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Correlation of Ultrasound Umbilical Venous Blood Flow in Normal Pregnancy with Gestational Age and Foetal Weight

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Authors' contributions

This work was carried out in collaboration among all authors. Author EKK wrote the research protocol, carried out hysterosalpingography, reported hysterosalpingography films and collected data. Author PCO conceptualized the research topic, collated data and wrote the introduction, methodology and the first draft of the manuscript. Author DCB wrote the discussion. Authors EGEK, OC, CO and TOA managed literature search. Author JUU reported hysterosalpingography films. Author AEU proofread the manuscript and wrote the abstract. Authors AOA, IJA and PYB recruited patients for this study. Author ADA analyzed data and wrote the results. All authors read and approved the final manuscript.

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ABSTRACT

Background: Umbilical venous (UV) blood flow is a direct and physiological measurement of vascular placental function.
Objectives: To correlate UV blood flow with gestational age (GA) and foetal weight (FW) in a cohort of normal pregnant Nigerian women.
Materials and Methods: 2,247 women with normal singleton pregnancy between 20 – 40 weeks were included in this study, which was conducted between May 2020 – October 2022, in Bayelsa State, South-South Nigeria. The women had ultrasound assessment of UV blood flow and foetal biometric parameters and weight. Data was analysed using SPSS version 25, associations between categorical variables and between categorical and continuous variables were assessed using chi square and t-test, respectively, with p-value <0.05 considered statistically significant. Correlation analysis was done, and presented in tables and charts.
Results: There was a strong linear correlation between UV blood flow volume and GA (correlation coefficient, ɼ= 0.95; p=0.001), FW (ɼ=0.81; p=0.001), foetal biparietal diameter (BPD) (ɼ=0.88; P=0.001) and abdominal circumference (AC) (ɼ=0.75; P=0.001). Conversely, UV blood flow volume/FW showed a strong inverse relationship with FW (ɼ=- 0.73; p = 0.001), and a weak inverse relationship with GA (ɼ=- 0.36; p = 0.001).
Conclusion: UV blood flow increases with advancing gestation and FW. The increase in UV blood flow in later gestation is however surpassed by the increase in FW, resulting in a reduction in UV blood flow volume per unit FW in the third trimester. The linear increase in UV blood flow volume with foetal BPD and AC suggests that these three parameters could be used in combination to estimate both GA and FW.

Keywords: UV blood flow; gestational age, foetal weight; pregnancy.

1. INTRODUCTION

The introduction of Doppler studies in obstetric practice has improved the quality of antenatal care, maternal and foetal outcomes in pregnancy. From 12 weeks' gestational age (GA) to term, Doppler studies can provide both qualitative and quantitative information on blood flow in maternal, placental and foetal vessels, which may be useful in predicting foetomaternal outcomes [1,2]. Umbilical blood flow in pregnancy increases with GA and foetal weight [3]. In pregnancy, physiological changes affect almost all the organs in the human body. Blood flow in the uterine vessels increases from <100 ml/min in the first trimester to 700 – 800 ml/min at term [4], and that in the umbilical vessels increases from 100 ml/min at 22 weeks' GA to 300 ml/min at 38 weeks [5]. For every unit gain in foetal weight, umbilical blood flow increases by 110 ml/min – 125 ml/min, until term [2,3]. While some studies have reported a slight decrease in umbilical blood flow after 35 weeks' GA, [1,2] others have however, reported that umbilical blood flow does not decrease, but the increase in foetal weight exceeds the increase in the umbilical blood flow in the third trimester of pregnancy [6].

In normal pregnancy, the utero-placental (spiral) arteries are transformed into large bore, high capacitance and low resistance vessels [7]. The foetus depends on the optimal transfer of oxygen and nutrients through the placenta for adequate weight gain. Therefore, there must be optimal maternal nutrition and utero-placental perfusion for adequate foetal weight gain. In foetal growth restriction and hypoxia, Doppler studies of the foetal circulation have revealed that there is a compensatory redistribution of arterial blood flow with increased flow to the foetal brain and heart, with decreased blood flow to the peripheral organs [8]. Therefore, the objective of this study is to determine the relationship between umbilical venous (UV) blood flow and the estimated foetal weight (EFW) and GA.

2. MATERIALS AND METHODS

This prospective, 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 and Silhouette Radiodiagnostic Consultants, Yenagoa, all in Bayelsa State, Nigeria. It was conducted from May 2020 – October 2022. The first two study centres are tertiary health facilities that provide specialised obstetrics and gynaecological services to women in Bayelsa State and serve as referral centres for other hospitals in Bayelsa State, and surrounding Rivers and Delta States, both in South-South Nigeria. The third study centre is a secondary health facility, while the fourth study centre is the biggest radiodiagnostic facility in Bayelsa State, Nigeria.

2.1 Sample Size

This was calculated using the formula: $n = Z\alpha^2 \times \sigma^2 / \delta^2$ [9,10].

