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Fetal Doppler Velocimetry of The Middle Cerebral Artery in Hypertensive Disorders of Pregnancy, In Kano, Nigeria

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Abstract

Background: Hypertension is one of the leading causes of maternal and fetal mortality and morbidity. The middle cerebral artery (MCA) is the major supplier of blood to the brain. Doppler velocimetry has made it possible to identify and insonate the fetal middle cerebral artery and is used in fetal surveillance in high-risk pregnancies and has been efficacious in antenatal fetal monitoring.

Methods: Sixty-five patients with hypertensive disorders of pregnancy and sixty-five normotensive pregnant controls between 20 and 39weeks gestational age were recruited for this study. Obstetric ultrasound scan was done to determine the gestational age, estimated fetal weight and amniotic fluid indices. Fetal middle cerebral artery Doppler velocimetric indices (PSV, EDV, RI, PI and S/D ratio) were also measured and documented.

Results: The mean PSV of the study group (32.1±10.1 cm/s) was lower than that of the control group (38.6±9.3cm/s). This difference was not statistically significant (p=0.416). However, the mean EDV of the study group (9.09±2.9 cm/s) was higher than that of the control group (8.6±2.0 cm/s) which was also not statistically significant (p=0.074). There was a statistically significant difference (p=<0.001) between the mean RI of the study group (0.70±0.10) and that of the control group (0.77±0.05). The mean PI of the study group (1.35±0.5) was also lower than that of the control group (1.49±0.3), which was statistically significant (p=<0.001). There was also a statistically significant difference (p=0.003) between the mean S/D ratio of the study group (3.64±1.4) and that of the control group (4.5±1.1).

Conclusion: There was significant statistical difference in the fetal middle cerebral artery Doppler velocimetric indices between hypertensive and normotensive groups indicating that Fetal middle cerebral artery Doppler ultrasound is a useful tool in monitoring the haemodynamic changes in the cerebral circulation of fetuses of mothers with hypertension in pregnancy.

Keywords: Middle Cerebral Artery; Doppler; Hypertension

Introduction

Hypertensive disorders of pregnancy represent a group of conditions associated with high blood pressure during pregnancy, proteinuria and in some cases, convulsions [1]. Hypertensive disorders complicating pregnancy are common and form a deadly triad along with haemorrhage and infection; which contribute greatly to maternal mortality and morbidity [2]. Hypertensive disorders accounted for 29.2% of all cases of medical disorders in pregnancy and 18% of all fetal deaths are associated with hypertension [3].

There are four categories of hypertension in pregnancy: chronic hypertension, gestational hypertension, preeclampsia and eclampsia; and preeclampsia superimposed on chronic hypertension [4]. In Nigeria, the prevalence of hypertensive disorders in pregnancy is about 10% [5].

Recent studies confirm the efficacy of middle cerebral artery (MCA) Doppler assessment and advocate it [6]. Its indices provide important information on the hemodynamics of the vascular area under study. MCA Doppler measurement is a well-known modality for detecting fetal compromise [7]. Today, with the advancement of pulsed and color-coded Doppler Ultrasound combined with better reproducibility, the MCA has emerged as the vessel of choice in the Doppler assessment of fetal intracranial circulation [8]. Evaluation of Doppler waveform of the middle cerebral artery can predict most of the at-risk fetuses in high-risk pregnancies. Circulatory changes, reflected in certain fetal Doppler waveforms, can predict adverse perinatal outcome [9].

This study is intended to determine the velocimetric pattern of fetal middle cerebral artery in patients with hypertensive disorders in pregnancy as well as their spectral waveform pattern and compare them with the indices from normal controls.

Materials and Methods

This was a cross sectional, hospital based prospective study that recruited Sixty-five (65) pregnant subjects with history of diagnosed HDP between gestational ages of 20-40 weeks from the antenatal clinic as the study group. Sixty-five (65) gestational age matched pregnant women with normal blood pressure were also recruited from routine antenatal clinic to constitute the control group at Aminu Kano Teaching Hospital (AKTH), Kano, North Western Nigeria; from April 2015 to March 2016. Informed consent was obtained from the subjects.

