EDV	20.32 ± 5.24	21.47± 6.64	0.423
S/D	2.35 ± 0.4	2.32 ± 0.43	0.736
RI	0.56 ± 0.07	0.56 ± 0.08	0.594
PI	0.91± 0.3	0.74 ± 0.17	0.024*

t independent sample t test

Table 9: Comparison between the two groups regarding umbilical artery Doppler indices at free loop.

Free lobe	Group		p
	Group A	Group B	
	Mean ± SD	Mean ± SD	
PSV	44.38± 9.97	46.52 ± 7.05	0.288
EDV	20.15± 5.7	20.71 ± 3.61	0.699
S/D	2.29 ± 0.53	2.1± 0.36	0.149
RI	0.55 ± 0.07	0.55 ± 0.05	0.91
PI	0.81 ± 0.19	0.76 ± 0.12	0.321

t independent sample t test

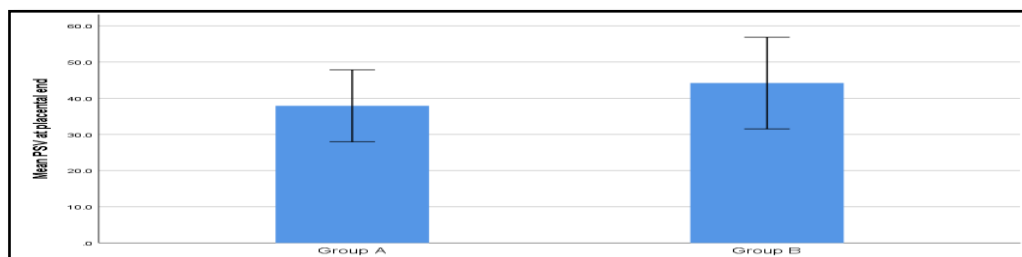


Figure (5): Simple bar chart showing relation between long umbilical cord and PI at placental end.

Table 10: The difference in the umbilical artery Doppler parameters between different sites of insonation among normal cord length group.

Doppler indices	Fetal end	Free loop	Placental end	P value
S/D ratio	2.35±0.4	2.29±0.53	2.1±0.36	0.03
RI	0.56±0.7	0.55±0.07	0.51±0.07	0.007
PI	0.91±0.3	0.81±0.19	0.74±0.15	0.001
PSV	46.59±10.46	44.38±9.97	37.91±9.94	0.001
EDV	20.32±5.24	20.15±5.7	18.17±5.04	0.01

P for repeated measure ANOVA.

Table 11: The difference in the umbilical artery Doppler parameters between different sites of insonation among long cord group.

Doppler indices	Fetal end	Free loop	Placental end	P value
S/D ratio	2.32±0.43	2.1±0.36	2.03±0.45	0.008
RI	0.56±0.08	0.55±0.05	0.5±0.1	0.001
PI	0.74±0.17	0.76±0.12	0.75±0.2	
PSV	46.14±10.89	46.52±7.05	44.2±12.73	
EDV	21.47±6.64	20.71±3.61	19.41±6.06	0.01

P for repeated measure ANOVA.

Table 16: Correlation between difference between placental end and fetal end Doppler measurements and umbilical cord length among normal cord length group:

Difference	r	p
PSV	-0.063	0.531
EDV	-0.066	0.513
SD	-0.057	0.574
RI	-0.15	0.134
PI	-0.063	0.529

r Spearman rank correlation coefficient.

Table 17: Correlation between difference between placental end and fetal end Doppler measurements and umbilical cord length among long cord group:

Difference	r	p
PSV	-0.242	0.319
EDV	-0.082	0.738
SD	0.099	0.686
RI	0.265	0.272
PI	0.395	0.094

r Spearman rank correlation coefficient.