Where: Zα = 95% CI, which is 1.96, σ = standard deviation of 17.04 ml/min/kg from a previous study [3]. δ = level of precision for our study (σ/√35). Two thousand, two hundred and forty-seven consecutive, eligible pregnant women, who presented to the Antenatal Clinics of the study centres during the second half of pregnancy (20 – 40 weeks), were recruited for this study.

2.1.1 Inclusion criteria

Pregnant women between 20-40 weeks' gestation, with uncomplicated singleton pregnancy, and no co-existing medical condition or foetal anomaly.

2.1.2 Exclusion criteria

Pregnant women less than 20 weeks' gestation, with multiple pregnancy, co-exiting medical condition, foetal, amniotic fluid or placental abnormalities.

Consenting, eligible women were referred to the Radiology Departments of the study centres for an obstetric ultrasound scan (USS) to assess foetal biometrics, EFW and UV blood flow. The woman's age, parity, GA from her last menstrual period (which was correlated with the GA from a first trimester/early USS), weight, and height were obtained and recorded.

2.2 Procedure

Ultrasound scans were performed transabdominally, by four Consultant Radiologists (one for each study centre), with requisite experience in Doppler scans. The woman took about four glasses of water, to get the urinary bladder filled, about one hour before the procedure. A full bladder served as a good acoustic window. With the patient lying supine, and the abdomen and pelvis exposed, adequate ultrasound gel was applied to the lower abdominal wall/pelvis. The gel served to remove air from the skin, and for ease of transducer movement.

Using the 2012 Philips HD11 USS machine, fitted with a 3.5 MHz curvilinear (convex) transducer (probe), the blood flow in the UV was determined by pulsed Doppler sonography. 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 foetal biometric parameters and EFW [11]. Umbilical venous frequency shift was recorded at the placental origin of the UV, with insonation angle of 30 – 60°.

The umbilical blood flow was calculated as $Q = V \times D^2 \times \pi \times 0.15$; where Q is the volume of umbilical blood flow (ml/min), V is the mean velocity (cm/s), and D is the diameter of the UV (mm). To minimise interobserver and intraobserver variations, all USS were performed by four Consultant Radiologists (one for each study centre), with requisite experience in Doppler scans. To reduce the error due to a single measurement, each measurement was obtained thrice, and the mean calculated and recorded. Interobserver and intraobserver

Fig. 1. Umbilical blood flow velocity (red arrow shows the pattern of blood flow)

variations were calculated with the use of the intraclass correlation coefficient (ICC) and documented. Fig. 1 shows the umbilical blood flow velocity.

2.3 Data Analysis

Data were entered into a pre-designed proforma and were analysed using the Statistical Product and Service Solutions for Windows® version 25, SPSS Inc.; Chicago, USA. Results were presented in frequencies and percentages for categorical variables, mean and standard deviation for continuous variables, while Chi-square and t-test were used to assess for associations between categorical variables, and between categorical and continuous variables, respectively. Correlation analysis was done, and presented in tables and charts.

3. RESULTS

3.1 Maternal Characteristics

Of the 2,247 participants recruited for this study, majority (742, 33.0%) were aged 25 – 29 years, with mean age ± SD of 27.8 ± 5.9 years. Most (1,213, 54.0%) of the women were multiparous. There were no statistically significant differences in maternal age (χ^2 =0.97; p=0.809) and parity (χ^2 =2.07; p=0.566) between women with preterm (20 – 36 weeks) and term (37 – 40 weeks) pregnancies. The mean ± SD weight, height and body mass index of the women were 75.5 ± 15.7 kg, 1.62 m ± 0.04 m, and 28.4 ± 5.4 kg/m^2, respectively. Weight (t-test = 30.8; p = 0.001) and body mass index (t-test = 28.5; p = 0.001) amongst women with term pregnancy were significantly higher than in those with preterm pregnancy (Table 1).

3.2 UV Parameters

The mean UV diameter (UVD) was 6.4 ± 1.2 mm, with mean velocity of blood flow in the UV, mean UV blood flow volume and mean UV blood flow volume/FW of 15.9 ± 4.0 cm/s, 346.2 ± 173.4 ml/min, and 194.3 ± 56.7 ml/min/kg, respectively. The mean velocity of UV blood flow was significantly higher among term foetuses compared to preterm foetuses (19.5 ± 2.8 cm/s vs.15.0 ± 3.8 cm/s; p=0.001). Similarly, UVD (7.8 ± 0.2 mm vs. 6.0 ± 1.0 mm; p=0.001) and UV blood flow volume (547.5 ± 63.2 ml/min vs. 288.9 ± 150.6 ml/min; p=0.001) were significantly higher in term foetuses than in preterm foetuses (Table 2). Conversely, preterm foetuses had significantly higher UV blood flow volume per FW (203.3 ± 60.5 ml/min/kg vs. 162.6 ± 19.2 ml/min/kg; p=0.001) (Table 2). Interobserver and intraobserver variations were assessed with the use of the ICC and presented in Table 3.

