Ultrasound Measurement of Umbilical Vein Diameter in Normal Pregnancy and Correlation with Gestational Age and Fetal Weight

Peter Chibuzor Oriji[1], Enefia Kelvin Kiridi[2], Chioma Okechukwu[3], Akaninyene Eseme Ubom[4], Datonye Christopher Briggs[3], Johnpatrick Uchenna Ugwoegbu[5], Panebi Yao Bosrotsi[6], Abednigo Ojanerohan Addah[7], Isaac Joel Abasi[7], Adedotun Daniel Adesina[8]

[1]Department of Obstetrics and Gynaecology, Federal Medical Centre, [6]Department of Obstetrics and Gynaecology, Diete Koki Memorial Hospital, [8]Department of Medical Services, Nigerian Law School, Yenagoa Campus, Yenagoa, [2]Department of Radiology, Niger Delta University Teaching Hospital, [7]Department of Obstetrics and Gynaecology, Niger Delta University Teaching Hospital, Okolobiri, Bayelsa State, [3]Department of Paediatrics and Child Health, Rivers State University Teaching Hospital, Port Harcourt, Rivers State, [4]Department of Obstetrics, Gynaecology and Perinatology, Obafemi Awolowo University Teaching Hospitals Complex, Ile-Ife, Osun State, [5]Department of Radiology, Federal Medical Centre, Owerri, Imo State, Nigeria

Abstract

Background: With the invention of more sophisticated ultrasonography techniques, there is room to explore and better comprehend the link between gestational age (GA), fetal weight (FW), and the diameter of the umbilical vein (UV). **Aim:** To explore the relationship between umbilical vein diameter (UVD) and GA as well as FW in normal pregnancy. **Materials and Methods:** This descriptive, cross-sectional study was conducted between February and August 2022 at the obstetric units and radiology departments of two tertiary health facilities: one secondary facility and one radiodiagnostic facility in the state. A transabdominal ultrasound scan was used to assess the UV. The relationship between UVD and GA and between UVD and estimated fetal weight (EFW) was explored using Pearson's correlation analysis. A nomogram was constructed, and the level of significance was set at $P < 0.05$. **Results:** There was a very strong, positive and significant relationship between UVD and GA (r =0.63; P = 0.001) and between UVD and EFW (r = 0.57; P = 0.001). For every unit change in GA, there was a 39% change in UVD (r^2 = 0.39), while every unit change in FW was associated with a corresponding 33% change in UVD (r^2 = 0.33). The regression coefficients for GA were 0.257 (β_0) and 0.015 (β_1), while β_0 and β_1 for FW were 0.590 and 0.069, respectively. **Conclusion:** Our study revealed a very strong, positive and significant relationship between UVD and GA and between UVD and EFW.

Keywords: Fetal weight, gestational age, normal pregnancy, umbilical vein diameter

Introduction

The umbilical cord (UC) and vessels, which act as a lifeline from the placenta to the developing fetus, are crucial to the fetal development process.[1] The cord consists of two umbilical arteries (UA) and one umbilical vein (UV), all covered in Wharton's jelly. The vein has a larger diameter compared to the arteries and functions as the sole vehicle of supply of oxygenated blood, rich in nutrients from the placenta to the fetus.[2] The average diameter of the UV ranges from 2 mm at 14–15 weeks gestation to 7–8 mm at term in normal pregnancy.[3] Ultrasound detection of the UC can be achieved as early as six weeks' gestation but is usually better visualised by the eighth–ninth week of gestation.[4,5] With the invention of more sophisticated ultrasonography techniques, there is room to explore and better comprehend the link between gestational age (GA), fetal weight (FW), and the diameter of the UV.[6]

The size of the UV often is not measured or considered during routine obstetric ultrasound scan assessment of the

Access this article online	
Quick Response Code:	**Website:** www.njmonline.org
	DOI: 10.4103/NJM.NJM_104_22

Address for correspondence: Dr. Enefia Kelvin Kiridi,
Department of Radiology, Niger Delta University Teaching Hospital,
Okolobiri, Bayelsa State, Nigeria.
E-mail: kiridienefia@gmail.com

How to cite this article: Oriji PC, Kiridi EK, Okechukwu C, Ubom AE, Briggs DC, Ugwoegbu JU, *et al.* Ultrasound measurement of umbilical vein diameter in normal pregnancy and correlation with gestational age and fetal weight. Niger J Med 2022;31:640-6.