All subjects with blood pressure of or greater than 140/90 mmHg and pregnant women whose systolic blood pressure exceeds 30 mmHg or diastolic blood pressure exceeds 15 mmHg above the recorded booking blood pressure with singleton fetus within the gestational age 20-40 weeks were included in the study. Whereas pregnant women less than 20 weeks and greater than 40weeks of gestation, non-consenting individuals, and those with presence of maternal diseases such as diabetes mellitus, chronic renal disease, multiple pregnancy, and fetal malformation were excluded for both groups [10]. For the control group all normal pregnant women between 20 to 40 weeks of normal gestation were included.

After documenting the age, parity, clinical history and gestational age of the subjects, blood pressure of the subjects was measured using aneroid sphygmomanometer and stethoscope. DC-6 Mindray (Biomed electronics, Shenzhen, China,2007) ultrasound machine was used. Trans-abdominal obstetric ultrasound scan was then done to determine the lie, presentation, viability of the fetus and gestational age of the pregnancy in the subjects using 3.5MHz transducer to measure a combination of two or more of the following parameters: Bi-parietal diameter (BPD), femur length (FL), head circumference (HC) and abdominal circumference (AC) [11]. Other obstetric measurements such as Amniotic Fluid Index (AFI) and Estimated Fetal Weight (EFW) were determined using appropriate anthropometric measurements.

The fetal MCA Doppler were examined using 7.5MHz linear transducer to insonate the MCA through the fetal head using gray scale and Doppler ultrasound. A transverse view of the fetal brain including the thalami and sphenoid bone wing was obtained and magnified. Using color flow imaging, the circle of Willis was first identified as tubular, colour fillings within the fetal brain anterior to the cerebral peduncles with three major vessels seen anterior, posterior and laterally. The MCA was appreciated as a major lateral branch of the circle of Willis, running anterolaterally at the borderline between the anterior and the middle cerebral fossae usually coloured red due to flow towards the transducer. The MCA is a paired vessel. The contralateral MCA was seen as tubular colour fillings with flow away from the transducer and coloured blue. The MCA close to the transducer (anterior) was interrogated. The pulsed Doppler sample gate was then placed on the

middle portion of this vessel to obtain flow velocity waveforms. The sample volume used was 2-3mm in width. The velocity waveforms were recorded 2mm from the origin of the vessel from the internal carotid artery. The angle between the ultrasound beam and the MCA was between 0-20°. The fetuses were examined in the episodes without breathing or gross fetal movements [12].

To ensure accuracy, a spectral Doppler tracing of at least five consistent cardiac cycles was frozen on the screen of the machine for consistent measurement of parameters. During the study, care was taken to apply minimal pressure to the maternal abdomen with the transducer, as fetal head compression is associated with alterations of intracranial arterial waveforms [13]. One cursor was placed at the highest point of the wave to get the PSV and another cursor placed at the lowest point of the wave to get the EDV. The RI, PI and S/D ratio were generated automatically from the ultrasound machine [14].

Data collected were analyzed using statistical package for social sciences (SPSS) software, version 17.0(SPSS Inc. IBM, Armonk, NY). The Peak systolic velocity (PSV), End diastolic velocity (EDV), Resistive index (RI), Pulsatility index (PI), Systolic/diastolic ratio (S/D), bio data and obstetric parameters of the hypertensive and normotensive pregnant women were recorded. Variables were presented as mean±SD. A p value of less than 0.05 was considered to be statistically significant. Student's t test was used to test the difference in means between variables. Regression analysis was used for evaluation of correlation between indices and gestational age and; between the indices and blood pressure. Findings were presented numerically, graphically and in tabular form.

Results

A total of 130 patients comprising 65 pregnant hypertensive patients and 65 gestational age matched control group were studied (Figure 1). The ages of the study group ranged from 22-43 years with a mean of 31.9±5.1 years while the ages of the control group ranged from 20-43 years with mean age of 27.8 ±4.4 years. Both patients in the study and control groups were classified into 4 groups: 20-24 years, 25-29 years, 30-34years, 35-39 years and 40-44 years. The modal group among the hypertensive patients was 30-34 years and 24-29 years among the control group (Figure 2). However, there was no statistically significant difference between the mean ages of the study and control groups (p=0.156) (Table 1). The parity of the study group ranged from 0-11 with mean of 4.1±2.7, while the parity of the control group ranged from 0-10 with mean of 2.78±2.0. There was statistically significant difference between the mean parity of the study and control group (p=0.002) (Table 1).