3.3 Relationship between UV Parameters, GA and EFW

All the foetal biometric indices (GA, EFW, biparietal diameter (BPD) and abdominal circumference (AC)) had a strong relationship with the UV parameters (Table 4). The relationship was strongest between UV blood flow volume and the foetal biometric indices; the correlation coefficient (r) ranged from 0.75 (p = 0.001), which reflected the relationship between UV blood flow volume and AC, to 0.97 (p = 0.001), an indicator of the relationship between

UV blood flow volume and GA (Table 4; Fig. 2). Other correlation coefficients (ɼ) ranged between 0.64 – 0.88, showing a strong to very strong positive relationship between foetal biometric and UV parameters (Table 4, Figs. 3 – 5). The UV blood flow volume/FW showed an inverse relationship with foetal biometric indices (Table 4; Fig. 6). The inverse relationship was strongest between UV blood flow volume/FW and EFW (ɼ = - 0.73; p = 0.001), while it was weakest with GA (ɼ = - 0.36; p = 0.001).

Table 5 further demonstrates the relationships between UV parameters and GA. Mean velocity of UV blood flow increased gradually from 6.85 ± 0.22 cm/s at 20 weeks to 21.04 ± 0.73 cm/s at 40 weeks; UVD increased from 4.40 ± 0.07 mm at 20 weeks to 8.30 ± 0.19 mm at 40 weeks. The mean UV blood flow volume/FW increased from 124.92 ± 6.72 ml/min/kg at 20 weeks to 343.99 ± 11.89 ml/min/kg at 26 weeks, and gradually began to reduce to 143.27 ± 6.72 ml/min/kg at 40 weeks (Table 5).

Table 1. Maternal demographic characteristics and anthropometric parameter

Characteristics		Gestational age (weeks)		Chi-square	p-value
	Total	**20 – 36**	**37 – 40**		
Maternal age (years)	**N = 2,247**	**N = 1,749**	**N = 498**		
20 – 24	645 (28.7)	523 (29.9)	142 (28.5)	0.97	0.809
25 – 29	742 (33.0)	581 (33.2)	161 (32.3)		
30 – 34	523 (23.3)	389 (22.2)	114 (22.9)		
>35	337 (15.0)	256 (14.6)	81 (16.3)		
Mean ± SD maternal age in years	27.8 ± 5.5	26.6 ± 4.2	27.3 ± 5.2	-3.22[a]	0.171
Mean ± SD GA in weeks	30.3 ± 5.9	28.2 ± 4.9	38.0 ± 1.0	-44.4[a]	0.001
Parity					
Nulliparous	359 (16.0)	274 (15.7)	85 (17.1)	2.07	0.566
Primiparous	608 (27.1)	482 (27.6)	126 (25.3)		
Multiparous	1213 (54.0)	944 (53.9)	269 (54.0)		
Grand multiparous	67 (3.0)	48 (2.8)	18 (3.6)		
Median (range) Parity	2 (0 – 5)	2 (0 – 5)	2 (0 – 4)	417.0[b]	0.142
Body mass index (kg/m^2)					
Normal	646 (28.7)	504 (28.8)	142 (28.5)	1.34	0.511
Overweight	749 (33.3)	592 (33.8)	157 (31.5)		
Obese	852 (37.9)	653 (37.3)	199 (40.0)		
Mean ± SD weight in kg	75.5 ± 15.7	70.9 ± 11.7	91.6 ± 17.5	-30.8[a]	0.001
Mean ± SD height in m	1.62 ± 0.10	1.64 ± 0.06	1.62 ± 0.12	-12.0[a]	0.101
Mean ± SD BMI in kg/m^2	28.4 ± 5.4	26.9 ± 4.2	33.6 ± 5.6	-28.5[a]	0.001

*BMI – Body mass index; SD – Standard deviation; *Statistically significant; [a]Student's t-test; [b]Mann-Whitney U test*

Table 2. Summary statistics of UV parameters in the study groups

Characteristics		Gestational age (weeks)		Student's t –test (p-value)
	Total	**20 – 36**	**37 – 40**	
Mean velocity of UV blood flow (cm/s)	15.9 ± 4.0	15.0 ± 3.8	19.5 ± 2.8	-25.0 (0.001*)
Mean UVD (mm)	6.4 ± 1.2	6.0 ± 1.0	7.8 ± 0.2	-38.2 (0.001*)
Mean UV blood flow volume (ml/min)	346.2 ± 173.4	288.9 ± 150.6	547.5 ± 63.2	-37.4 (0.001*)
Mean UV blood flow volume/FW (ml/min/kg)	194.3 ± 56.7	203.3 ± 60.5	162.6 ± 19.2	14.8 (0.001*)

**Statistically significant*

Table 3. Interobserver and intraobserver ICC results

Ultrasound parameter	Intraclass correlation coefficient	
	Interobserver	**Intraobserver**
Umbilical venous blood flow	0.99 (95% CI 0.39 – 0.99)	0.98 (95% CI 0.40 – 0.99)