Submitted: 06-Oct-2022 **Revised:** 27-Oct-2022
Accepted: 30-Nov-2022 **Published:** 28-Feb-2023

fetus.[7] More attention is usually given to other parameters outside the UC. Earlier research has shown that assessing the diameter of the UV can assist in the early detection of some congenital anomalies associated with increased umbilical vein diameter (UVD).[7,8] It can also be useful in the early prediction of fetal intrauterine growth restriction (IUGR). The size of the UV directly impacts the velocity of blood flow and ultimately the blood supply to the growing fetus. Any compromise to the blood flow to the fetus will adversely affect its growth. A nomogram that defines the relationship between the UVD, GA, and FW will help detect early, any deviations from normal. Hence, more attention should be given to understanding the normal mean UV diameter and its variations with increasing GA and FW.

The linear diameter of the UV and the UC is known to increase with advancing GA, but the rate of increase is not known.[8,9] There have been reports showing a relationship between a small UVD and unfavorable pregnancy outcome;[10,11] however, other researchers reported no relationship between the UVD and FW in low-risk pregnancies.[12] While some studies have been done assessing the UVD and its relationship with fetal outcomes in Caucasian populations and high-risk or complicated pregnancies, there is limited information in this field on African women and low-risk pregnancies. This study, therefore, set out to explore the relationship between UVD and GA as well as FW in normal pregnancy in the African context.

Materials and Methods

Study design and setting

This descriptive, cross-sectional study was conducted at the Obstetric Units and Radiology Departments of the Federal Medical Centre, Yenagoa, Niger Delta University Teaching Hospital, Okolobiri, Diete Koki Memorial Hospital, Yenagoa, and Silhouette Radiodiagnostic Consultants, Yenagoa, all in Bayelsa State, Nigeria. It was conducted from February to August 2022. The first two study centres are tertiary health facilities that provide specialised gynaecological services to women in the state and serve as referral centres for other hospitals in the state, and surrounding states. The third study centre is a secondary health institution. The fourth study centre is the biggest radiodiagnostic institution in the state.

Sample size

This was calculated using the formula for one sample, continuous outcome variable (mean).

$n = Z\alpha^2 \times \sigma^2/\delta^2$[13,14]

Where

$Z\alpha$ = 95% confidence interval (CI), which is 1.96,

σ = standard deviation of 7.2 mm from a previous study done in Enugu, Nigeria.[15]

δ = level of precision for our study of 7%.

Therefore, a total of 423 consecutive women that presented to the antenatal clinics of the study centres during the second half of pregnancy (20–40 weeks) were selected using simple random sampling and recruited for the study.

Inclusion criteria

Women with uncomplicated singleton pregnancies, with no fetal anomaly and no co-existing maternal medical conditions.

Exclusion criteria

Fetal congenital structural and/or chromosomal anomalies, abnormal fetal growth, and multiple pregnancies.

Women who met the inclusion criteria for the study were counseled and, after obtaining written informed consent, were recruited for the study. They were referred to the radiology departments of the study centres for routine obstetric ultrasound scans (USS). The sociodemographic and obstetric characteristics, including the weight and height of the study participants, were obtained and documented in a purpose-designed pro forma. GA was calculated using the last menstrual period and first-trimester ultrasound scan.

Procedure

USS were performed transabdominally and were performed by four consultant radiologists (one for each study centre), with requisite experience in fetal USS. The four consultant radiologists involved in the study met before data collection commenced, and agreed on the appropriate landmarks and points on the UC for measurement of the UVD. Measurements were taken and cross-checked on 20 fetuses to confirm compliance and to reduce interobserver errors before the research and data collection started. Each patient took about four glasses of water, to get the urinary bladder filled, about 1 h before the procedure. A full bladder served as an acoustic window. A chaperone was present to ensure the women's comfort and ease any possible anxiety they may experience during the procedure. With the patient lying supine, and the abdomen and pelvis exposed, adequate ultrasound gel was applied to the lower abdominal wall or pelvis. The gel served to remove air from the skin, and for ease of transducer movement.