The systolic BP of the study group ranged from 140-200 mmHg with mean of 157±13.8 mmHg, while the systolic BP of the control group ranged from 90-130 mmHg with a mean of 111±8.8 mmHg. There was statistically significant difference between the mean systolic BP of the study and control groups (p=0.004). There was also statistically significant difference between the mean diastolic BP of the study and control groups. (p=0.001) The diastolic BP of the study group ranged from 91-120 mmHg with mean of 96±11.0 mmHg, while the diastolic BP of the control group ranged from 60-90 mmHg with a mean of 77.5±6.6 mmHg (Table 1).

The gestational age of the fetuses of the study group ranged from 20-39 weeks with mean of 32.4±4.9 weeks while the gestation-

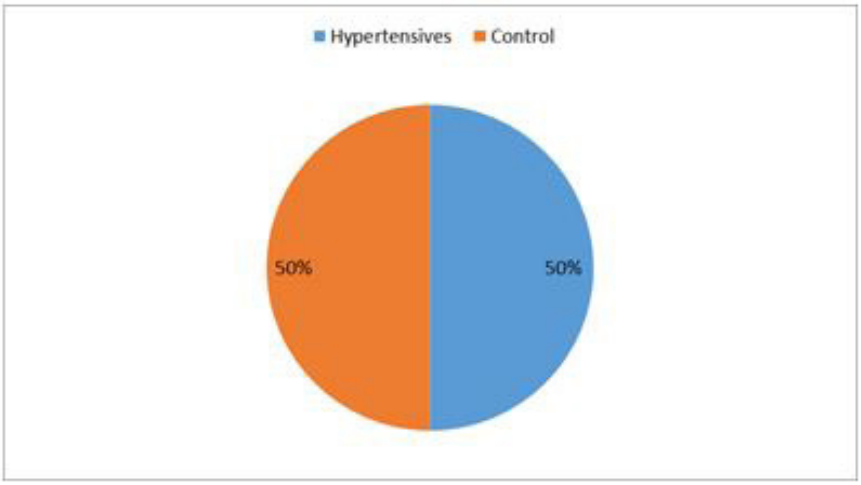

Figure 1: Pie chart showing composition of the respondents

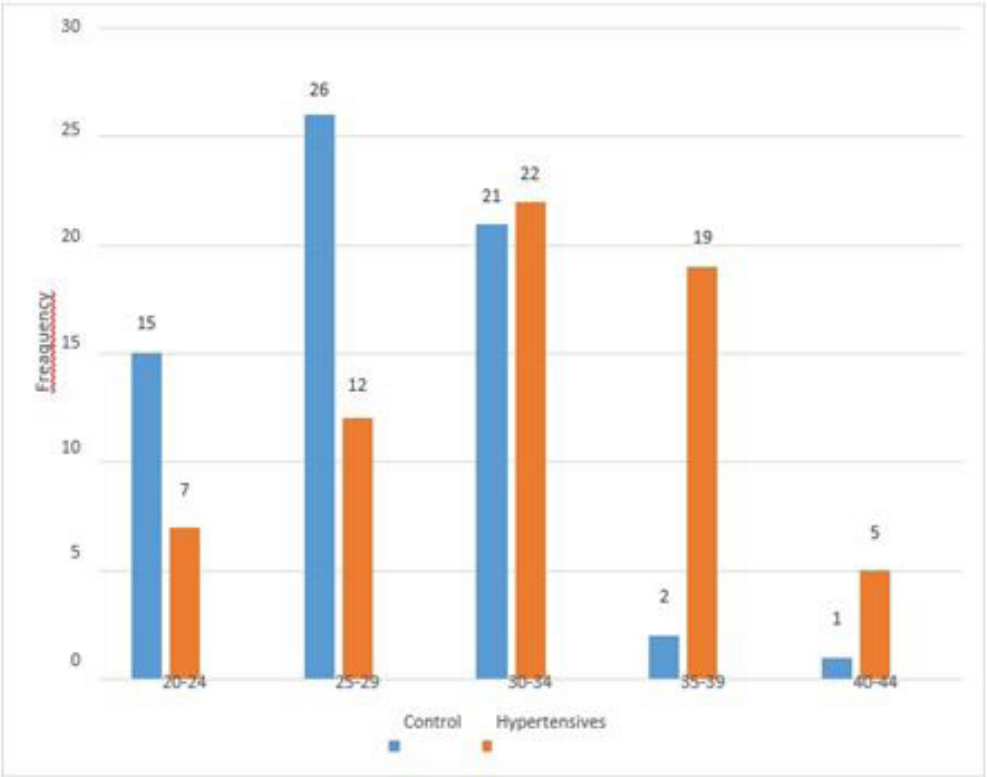

Figure 2: Bar chart showing the mean gestational age distribution among the respondents