Table 4. Relationship between UV and foetal biometric parameters

Foetal biometric parameters	UV parameters – r (p-value)			
	Mean velocity of UV blood flow (cm/s)	UVD (mm)	UV blood flow volume (ml/min)	UV blood flow volume/FW (ml/min/kg)
Gestational age in weeks	0.87 (0.001*)	0.90 (0.001*)	0.97 (0.001*)	-0.36 (0.001*)
EFW in kg	0.69 (0.001*)	0.79 (0.001*)	0.81 (0.001*)	-0.73 (0.001*)
BPD in mm	0.76 (0.001*)	0.88 (0.001*)	0.88 (0.001*)	-0.63 (0.001*)
AC in mm	0.64 (0.001*)	0.77 (0.001*)	0.75 (0.001*)	-0.71 (0.001*)

**Statistically significant*

Table 5. Relationship between UV parameters and GA

GA (weeks)	UV parameters				
	Frequency N = 2,247 (%)	Mean velocity of UV blood flow (cm/s)	Mean UVD (mm)	Mean UV blood flow volume (ml/min)	Mean UV blood flow volume/FW (ml/min/kg)
20	62 (2.8)	6.85 ± 0.22	4.40 ± 0.07	62.46 ± 4.38	124.92 ± 6.72
21	62 (2.8)	9.05 ± 0.18	4.50 ± 0.11	92.04 ± 4.78	184.08 ± 8.97
22	167 (7.4)	11.69 ± 0.26	4.66 ± 0.12	119.60 ± 5.03	239.20 ±10.07
23	62 (2.8)	12.75 ± 0.34	4.80 ± 0.09	138.36 ± 4.87	230.60 ± 6.96
24	195 (8.6)	13.00 ± 0.10	5.00 ± 0.05	150.04 ± 4.20	250.07 ± 6.99
25	134 (5.9)	12.98 ± 0.23	5.65 ± 0.05	195.16 ± 6.86	278.79 ± 9.80
26	62 (2.8)	13.20 ± 0.27	5.89 ± 1.08	240.79 ± 5.82	343.99 ± 11.89
27	98 (4.3)	13.45 ± 0.41	6.20 ± 0.90	251.43 ± 4.67	266.17 ± 7.31
28	62 (2.8)	13.50 ± 0.33	6.30 ± 0.80	260.44 ± 5.69	268.54 ± 6.78
29	62 (2.8)	13.55 ± 0.29	6.40 ± 0.91	277.18 ± 7.11	184.79 ± 2.45
30	165 (7.3)	14.67 ± 0.20	6.60 ± 0.84)	310.11 ± 4.19	206.74 ± 2.79
31	96 (4.2)	15.50 ± 0.37	6.72 ± 0.63	337.57 ± 5.20	177.67 ± 3.71
32	61 (2.7)	17.30 ± 0.41	6.80 ± 0.54	387.94 ± 6.21	184.73 ± 8.97
33	98 (4.3)	19.50 ± 0.39	6.90 ± 0.72	450.04 ± 7.21	214.31 ± 12.89
34	165(7.3)	20.40 ± 0.44	7.00 ± 0.62	487.11 ± 75.38	200.72 ± 3.30
35	62 (2.8)	20.44 ± 0.53	7.30 ± 0.42	489.99 ± 16.60	211.24 ± 7.33
36	136 (6.0)	20.54 ± 1.60	7.45 ± 0.35	510.30 ± 72.22	168.25 ± 11.90
37	205 (9.1)	20.53 ± 1.56	7.60 ± 0.26	528.10 ± 18.34	166.09 ±12.35
38	169 (7.5)	20.56 ± 2.28	7.67 ± 0.29	543.48 ± 18.10	168.48 ± 18.51
39	62 (2.8)	21.79 ± 0.63	7.92 ± 0.17	559.14 ± 40.55	154.64 ± 21.88
40	62 (2.8)	21.04 ± 0.73	8.30 ± 0.19	569.20 ± 58.04	143.27 ± 22.14