A 2012 Philips HD11 machine, fitted with a 3.5 MHz curvilinear (convex) transducer (probe), was used for the studies. The probe was moved back and forth on the skin, and in orthogonal planes, with gain adjusted, as required, for good image quality. The Hadlock method was used to calculate the fetal biometric parameters and estimated fetal weight (EFW).[16] All USS were performed in the morning and limited to 10 min per patient for uniformity. The UV diameter was measured at three different free loops along the UC, and the mean of the three measurements was noted and recorded in centimetres. This allowed for any minor disparities in the diameter of the UV along the length of the UC. Perpendicular views of the UC at maximum magnification, followed by caliper placement at the inner edge of the blood vessel, were used to obtain the internal diameter of the UV [Figure 1].

Data analysis

Data were entered into a predesigned pro forma and were analysed using Statistical Product and Service Solutions for

Figure 1: Sonogram showing measurement of umbilical vein diameter (green arrow)

Windows® version 25, SPSS Inc., Chicago, IL, USA. Results were presented in frequencies and percentages for categorical variables, and the mean and standard deviation for continuous variables after the normality (Shapiro–Wilk) test revealed that the variables were normally distributed. The relationship between the UVD and GA, EFW, parity, maternal weight, and maternal height was explored using Pearson's correlation analysis. A nomogram was constructed, giving UVD values at different GA and EFW. Interobserver and intraobserver variations were calculated with the use of the intraclass correlation coefficient (ICC) and documented. A $P < 0.05$ was taken as statistically significant set at 95% CI.

Ethics

Ethical approval for this study was obtained from the Research and Ethics Committee of the Federal Medical Centre, Yenagoa, Bayelsa State, Nigeria (FMCY/REC/ECC/2022/630).

Results

Demographic, anthropometric, and obstetric characteristics of the study participants

Four hundred and twenty-three pregnant women participated in this study, with a mean age of 27.6 ± 8.2 years. The modal age group was 25–29 years (131, 31%). The mean weight and height of the study participants were 74.9 ± 10.5 kg and 1.64 ± 0.57 m, respectively. Parity ranged from 0 to 6, with most (177, 41.8%) of the women being nulliparous. The mean GA was 32.4 ± 6.5 weeks [Table 1].

Relationship between gestational age, estimated fetal weight, and umbilical vein diameter

The mean UVD at 20 weeks' and 40 weeks' gestation was 0.51 ± 0.03 cm and 0.91 ± 0.03 cm, respectively, showing a gradual increase in mean UVD as GA increases [Table 2]. The mean UVD increased from 20 weeks' gestation until a maximum average of 0.91 ± 0.03 cm at 40 weeks' GA. The mean UVD also increased gradually with EFW, from a mean of 0.51 ± 0.02 cm among fetuses weighing 500 g to 0.94 ± 0.10 cm among those weighing 4000 g. Interobserver and intraobserver variations were assessed with the use of the ICC and are presented in Table 3.

Table 1: Maternal characteristics

Characteristics	Frequency (*n*=423), *n* (%)
Age (years)	
<20	34 (8.0)
20-24	65 (15.4)
25-29	131 (31.0)
30-34	100 (23.6)
>35	93 (22.0)
Age range (years)	16–40
Mean age±SD (years)	27.6±8.2
Weight (kg), mean±SD	74.9±10.5
Height (m), mean±SD	1.64±0.57
Parity	
Nulliparity	177 (41.8)
Primiparity	70 (16.5)
Multiparity	139 (32.9)
Grand multiparity	37 (8.7)
Median parity (range)	1 (0–6)
GA (weeks)	
20-24	70 (16.5)
25-28	57 (13.5)
29-32	68 (16.1)
33-36	150 (35.5)
37-40	78 (18.4)
GA (weeks), mean±SD	32.4±6.5

SD: Standard deviation, GA: Gestational age

Correlation between feto–maternal indices and umbilical vein diameter

There was a very strong, positive and significant relationship between UVD and GA ($r = 0.63$; $P = 0.001$), between UVD and EFW ($r = 0.57$; $P = 0.001$), and between UVD and parity ($r = 0.16$; $P = 0.001$), and for every unit change in GA, there was a 39% change in UVD ($r^2 = 0.39$), while every unit change in FW was associated with a corresponding 33% change in UVD ($r^2 = 0.33$) [Table 4]. There was no relationship between maternal height, maternal weight, and UVD; however, there was a significant relationship between parity and UVD [Table 4].