al age of fetuses of the control group ranged from 20-39 weeks 46 with mean gestational age of 32.1±5.0 weeks (Figure 3). There was no statistically significant difference between the mean gestational age of the study and control groups (p=0.736). The patients in the study group were classified into 4 groups based on gestational age:

Index	Control	Hypertensive	p value
Age (yrs)	27.83±4.40	31.94±5.07	0.156
Parity	2.78±2.00	4.08±2.72	0.002*
GA	32.12±4.99	32.43±4.85	0.736
EFW(kg)	2.12±0.98	2.10±9.11	0.125
AFI	14.87±1.89	13.75±2.73	0.002*
SBP (mmHg)	111.7±8.76	156.9±13.80	0.004*
DBP (mmHg)	77.54±6.62	96.0±10.98	<0.001*

*=significant at p≤0.05

Table 1: Mean values of demographic and clinical indices of hypertensive and control groups

20-24 weeks, 25-29 weeks,30-34 weeks and 35-39 weeks gestational age. Majority of the patients belong to the 35-39 weeks gestational age (50.7%). The patients in the control group were matched for gestational age with the patients in the study group (Table 2).

The estimated fetal weight (EFW) of the fetuses of the study group ranged from 0.34-3.78 kg with mean of 2.1kg±0.9 kg. The EFW of the fetuses of the control group ranged from 0.34-3.5 kg with mean of 2.1±0.98 kg. The difference between the mean estimated fetal weight of the study and control groups was not statistically significant (p=0.125) (Table 1).

Gestational age (weeks)	Hypertensives	Control
20-24	6	6
24-29	11	11
30-34	15	15
35-39	33	33
Total	65	65

Table 2: Classification of the patients according to gestational age

There is statistically significant difference between the mean amniotic fluid indices of the study and control group (p=0.002) (Table 1). The amniotic fluid indices (AFI) of the study group ranged from 7.5-19.7 with mean of 13.75±2.73 while the AFI of the fetuses of the control group ranged from 10.5-19.2 with mean of 14.9±1.9.

The PSV of the study group ranged from 17.75-53.15cm/s with mean of 32.1±10.1cm/s while the PSV of the control group ranged from 22.68-58.18cm/s with mean of 38.6±9.3cm/s (Figure 4). There was no statistically significant difference between the mean PSV of the study and control groups (p=0.416) (Table 3). There was no statistically significant difference between the mean EDV of the study and control groups (p=0.074) (Table 3). The EDV of the study group ranged from 3.61-21.26cm/s with mean of 9.09±2.90 while the EDV of control group ranged from 5.92-15.78cm/s with a mean of 8.61±2.03cm/s. (Figure 4). However, the mean RI of the

Index	Control	Hypertensive	p value
(PSV(cm/s	38.41±9.17	32.06±10.10	0.416
(EDV(cm/s	8.61±2.04	9.09±2.90	0.074
RI	0.77±0.05	0.70±0.10	0.001*
PI	1.49±0.26	1.35±0.45	0.001*
SD	4.53±1.07	3.64±1.36	0.003*

Table 3: Mean values of Doppler velocimetric indices of hypertensive and control subjects