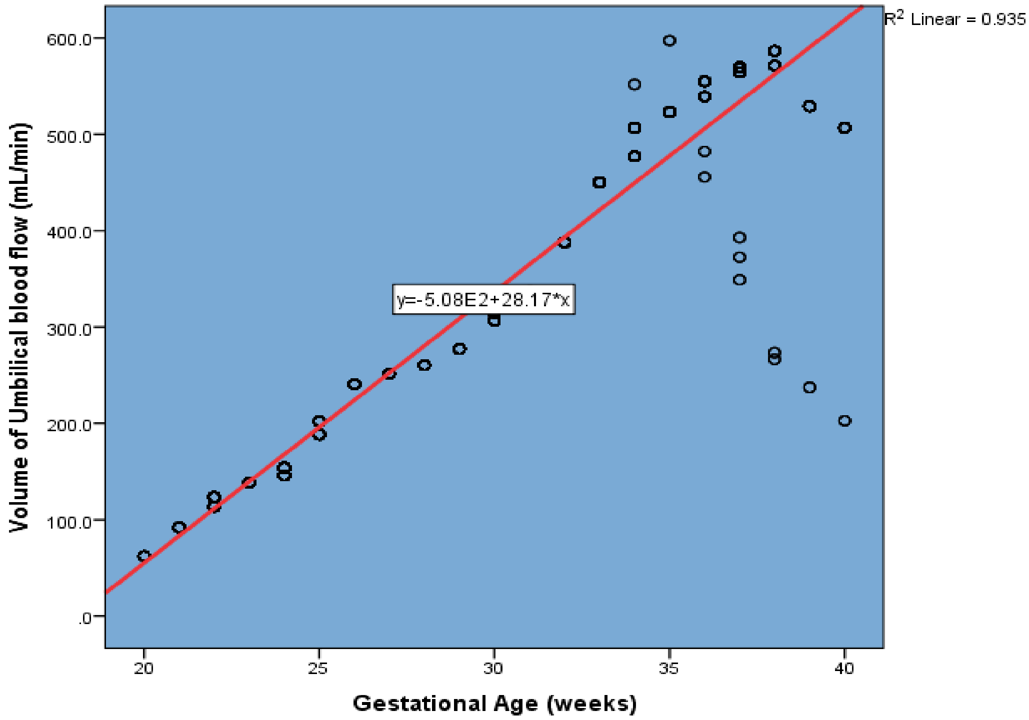

Fig. 2. Scatterplot showing relationship between GA and volume of UV blood flow (ml/min)

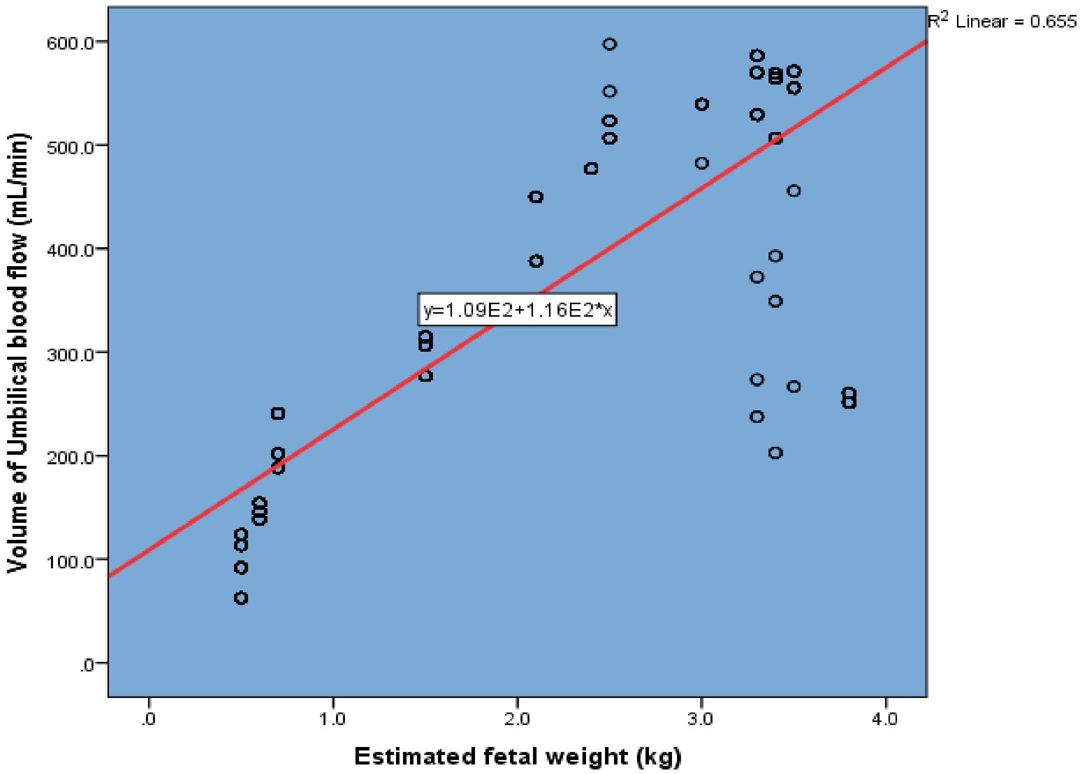

Fig. 3. Scatterplot showing relationship between EFW and volume of UV blood flow (ml/min)