The regression coefficients for GA were 0.257 (β_0) and 0.015 (β_1), while β_0 and β_1 for FW were 0.590 and 0.069, respectively [Table 4]. The regression equations expressing the relationship between UVD and GA and between UVD and EFW are shown in Figures 2 and 3. Tables 4-6 show the reference values for UVD at different GA and EFW, respectively, as calculated from the regression equations.

Discussion

Our study demonstrated an increase in UVD with advancing GA, with a strong correlation between UVD and GA in the second half of pregnancy. The first study to establish

Table 2: Mean umbilical vein diameter at different gestational age and estimated fetal weight in the second half of pregnancy

GA (weeks)	Frequency	UVD (cm), mean±SD	EFW (g)	Frequency	UVD (cm), mean±SD
20	12	0.51±0.03	500	12	0.51±0.02
21	12	0.55±0.04	540	12	0.53±0.07
22	13	0.56±0.06	590	13	0.55±0.01
23	13	0.56±0.07	610	13	0.56±0.02
24	20	0.58±0.04	680	13	0.56±0.04
25	13	0.60±0.04	740	13	0.58±0.04
26	13	0.61±0.05	970	20	0.61±0.03
27	12	0.62±0.06	980	12	0.60±0.05
28	19	0.62±0.08	1100	15	0.62±0.04
29	12	0.65±0.07	1200	19	0.61±0.03
30	13	0.67±0.14	1600	13	0.63±0.04
31	25	0.70±0.07	1700	25	0.65±0.03
32	18	0.69±0.07	1800	12	0.73±0.06
33	26	0.73±0.07	2000	13	0.75±0.07
34	25	0.80±0.08	2100	14	0.79±0.09
35	37	0.82±0.03	2200	14	0.80±0.09
36	77	0.82±0.06	2400	13	0.80±0.04
37	13	0.87±0.07	2500	13	0.81±0.08
38	12	0.91±0.06	2700	14	0.82±0.07
39	13	0.91±0.03	2800	30	0.86±0.07
40	25	0.91±0.03	2900	27	0.86±0.08
			3000	26	0.87±0.08
			3300	14	0.88±0.08
			3600	13	0.94±0.09
			3800	27	0.93±0.08
			4000	13	0.94±0.10

UVD: Umbilical vein diameter, GA: Gestational age, EFW: Estimated fetal weight, SD: Standard deviation

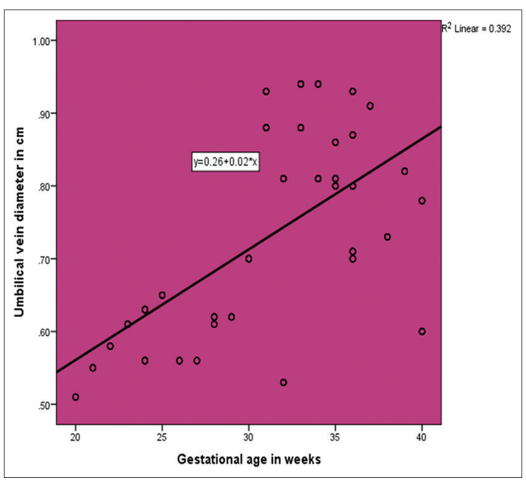

Figure 2: Scatter plot and line of best fit showing the relationship between UVD and GA. UVD: Umbilical vein diameter, GA: Gestational age