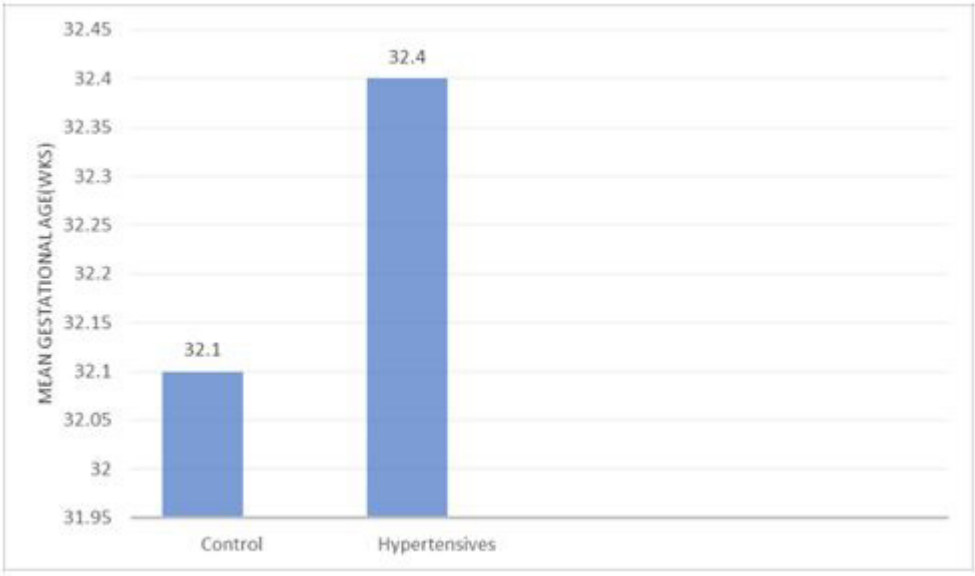

Figure 3: Bar chart showing the mean parity of the respondents

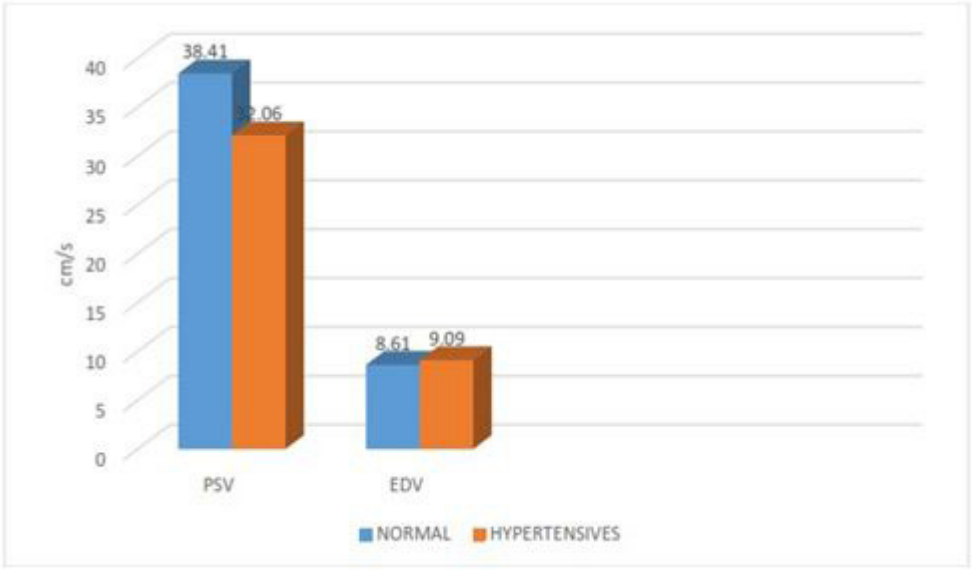

Figure 4: Histogram showing mean PSV and EDV among hypertensive and control groups

study and control groups showed statistically significant difference (p=0.001) (Table 3). The RI of the control group ranged from 0.67-0.88 with mean of 0.77±0.05 while the RI of the study group ranged from 0.37-0.89 with mean of 0.69 (Figure 5). There was also statistically significant difference between mean PI of the study and control groups (p=0.001). (Table 3) The PI of the study group ranged from 1.02-2.08 with mean of 1.49±0.26 while the PI of the study group ranged from 0.50-2.34 with mean of 1.34±0.44 (Figure 5).

ratio also showed negative correlation with systolic BP among hypertensives. (r=-0.227 and -0.209 respectively). However, the correlation was not statistically significant (p=0.069 and 0.095 respectively). RI also showed negative correlation with systolic BP and the correlation was statistically significant. (r=-0.314, p=0.011) (Table 5). In patients with severe hypertension with systolic BP ≥160mmHg, EDV, RI, PI and S/D ratio showed statistically significant correlation with systolic BP (p=0.008, 0.001, 0.050 and 0.025 respectively). (Table 6)