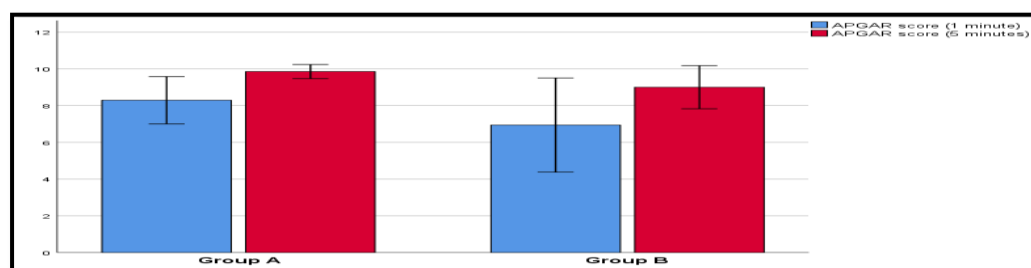


Figure (6): Multiple bar chart showing relation between long cord and APGAR at 1st and 5th minutes.

Case Presentation

Case 1: Pregnant women aged 29 years old with BMI 32 & gravidity (G) 3. Her GA by LMP was 38+2d & 38w+0d by US. The delivered baby was female weighting 3.6 kg at birth with APGAR score of 10 at the 1st & 5th minutes. The umbilical cord length was 55 cm. Doppler indices were PSV=40.3 EDV=13.9; PI=0.97; RI=0.65; S/D=2.89 at fetal end Doppler indices were PSV=24.1; EDV=9.8; PI=3.15; RI=0.59; S/D=2.46 at free loop and Doppler indices were PSV=37.9; EDV=19.7; PI=0.64; RI=0.48; S/D=1.92 at placental end. APGAR score at 5th minute is higher at group A, RI & S/D had highest value at fetal end and

decreased at free loop with lowest value at placental end and that correlate with our results (Figure 7).

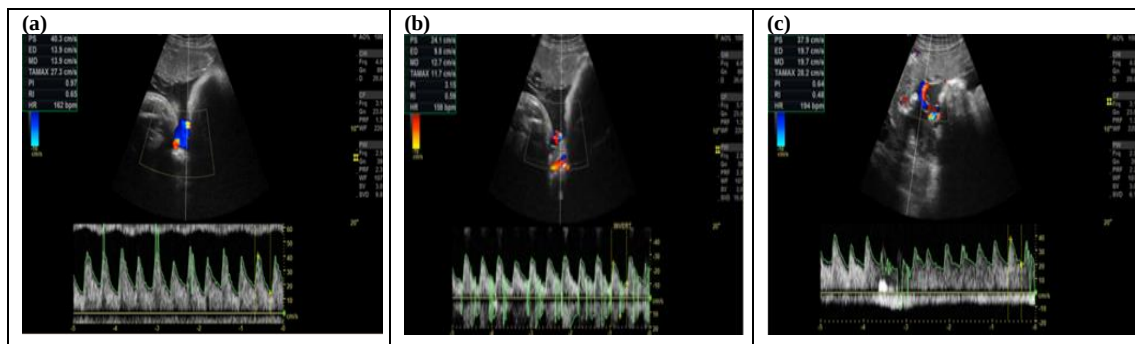


Figure (7): Showing Umbilical artery Doppler assessment in the three potential sites: (a) Fetal end; (b) free loop; (c) Placental end of umbilical artery at the day of the delivery.

Case (2): group (B)

Pregnant women aged 25 years old with BMI 35 & gravidity (G) 3. Her GA by LMP was 38+1d & 38w+0d by US. The delivered baby was female weighting 4 kg at birth with APGAR score of 8 at the 1st minute & 10 at the 5th minute. The umbilical cord length was 66 cm. Doppler indices were PSV=39.9; EDV=16.3; PI=0.94; RI=0.59; S/D=2.44 at fetal end . Doppler indices were PSV=52; EDV=29.5; PI=0.54; RI=0.43; S/D=1.76 at free loop and Doppler indices were PSV=36.6; EDV=21.2 PI=0.54; RI=0.42; S/D=1.73 at placental .PSV had highest value at free loop ,decreased at fetal end with lowest value at placental end. RI & S/D had highest value at fetal end, decreased at free loop with lowest value at placental end. RI & S/D of placental end had negative correlation to umbilical cord length (Figure 8).