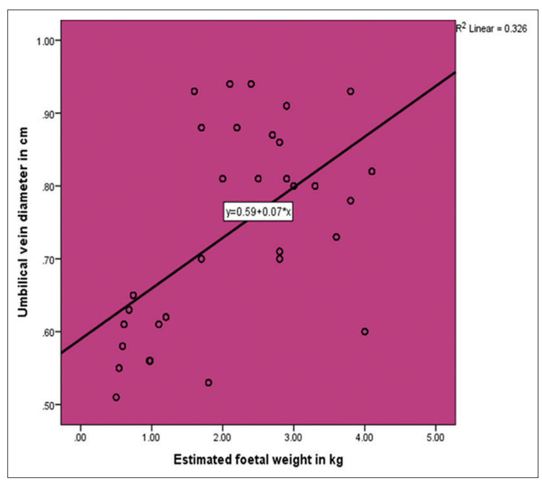

Figure 3: Scatter plot and line of best fit showing the relationship between UVD and estimated fetal weight. UVD: Umbilical vein diameter

nomograms for the UC and its components in normal pregnancies was conducted by Weissman *et al*. Before the study by Weissman *et al.*, previous reports on thick or lean UC were subjective, as nomograms of the UC and its vessels in pregnancy were lacking.[3] Weissman *et al.* established reference values for the diameters of the UC, UV, and UA. They observed that the diameter of the UV increased with GA up to 32–33 weeks, and then remained stable until the end of pregnancy. Spurway *et al.* also observed that the diameter of the UV increased with GA.[17]

Our study also observed a linear relationship and significant correlation between UVD and EFW. Köşüş *et al.* similarly reported a strong correlation between UVD and EFW.[18] In their study, UVD increased linearly up to 34 weeks' gestation,

Table 3: Interobserver and intraobserver intraclass correlation coefficient results

Ultrasound parameter	Intraclass correlation coefficient	
	Interobserver	Intraobserver
Umbilical vein diameter	0.98 (95% CI: 0.39-0.99)	0.99 (95% CI: 0.37-0.99)

CI: Confidence interval

after which it plateaued. Based on their findings, they concluded that UVD may be useful for the prediction of EFW under 34 weeks. In contrast, Tutus *et al*. observed an inverse relationship between UVD and EFW.[19] They could, however, not explain the pathophysiology of their finding.

In our study, UVD also increased with an increase in parity. This finding is in contrast with the observation of Rostamzadeh *et al.,*

Table 4: Correlation between feto–maternal indices and umbilical vein diameter

Characteristics	Correlation coefficient – *r*	r^2	Regression co-efficient		*P*
			Constant – β0 (95%CI)	Coefficients – β1 (95% CI)	
Fetal indices					
GA	0.63	0.39	0.257 (0.199-0.316)	0.015 (0.013-0.017)	0.001*
Estimated fetal weight	0.57	0.33	0.590 (0.570-0.610)	0.069 (0.060-0.079)	0.001*
Maternal indices					
Maternal weight	−0.05	0.02	0.78 (0.699-0.856)	−0.001 (−0.002-0.001)	0.342
Maternal height	0.08	0.01	0.489 (0.179-0.799)	0.155 (−0.036-0.346)	0.112
Parity	0.16	0.03	0.721 (0.704-0.738)	0.012 (0.005-0.019)	0.001*

*Statistically significant, GA: Gestational age, CI: Confidence interval

Table 5: Nomogram showing reference ranges for umbilical vein diameter at different gestational age and estimated fetal weight