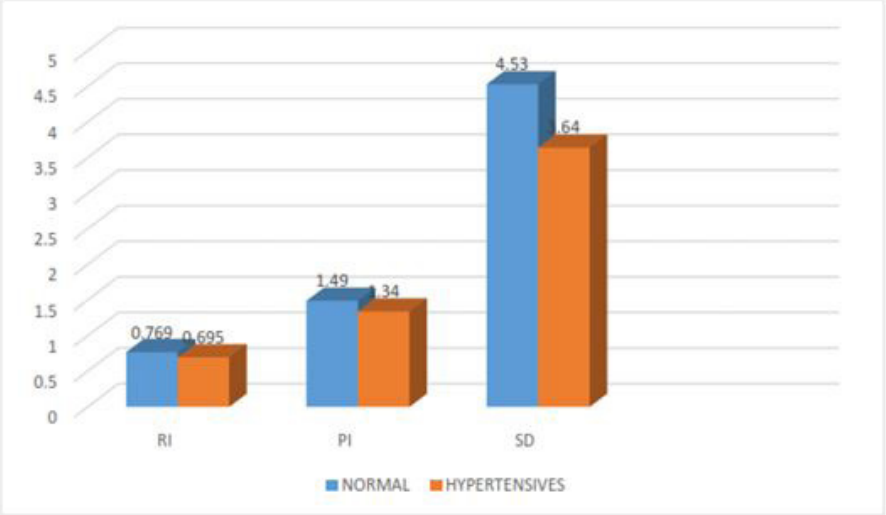

Figure 5: Histogram showing mean PI, RI and S/D ratio among hypertensive and controls

There was statistically significant difference between the mean S/D ratio of the study and control groups (p=0.003). (Table 3) The S/D ratio of the study group ranged from 1.58-8.17 with mean of 3.64±1.36 while S/D ratio of the control group ranged from 3.00-8.43 with mean of 4.53±1.07 (Figure 5). Majority of the patients in the study group had normal PSV (84.6%) while 15.4% had decreased PSV. The EDV was normal in 49.2% of the patients in the study group, 49.2% showed decreased EDV and 1.5% had increased EDV. RI was normal in 69.2% of patients in the study group, 27.7% showed decreased RI while 3.1% showed higher RI values. PI was normal in majority of the patients in the study group (49.2%) while 46.2% showed decreased PI and 4.6% had higher PI. Majority of the patients (55.4%) in the study group showed decreased S/D ratio, while 43.1% had normal S/D ratio and 1.5% showed higher S/D ratio. (Table 4)

PSV showed negative correlation with systolic BP among fetuses of hypertensive patients (p=-0.067). However, the correlation was not statistically significant. (p=0.597). There was statistically significant correlation between the EDV and systolic BP among hypertensives. (p=0.299, r=0.016). PI and S/D

Index	r value	p value
PSV	0.400	0.001*
EDV	0.378	0.002*
RI	-0.038	0.764
PI	-0.275	0.026*
S/D ratio	-0.063	0.619

Table 4: Correlation of Doppler indices with gestational age among control group

Index	Low	Normal	High
PSV	(15.4%)10	(84.6%)55	**0(0%)**
EDV	(49.2%)32	(49.2%)32	**1(1.5%)**
RI	(27.7%)18	(69.2%)45	**2(3.1%)**
PI	(46.2%)30	(49.2%)32	**3(4.6%)**
S/D	(55.4%)36	(43.1%)28	**1(1.5%)**

.**Table 5**: Pattern of abnormalities of indices in hypertensive group

Only RI showed negative correlation with diastolic BP among fetuses of hypertensive patients that was statistically significant. (r=-0.283, p=0.002). (Table 5). Although, PSV, PI and S/D ratio showed negative correlation with diastolic BP, however they were not statistically significant (r=-0235, p=0.06), (r=-0124, p=0.326) and (r=-0.206, p=0.99) respectively. (Table 7). However, at diastolic BP≥ 100mmHg, RI, PI and S/D showed correlation that was statistically significant (r=-0.431, p=0.02), (r=-0.402, p=0.03) and (r=-0.380, p=0.04.) (Table 8)

Index	r value	p value
PSV	-0.067	0.597
EDV	0.299	0.016*
RI	-0.314	0.011*
PI	-0.227	0.069
S/D ratio	-0.209	0.095

Table 6: Regression statistics of indices with systolic BP among hypertensives

Index	r value	p value
PSV	-0.235	0.060
EDV	0.048	0.704
RI	-0.283	0.023*
PI	-0.124	0.326
S/D ratio	-0.206	0.099