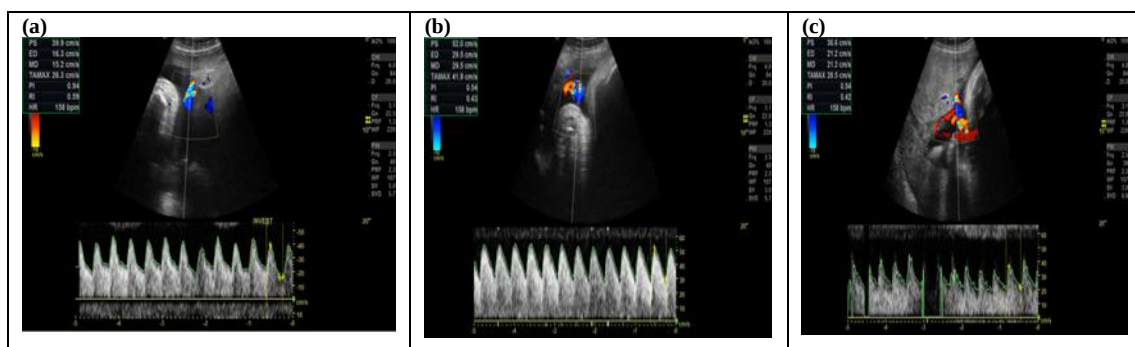


Figure (8): Showing Umbilical artery Doppler assessment in the three potential sites: (a) Fetal end; (b) free loop; (c) Placental end of umbilical artery at the day of the delivery.

Discussion

The umbilical cord is the vital connection between the fetus and the placenta. Umbilical cord development begins in the embryologic period around week 3 and by the week 7, the umbilical cord has fully formed. Cord length at term has appreciable variation, with extremes ranging from no cord (achordia) to lengths up to 300 cm. At birth, the mature cord is about 50–60 cm in length and 12 mm in diameter. As short cords were defined as < 30 cm and long cords > 70 cm in length (9). UC length is a significant factor when assessing fetal risk. Antenatal estimation of cord length is however extremely difficult (4).

Umbilical arterial (UA) Doppler assessment is used in surveillance of fetal well-being in the third trimester of pregnancy. Doppler ultrasound enables investigators to deduce the

state of the fetoplacental vascular bed, providing essential information on the condition of the fetus (10).

The study was conducted on 120 singleton pregnant women at term candidate for elective cesarean section recruited from the outpatient clinic of both Helwan University Hospital and Ain Shams University Maternity Hospital. The aim of our study was to investigate the relation between umbilical arteries Doppler indices difference between placental and fetal ends and umbilical cord length.

In our study, there was significant negative correlation between umbilical cord length and umbilical artery S/D and RI at placental end. While there was no significant correlation between umbilical cord length and Doppler indices at fetal end and free loop including PSV, EDV, S/D, RI as well as PI ($P > 0.05$). Also, there is statistically non-significant correlation between umbilical cord length and umbilical artery PSV, PI or EDV at placental end.

It is demonstrated that the location of the Doppler sampling site in the UC affects the Doppler waveform and the impedance indices are significantly higher at the FE of the cord than at the PE in several studies: **Mine et al. (11)**; **Vieyres et al.(12)**; **Khare, (13)**.

In our study, there is significant difference between Doppler indices at placental end, free loop and fetal end. PSV, EDV, SD, PI and RI have highest value at fetal end which decreases in free loop and low level is at placental end.

In agreement with our results **Gur et al. (6)** that studied variation in Doppler indices along the length of UC from intra-abdominal to placental insertion reported that the highest mean values for PSV,EDV, PI, RI &S/D were obtained from the intra-abdominal portion site, followed in a descending order by fetal end, free loop, and placental end.

Acharya et al. (14) have taken repeated measurements of the umbilical artery indices in 133 low-risk pregnancies at the intra-abdominal portion, fetal end, and placental end of the cord. They found that the mean umbilical artery PI was higher at the intra-abdominal portion and fetal end than at the placental end of the cord.

Mehalek et al. (15) performed pulsed Doppler duplex sonography on 58 pregnant patients, measuring umbilical artery waveforms at the fetal abdomen and near the placental end of the cord. Their results showed that the mean PI was significantly higher at the fetal site than the placental site (1.6 ± 0.4 and $\pm 1.1 \pm 0.2$, respectively, $p < 0.01$). Similar significant differences were also observed in S/D and RI between the two sites.