GA in weeks	UVD (cm)			FW (g)	UVD (cm)		
	Estimate	95% CI			Estimate	95% CI	
		Minimum	Maximum			Minimum	Maximum
20	0.56	0.46	0.66	500	0.60	0.60	0.65
21	0.57	0.47	0.67	540	0.61	0.60	0.65
22	0.59	0.49	0.69	590	0.61	0.61	0.66
23	0.60	0.50	0.71	610	0.61	0.61	0.66
24	0.62	0.51	0.72	680	0.62	0.61	0.66
25	0.63	0.52	0.74	740	0.62	0.61	0.67
26	0.65	0.54	0.76	970	0.64	0.63	0.69
27	0.66	0.55	0.78	980	0.64	0.63	0.69
28	0.68	0.56	0.79	1100	0.65	0.64	0.70
29	0.69	0.58	0.81	1200	0.65	0.64	0.70
30	0.71	0.59	0.83	1600	0.68	0.67	0.74
31	0.72	0.60	0.84	1700	0.69	0.67	0.74
32	0.74	0.62	0.86	1800	0.69	0.68	0.75
33	0.75	0.63	0.88	2000	0.71	0.69	0.77
34	0.77	0.64	0.89	2100	0.71	0.70	0.78
35	0.78	0.65	0.91	2200	0.72	0.70	0.78
36	0.80	0.67	0.93	2400	0.74	0.71	0.80
37	0.81	0.68	0.95	2500	0.74	0.72	0.81
38	0.83	0.69	0.96	2700	0.76	0.73	0.82
39	0.84	0.71	0.98	2800	0.76	0.74	0.83
40	0.86	0.72	1.00	2900	0.77	0.74	0.84
				3000	0.78	0.75	0.85
				3300	0.80	0.77	0.87
				3600	0.82	0.79	0.89
				3800	0.83	0.80	0.91
				4000	0.85	0.81	0.93

UVD: Umbilical vein diameter, GA: Gestational age, EFW: Estimated fetal weight, SD: Standard deviation, CI: Confidence interval

Table 6: Estimated gestational age using different umbilical vein diameters in the second half of pregnancy

UVD (cm)	EGA (weeks)	95% CI for EGA	
		Minimum	Maximum
0.51	25.83	21.96	29.71
0.53	26.35	22.41	30.29
0.55	26.86	22.87	30.87
0.56	27.12	23.09	31.16
0.58	27.64	23.55	31.73
0.60	28.15	24.00	32.31
0.61	28.41	24.23	32.60
0.62	28.67	24.46	32.89
0.63	28.93	24.68	33.18
0.65	29.44	25.14	33.76
0.70	30.73	26.27	35.20
0.71	30.99	26.50	35.49
0.73	31.51	26.96	36.07
0.78	32.80	28.09	37.51
0.80	33.31	28.55	38.09
0.81	33.57	28.77	38.37
0.82	33.83	29.00	38.66
0.86	34.86	29.91	39.82
0.87	35.12	30.14	40.11
0.88	35.38	30.36	40.40
0.91	36.15	31.05	41.26
0.93	36.66	31.50	41.84
0.94	36.92	31.73	42.13

UVD: Umbilical vein diameter, CI: Confidence interval, EGA: Estimated gestational age

who reported no association of UVD with parity.[20] There is a paucity of published data on the relationship between UVD and parity. However, reports have observed an association between UC length and parity, where the length of the UC increases with increasing parity.[21,22] To minimize interobserver and intraobserver variations for these measurements, the ICC was used. The ICC assesses the regularity of measurements taken by different clinicians who are measuring the same item.[23] The variance obtained from an ANOVA was used in this study, and the ICC compares the variance of several data with the sum of all measurements.[24,25] A value >0.8 denotes almost perfect agreement, and it ranges from 0 to 1.[24,25] Our values for interobserver and intraobserver variations were 0.98 and 0.99, respectively, which suggests an almost perfect agreement. ICC considers the differences between the observers and the variance of all the measurements.[23,26]

Several studies have shown an association between morphometric characteristics of the UC components and perinatal outcomes.[27-29] Raio *et al.* demonstrated a reduction in the cross-sectional areas of Wharton's jelly and UV in pregnancies complicated by early-onset preeclampsia compared with normal pregnancy.[27] Weissman and Jakobi reported an association between increased UC diameter in the second trimester and gestational diabetes mellitus.[28] Studies have also shown that the UC of fetuses with chromosomal abnormalities are thicker than those of chromosomally normal fetuses of the same GA, while the cross-sectional area of all components of the UC is reduced in fetuses with IUGR; Rigano *et al*.,[30] however, observed that although UV velocity was significantly reduced in fetuses with IUGR, UVD was unchanged. They explained that the reduced UV blood flow observed in IUGR fetuses was mainly due to a reduction in UV blood flow velocity and not to the size of the UV.[29-31]

A lean UC is also associated with a higher incidence of small for GA fetuses and fetal distress at delivery.[11] When the UV area reduces significantly, UA Doppler parameters worsen.[31] Furthermore, a morphometrically abnormal UC, easily detectable on ultrasound, seems to be an earlier sign of fetal growth disturbance than fetal biometric measurements or UA Doppler flow parameters.[11,27] These underscore the need to establish nomograms for the UC and its vessels.