Table 7: Regression statistics of indices with diastolic BP among hypertensives

Index	r value	p value
PSV	-0.054	0.781
EDV	0.486	0.008*
RI	-0.583	0.001*
PI	-0.365	0.050*
S/D ratio	-0.416	0.025*

Table 8: Regression statistics of indices with systolic BP≥160

Discussion

The mean age of the subjects in the study group was 31.5±5.1 years which was similar to 31.33±5.92 years reported by Ayyuba, *et al.* [15] in Kano and 29.9±6.4 years reported by Ye, *et al.* [16] in China. However, the finding is slightly higher than 27±6.0 years reported by Al-Ghamdi, *et al.* [17] in Saudi Arabia. The variation in mean age of the study group with the one reported by Al Ghamdi, *et al.* [17] could be attributed to the difference in age at marriage and urbanization between Kano and North Western province of Saudi Arabia. The mean age at first marriage of women in semi urban and rural centers of Saudi area was 16 years, [18] while the mean age at first marriage for urban centers of Nigeria was 20.8 years. The mean age of the control group was 27.8±4.4 years. Even though there was difference between the mean age of the study and control groups, it was not statistically significant. (p=0.156). This is similar to the findings of Ali, *et al.* [19] in Khartoum.

The mean parity of the study group was 4.1±2.7. This finding is similar to the findings of Al Ghamdi, *et al.* [17] in Saudi Arabia who recorded a mean parity of 4.9±3.9. However, the finding is higher than that of Ali, *et al.* [19] in Sudan who recorded a mean parity of 2.7±1.7. The difference in parity between this study and that of Kassala, Sudan could be attributed to the fact that Kassala is a rural area with many of the patients nulliparous and not educated up to the secondary school level. [19] Singh, *et al.* [20] in Sokoto, found a higher prevalence of hypertensive disorders in nulliparous and grand multiparous women. The higher parity recorded in this study could also be attributed to higher number of grand multiparous women in the study who have greater risk for medical disorders such as essential hypertension. The mean parity of the control group was 2.8±2.0. There was statistically significant difference between the mean parity of the study and control groups (p=0.002). This is similar to the findings of Ye, *et al.* [16] in China who found statistically significant difference between the parity of the hypertensive and normotensive patients.

The mean systolic BP of the study group was 157±13.8 mmHg which is comparable to 158±19.3 mmHg found by Koofreh, *et al.* [21] in their study on Pre-eclamptic patients in Calabar Nigeria and slightly higher than the findings of Al-Ghamdi, *et al.* [17] in Saudi Arabia who found a mean systolic BP of 142 mmHg. There is statistically significant difference between the mean systolic BP of the study and control groups (p=0.004) The mean diastolic BP of the study group was 96±11 mmHg which was similar to 98±8 mmHg found by Al-Ghamdi, *et al.*[17] in Saudi Arabia and 101.7 mmHg found by Koofreh, *et al.* [21] in Calabar. There is statistically significant difference between mean diastolic BP of the study and control groups (p<0.001).

The mean estimated fetal weight (EFW) of the study group was 2.10±0.9 kg and 2.12±1.0 kg for the control group. There is no statistically significant difference between the mean

EFW between the study and control groups (p=0.125). This is similar to the findings of Ayyuba, *et al.* [15] in Kano who found no statistically significant difference between the EFW of babies of mothers with hypertensive disorders of pregnancy and normotensive mothers (p=0.648). Similar finding was recorded by Singh, *et al.* [20] in Sokoto who found no statistically significant difference between EFW of babies whose mothers have pregnancy induced hypertension and those of normotensive mothers. (p=0.07)

There is statistically significant difference between the mean AFI of the study and control groups. (p=0.002) The mean Amniotic fluid index of the study group was 13.8±2.7 and 14.9±1.9 for the control group. This is similar to the findings of Messawa, *et al.* [22] who found statistically significant difference between the mean AFI of normal pregnant women and those with hypertensive disorders of pregnancy in their study on the Doppler ultrasound in high risk pregnancies in Makkah, Saudi Arabia. (p=<0.001). The similarity between the findings of this study and that of Messawa, *et al.* [22] could be attributed to the relative placental insufficiency that occurs in hypertensive disorders of pregnancy. Amniotic fluid is partly produced by the placenta and other sources like the urine produced by the fetus. Decreased placental blood flow and ischaemia that occurs in patients with hypertensive disorders of pregnancy causes reduction in amniotic fluid volume.