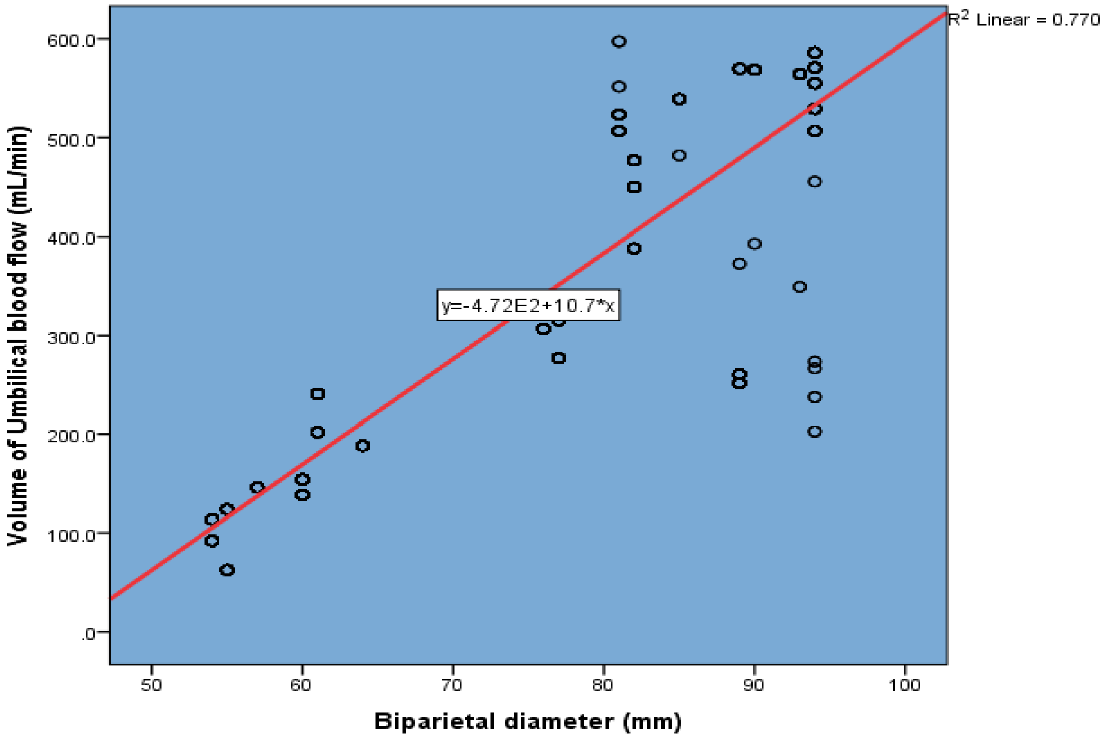

Fig. 4. Scatterplot showing relationship between BPD and volume of UV blood flow (ml/min)

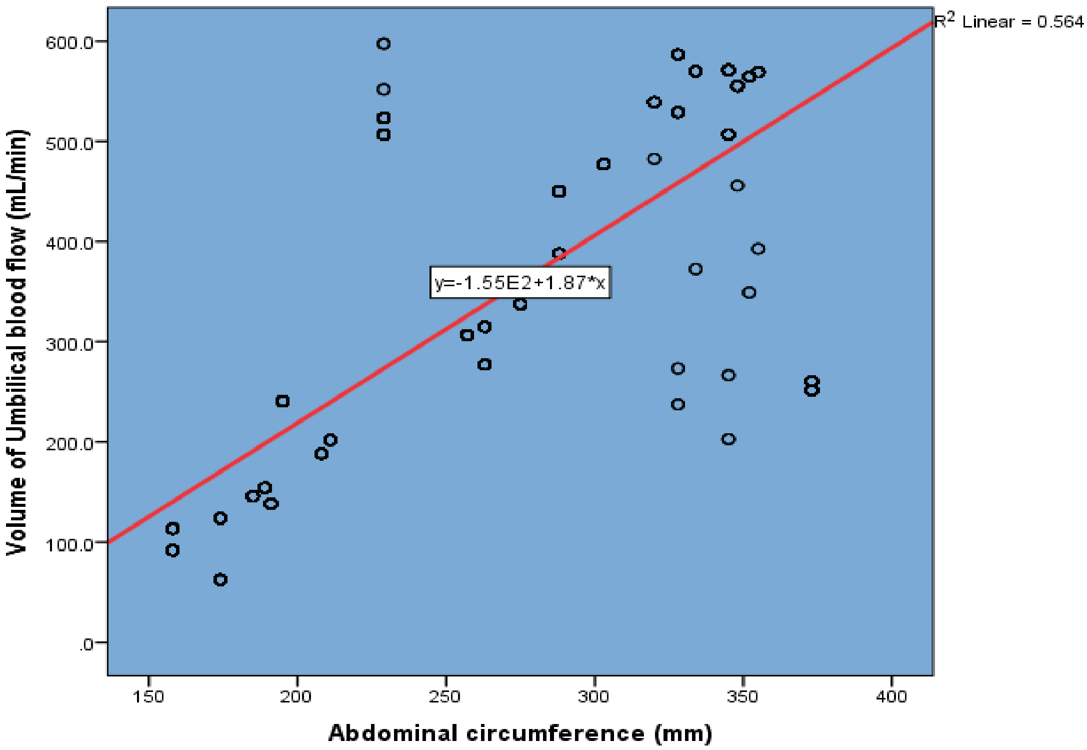

Fig. 5. Scatterplot showing relationship between AC and volume of UV blood flow (ml/min)