Our nomogram will be useful in differentiating fetuses with normal UVD from those with conditions that affect the UVD, and thus aid in the early detection/prediction of these conditions in our population. For instance, DeVore *et al.* suggested that a significant increase in fetal UVD may be a predictor of severe disease in rhesus haemolytic anaemia.[8] Our nomogram values will also provide a basis for studying UVD in pregnancies complicated by maternal or fetal disease in our population.

This study is one of the first to use a considerably large sample size of fetuses to attempt to make a reference range within this region of sub-Saharan Africa. However, our findings and reference ranges may not reflect those obtainable from other regions of the world. Yet, our study provides crucial data on the relationship between UVD and GA and between UVD and EFW in normal pregnancy among a population of pregnant women in our region. Furthermore, the study was multicentred and USS were performed by consultant radiologists (one for each centre), with a specific interest in fetal USS.

Conclusion

Our study revealed a very strong, positive and significant relationship between UVD and GA and between UVD and EFW. This study provides important data upon which further larger, prospective, multicenter studies can be conducted to establish a UVD nomogram that can be used not just in our region/population but throughout our country.

Acknowledgment

We appreciate all the patients and staff of all the health facilities used for this study, for all the roles they played in making this research successful.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Hill LM, Kislak S, Runco C. An ultrasonic view of the umbilical cord. Obstet Gynecol Surv 1987;42:82-8.
2. Kiserud T, Acharya G. The fetal circulation. Prenat Diagn 2004;24:1049-59.
3. Weissman A, Jakobi P, Bronshtein M, Goldstein I. Sonographic measurements of the umbilical cord and vessels during normal pregnancies. J Ultrasound Med 1994;13:11-4.
4. Moshiri M, Zaidi SF, Robinson TJ, Bhargava P, Siebert JR, Dubinsky TJ, *et al.* Comprehensive imaging review of abnormalities of the umbilical cord. Radiographics 2014;34:179-96.
5. Sepulveda W, Wong AE, Gomez L, Alcalde JL. Improving sonographic evaluation of the umbilical cord at the second-trimester anatomy scan. J Ultrasound Med 2009;28:831-5.
6. Sepulveda W. Time for a more detailed prenatal examination of the umbilical cord? Ultrasound Obstet Gynecol 1999;13:157-60.
7. Wu MH, Chang FM, Shen MR, Yao BL, Chang CH, Yu CH, *et al.* Prenatal sonographic diagnosis of single umbilical artery. J Clin Ultrasound 1997;25:425-30.
8. DeVore GR, Mayden K, Tortora M, Berkowitz RL, Hobbins JC. Dilation of the fetal umbilical vein in rhesus hemolytic anemia: A predictor of severe disease. Am J Obstet Gynecol 1981;141:464-6.
9. Faustin D, Shiffman RL, Francois G, Amir E, Francisco M, Fox F, *et al.* Sonographic measurement of umbilical vein and umbilical cord diameters in normal and diabetic pregnancies. J Matern Fetal Med 1992;1:128-31.
10. Ghezzi F, Raio L, Günter Duwe D, Cromi A, Karousou E, Dürig P. Sonographic umbilical vessel morphometry and perinatal outcome of fetuses with a lean umbilical cord. J Clin Ultrasound 2005;33:18-23.
11. Raio L, Ghezzi F, Di Naro E, Franchi M, Maymon E, Mueller MD, *et al.* Prenatal diagnosis of a lean umbilical cord: A simple marker for the fetus at risk of being small for gestational age at birth. Ultrasound Obstet Gynecol 1999;13:176-80.
12. Soysal C, Şişman Hİ, Bıyık İ, Erten Ö, Deliloğlu B, Geçkalan Soysal D, *et al.* The relationship between umbilical cord measurements and newborn outcomes. Perinat J 2021;29:225-30.