Sonesson et al. (16) studied umbilical artery Doppler waveforms in 269 normal pregnancies. They concluded that the S/D ratio, PI, and RI were significantly higher at the fetal end of the cord compared to the measurements obtained at placental end, regardless of the gestational age.

Correlation between difference between placental and fetal ends Doppler measurements and umbilical cord length among studied patients was done in this study. There was statistically non-significant correlation between difference in PSV, EDV, PI, SD or RI and umbilical cord length.

In disagreement with our study **Gur et al. (6)** found that the mean differences (delta values) of UA PSV between the fetal and PEs were correlated with UC length ($c = 0.32$, $p = .04$) but the study was carried out with smaller sample of women (74 women).

In study by **Olaya et al. (4)** found that flow velocities in the two edges were different: fetal edges exhibited greater velocity in the majority of cases; but, when they compared pressure differentials (ΔP), the pulsatility index was significantly related to umbilical cord length. They found that greater length corresponds to greater alteration in the pulsatile index but they had smaller sample size and detected few cases of interest (long and short UCs).

Our study showed 2 groups of umbilical cord length: group for the long cords and the other for the normal umbilical cords as no short chord was found in measurements. The cord length ranged from 30 to 84 cm with mean 57.53 ± 10.41 cm. There was statistically significant difference of Doppler indices between two groups (long and normal length cords) as regard PSV ratio at placental end which was significantly higher in patients with long umbilical cord and PI in fetal end which was higher in normal length cords.

In **Olaya et al. (4)** two cases with abnormally high placental PI were observed; this was associated with short UC length.

The Apgar score was developed primarily to assess term infants during a time when neonatal mortality was very high among preterm infants. The frequency of low Apgar scores increases with decreasing gestational age and may reflect biologic immaturity in preterm infants. Extremely preterm infants (<28 weeks) and very preterm infants (28 to 31 weeks) in particular may seem less vigorous and be assigned a lower score because of an immature breathing drive and lower muscle tone (17).

Our study showed that there was non-significant correlation between umbilical cord length and birth weight or APGAR at 1 minute in all studied cases. While there was a high significant negative correlation between umbilical cord length and APGAR score at 5th minute. Also, APGAR score at 5th minute was significantly higher in group A. There was no statistically significant difference between the two groups regarding sex of newborn, APGAR at 1st minute or birth weight.

Similarly, **Balkawade and Shinde (18)** that Study of length of umbilical cord and fetal outcome found that abnormal cord length cases had higher incidence of fetal heart rate abnormalities, and more chances of birth asphyxia. But cord length did not vary according to the weight, length, and sex of the baby. Also, **Shafqat et al. (19)** that study length of umbilical cord and perinatal outcome found low Apgar score was significantly high in short (30.64%) and long cords (23.89%) compared to cords with normal length ($p < 0.001$).

In **Sharma et al. (20)** a study which assessed the length of umbilical cord at term and its correlation with fetal outcome, the mean cord length was 64.2 (SD $\pm$ 17.26 cm) max 144 cm & min 16 cm. A positive correlation existed between the cord length and birth weight. There was no significant difference between sex of the fetuses and the cord length but this study was conducted to larger sample (500 patients) with 100 patients of them had comorbidities.

Also, In discordant with our results **Ogunlaja and Ogunlaja (21)** who assessed the correlation between umbilical cord length, birth weight and length of singleton deliveries at term in a Nigerian population in which there was a positive correlation between birth weight and cord length.

Limitations of this study. we investigated only UA Doppler indices, but not umbilical vein Doppler. It is demonstrated that there is significant difference at umbilical vein quantitative Doppler between the intrahepatic part and FL of umbilical vein. The quantitative Doppler value of umbilical vein may be different at the different point of umbilical vein along the UC and this difference may be related UC length.

Conclusion:

There is non-significant correlation between difference in Doppler indices and umbilical cord length. PSV, EDV, S/D, PI and RI have highest value at fetal end which decrease at free loop and low level at placental end. PSV at placental end is higher in patients with long cords. There is high significant negative correlation between umbilical cord length and APGAR score.

Recommendations:

Further multicenter studies to obtain larger sample size to prove the relation between Doppler indices and umbilical cord length with investigation of umbilical vein Doppler should be the focus of future research.

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