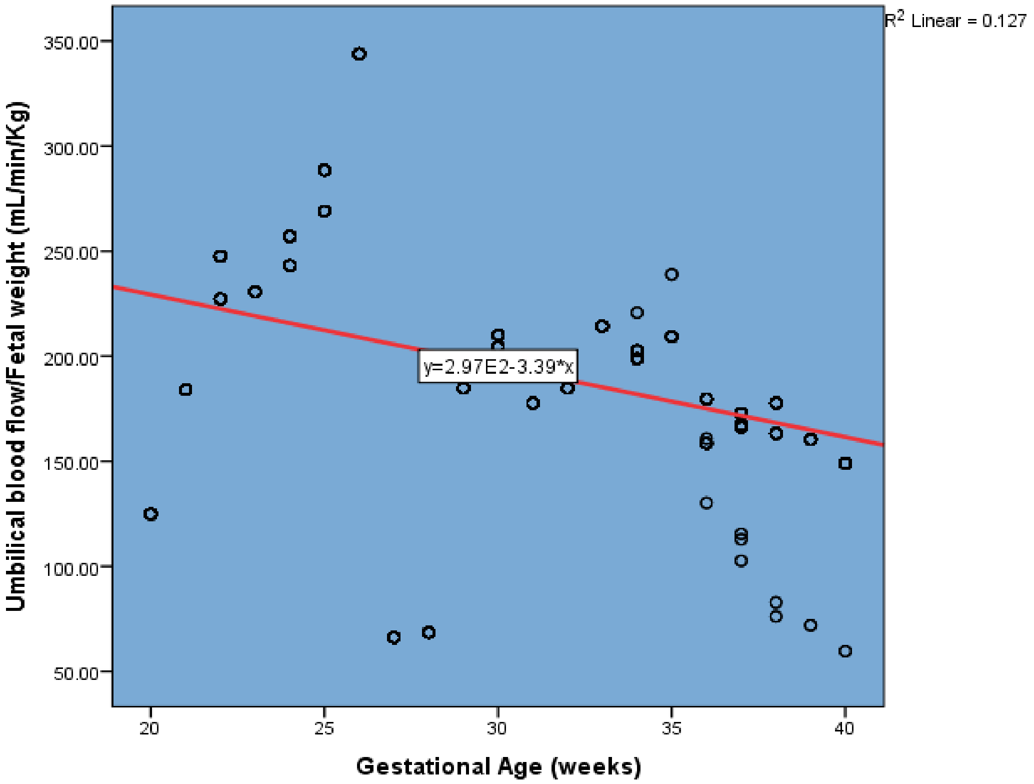

Fig. 6. Scatterplot showing relationship between GA and volume of UV blood flow/FW (ml/min/kg)

4. DISCUSSION

Umbilical venous blood flow is a surrogate physiological measurement of vascular placental function, which reflects oxygen and nutrients transfer to the foetus, and is a key determinant of foetal development and growth. It has recently attracted numerous attentions for both clinical and experimental studies because of its physiologic significance and potential in detecting foetuses with a possibility for an adverse perinatal outcome. Knowledge is still growing as to its full clinical applicability in the field of perinatology and obstetrics. This study aimed to determine the relationship between UV blood flow and EFW and GA, since little has been done in this regard in our setting. It is anticipated that this study will serve as a pilot normative study and a fulcrum for further studies in low resource settings.

This study demonstrates a linear increase in mean UV blood flow volume with GA, from 62.46 ± 4.38 ml/min at 20 weeks to 569.20 ± 58.04 ml/min at 40 weeks of gestation. Our finding is similar to that of Barbera *et al.* in Milan, who documented a UV blood flow volume of 97.3 ml/min at 20 weeks gestation and 529.1 ml/min at 38 weeks of gestation [12]. It however differs from, and is higher than the mean UV blood flow volume of 33.2 ± 15.2 ml/min at 20 weeks and 221.0 ± 32.8 ml/min at 36 weeks of gestation, reported in another study by Boito et al. [13] in the Netherlands. The overall mean UV blood flow volume in this study was 346.2 ± 173.4 ml/min. This is lower than the 443 ± 91.6 ml/min reported by El Behery et al. [14] among a cohort of 124 foetuses with normal umbilical cords. The plausible explanation for our finding of an exponential increase in UV blood flow volume with advancing GA is largely due to the growth of the foetal vessels as has been corroborated by other authors [12]. When further categorised by gestational age, the UV blood flow volume was significantly higher for term foetuses (547.5 ± 63 ml/min) compared to preterm foetuses (288.9 ± 150.6 ml/min). This is consistent with the finding of Link et al. [4] who demonstrated that UV blood flow volume was higher in full term infants (515 ± 125 ml/min) than in preterm infants (423 ± 120 ml/min).