13. Bolarinwa OA. Sample size estimation for health and social science researchers: The principles and considerations for different study designs. Niger Postgrad Med J 2020;27:67-75.
14. LaMorte WW. Sample size for one sample, continuous outcome. Boston Univ Sch Public Health 2020. Available from: https://sphweb.bumc.bu.edu/otlt/mph-modules/bs/bs704_power/BS704_Power3.html. [Last accessed on 2022 Oct 26].
15. Eze C, Ugwuja M, Eze C, Ugwu G, Agwuna K, Ituk-Ozalla. Relationship between sonographic umbilical cord size and gestational age among pregnant women in Enugu, Nigeria. Afr Health Sci 2014;14:334-8.
16. Hadlock FP, Harrist RB, Sharman RS, Deter RL, Park SK. Estimation of fetal weight with the use of head, body, and femur measurements – A prospective study. Am J Obstet Gynecol 1985;151:333-7.
17. Spurway J, Logan P, Pak SC, Nielsen S. Reference ranges for the intra-amniotic umbilical cord vein diameter, peak velocity and blood flow in a regional NSW population. Australas J Ultrasound Med 2017;20:155-62.
18. Köşüş A, Köşüş N, Turhan NÖ. Is there any relation between umbilical artery and vein diameter and estimated fetal weight in healthy pregnant women? J Med Ultrason 2012;39:227-34.
19. Tutus S, Asal N, Uysal G, Şahin H. Is there a relationship between high birth weight and umbilical vein diameter? J Matern Fetal Neonatal Med 2021;34:3609-13.
20. Rostamzadeh S, Kalantari M, Shahriari M, Shakiba M. Sonographic measurement of the umbilical cord and its vessels and their relation with fetal anthropometric measurements. Iran J Radiol 2015;12:e12230.
21. Sørnes T, Bakke T. Uterine size, parity and umbilical cord length. Acta Obstet Gynecol Scand 1989;68:439-41.
22. Stefos T, Sotiriadis A, Vasilios D, Tsirkas P, Korkontzelos I, Avgoustatos F, *et al.* Umbilical cord length and parity – The Greek experience. Eur J Obstet Gynecol Reprod Biol 2003;107:41-4.
23. Shrout PE, Fleiss JL. Intraclass correlations: Uses in assessing rater reliability. Psychol Bull 1979;86:420-8.
24. Costa-Santos C, Bernardes J, Ayres-de-Campos D, Costa A, Amorim-Costa C. The limits of agreement and the intraclass correlation coefficient may be inconsistent in the interpretation of agreement. J Clin Epidemiol 2011;64:264-9.
25. Fernandez S, Figueras F, Gomez O, Martinez JM, Eixarch E, Comas M, *et al.* Intra and interobserver reliability of umbilical vein blood flow. Prenat Diagn 2008;28:999-1003.
26. Figueras F, Fernández S, Hernández-Andrade E, Gratacós E. Umbilical venous blood flow measurement: Accuracy and reproducibility. Ultrasound Obstet Gynecol 2008;32:587-91.
27. Raio L, Ghezzi F, Di Naro E, Franchi M, Bolla D, Schneider H. Altered sonographic umbilical cord morphometry in early-onset preeclampsia. Obstet Gynecol 2002;100:311-6.
28. Weissman A, Jakobi P. Sonographic measurements of the umbilical cord in pregnancies complicated by gestational diabetes. J Ultrasound Med 1997;16:691-4.
29. Ghezzi F, Raio L, Di Naro E, Franchi M, Buttarelli M, Schneider H. First-trimester umbilical cord diameter: A novel marker of fetal aneuploidy. Ultrasound Obstet Gynecol 2002;19:235-9.
30. Rigano S, Bozzo M, Ferrazzi E, Bellotti M, Battaglia FC, Galan HL. Early and persistent reduction in umbilical vein blood flow in the growth-restricted fetus: A longitudinal study. Am J Obstet Gynecol 2001;185:834-8.
31. Raio L, Ghezzi F, Di Naro E, Duwe DG, Cromi A, Schneider H. Umbilical cord morphologic characteristics and umbilical artery Doppler parameters in intrauterine growth-restricted fetuses. J Ultrasound Med 2003;22:1341-7.