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We also found that a GA–related linear increase exists for the mean velocity of UV blood flow, which increased from 6.85 ± 0.22 cm/s at 20 weeks to 21.04 ± 0.73 cm/s at 40 weeks. The overall mean velocity of UV blood flow was 15.9 ± 4.0 cm/s, which was comparable but slightly higher than the venous blood flow velocity of 12.1 ± 2.8 cm/s in a study by El Behery et al. [14] among a cohort of 124 Egyptian foetuses with normal umbilical cords and also the 9.0 ± 3.6 cm/s reported by Di Naro et al. [15] among a cohort of 104 Italian foetuses with normal umbilical cords. The plausible reason for our higher values may be due to variations in frequencies of ultrasound machines used for tissue doppler velocities in foetuses, interobserver variability [16], and difference in study setting, genetic make-up and geographical location.

This study also showed that the mean UVD linearly increased with GA, from 4.4 ± 0.07 mm at 20 weeks to 8.30± 0.19 mm at 40 weeks of gestation. This is consistent with findings from other studies, which reported linearly increasing UVD, ranging from 4.1 mm at 20 weeks of gestation to 8.8 mm at 38 weeks' gestation [4,12]. We also found that UVD increased in a linear fashion with UV blood flow. A plausible explanation for our finding is largely due to the growth of the foetal vessels. This further suggests that the most important factor for the increase in UV blood flow with GA is actually the growth of the vasculature, which is reflected by an increase in UVD, and not the increase in mean flow velocity. This is consistent with reports from other studies [4,17].

We also found that there exists a roughly linear positive relationship between UV blood flow volume and FW. However, the UV blood flow volume/FW differed from the other UV parameters. It increased from 124.92 ± 6.72 ml/min/kg at 20 weeks to 343.99 ± 11.89 ml/min/kg at 26 weeks, and gradually began to reduce unsymmetrically to 143.27 ± 6.72 ml/min/kg at 40 weeks of gestation. Our result, although higher in absolute value, was comparable with findings from other studies which demonstrated a non-significant linear decrease in UV blood flow volume/FW with increasing GA [12,13,18]. The mean UV blood flow volume/FW in this study was 194.3 ± 56.7 ml/min/kg and was much higher than the 131.0 ± 19.8 ml/min/kg reported by El Behery et al. [14] and the 126.0 ± 23.4 ml/min/kg reported by Di Naro et al [15]. Hence, our study also suggests, as other authors did, that the increase in UV blood flow with advancing gestation was surpassed by the increase in FW in later gestation, consequently causing a reduction in UV blood volume flow per unit FW in later gestation. This suggests that tissue perfusion in the later stages of pregnancy is reduced, which could help to explain the 'redistribution phenomenon', where oxygenated blood is selectively redirected through the heart to the foetal brain in association with decreased brain resistance [19].

This study also presents the evidence that there exists a relationship between growth of the umbilical venous blood flow and foetal growth maturation as demonstrated by linear increase in the foetal biometric parameters such as the BPD and AC. Our findings was consistent with those from another study by Barbera et al. [12] conducted among 70 foetuses in Milan. This suggests that measuring the UV blood flow together with either the BPD or AC could be used for estimating foetal GA and maturation.

The ICC was employed to reduce interobserver and intraobserver variability for the measurements of the umbilical parameters. The ICC assesses the closeness of the agreement between the results of measurements of the same parameter when performed by different radiologists or at different times [20]. ICC compares the variance of multiple data sets with the total of all measurements [21,22]. The variance of all measurements is taken into account by ICC in addition to the variations between the observers [20]. The normal range is between 0 and 1, and a number greater than 0.8 indicates nearly perfect agreement [21,22]. Our inter- and intra-observer variance values were 0.99 and 0.98, respectively, indicating an almost perfect agreement.

The strength of this study lies in its large sample size and the multi-centre design. This study is however limited by the fact it was hospital based in a single region in Nigeria, and thus findings may not be generalizable to the general population of Nigerian pregnant women. This limitation notwithstanding, our study provides important and robust data upon which larger, highly powered, population-based studies on UV blood flow and its relationship with GA and FW could be conducted in Nigeria.

5. CONCLUSION

This study has been able to demonstrate that using Doppler USS, a strongly positive linear relationship exists between UV parameters, especially the UV blood flow volume and GA, as well as foetal biometric indices, particularly the AC. However, umbilical blood flow/foetal weight showed an inverse relationship with foetal biometric indices the inverse relationship was strongest between umbilical blood flow/foetal weight and EFW. The linear increase in UV blood flow volume with foetal BPD and AC suggests that these three parameters could be used in combination to estimate both GA and FW.

CONSENT AND ETHICAL APPROVAL

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).

Women who met the inclusion criteria for the study were counselled on the aim of the study, and after obtaining a written informed consent, were enrolled for the study.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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