This study found that PSV increased with increase in gestational age in normotensive pregnant women. This is similar to the findings of Tarzanmi, *et al.* [8] in Iran that showed increase of PSV with increasing gestational age. Similar findings were documented by Ehigiamusoe, *et al.* [23] in Benin City and Taher, *et al.* [24] in Bangladesh. Furthermore, this study found a positive linear relationship between PSV and gestational age. (r=0.400, p= 0.001) This finding was similar to that of Seffah, *et al.* [25] in Ghana. This finding of increase in PSV with advancing gestational age consistent with other studies is attributed to the progressive increase in fetal cardiac output as the pregnancy advances to compensate for increased fetal demand of oxygen and nutrients.

Similarly, this study found an increase in EDV with advancing gestational age. This is similar to the findings of Ehigiamusoe, *et al.* [23] in Benin. This finding of increase in EDV with advancing gestational age is attributed to the decrease in vascular resistance of the fetal MCA with advancing gestational age.

RI was found to decrease with increasing gestational age. This was similar to the findings of Ehigiamusoe, *et al.* [23], Taher, *et al.* [24] and Seffah, *et al.* [25]. There was negative linear correlation between the RI and gestational age (r=-0.038, p=0.764), but the relationship was not statistically significant. The finding was however slightly different from that of Tarzanmi, *et al.* [8] who found significant relationship between RI and increasing gestational age. This could be attributed to the marked difference in sample size between this study and that of Tarzanmi, *et al.* [8], who conducted their study on 1037 patients.

PI also showed decrease with increasing gestational age. This is similar to the findings of Tarzanmi, *et al.* [8], Ehigiamusoe, *et al.* [23], Taher, *et al.* [24] and Seffah, *et al.* [25]. PI showed significant negative relationship with increasing gestational age (r=-0.063, p=0.026). This is similar to the findings of Tarzanmi, *et al.* [8]. The reduction in PI with advanced gestational age is attributed to decrease in fetal MCA vascular resistance as the pregnancy advances.

Similarly, the S/D ratio was found to decrease with increasing gestational age. This was similar to the findings of other workers. There was no statistically significant correlation between the S/D ratio and increasing gestational age (r=-0.063, p=0.619). This was similar to the finding of Taher, *et al.* [24] but different from the finding of Tarzanmi, *et al.* [8] who found statistically significant correlation between decrease in S/D ratio and increasing gestational age. This could be attributed to the difference between the sample size of this study and that of Tarzanmi, *et al.* [8] whose sample size was significantly larger.

This study found a spectrum of abnormalities of MCA Doppler indices in patients with hypertensive disorder of pregnancy. Only 15.4% of the patients in this study showed abnormal decrease in PSV. This is significantly lower than 76% of abnormalities of MCA PSV found by Yakasai, *et al.* [26] in their study of the pattern of arterial blood flow in some selected vessels in patients with pregnancy induced hypertension in Kano, Nigeria. This could be accounted for by the difference in sample size between this study and that of Yakasai, *el al.* [26] who conducted their study in 34 patients as against 65 in this study. Moreover, Yakasai, *et al.* [26] conducted their study in patients with pregnancy induced hypertension alone excluding other forms of hypertensive disorders of pregnancy. Patients in the study group showed decrease in fetal MCA PSV when compared with the control group with mean PSV of 32.1±10cm/s and 38.4±9.2cm/s respectively. This is similar to the findings of Yakasai, *et al.* [26]

who found lower mean fetal MCA PSV in patients with pregnancy induced hypertension when compared with normotensive patients. There was no statistically significant correlation between the fetal MCA PSV with both maternal systolic and diastolic BP (p=0.597 and 0.06 respectively). Even in patients with severe systolic hypertension with BP≥160mmHg; and diastolic BP≥100mmHg, there was no statistically significant correlation between fetal MCA PSV with maternal systolic and diastolic BP (p=0.781 and 0.301 respectively)

The patients in the study group showed higher EDV values when compared with normotensive patients with mean EDV of 9.1±2.9cm/s and 8.61cm/s respectively, even though the difference was not statistically significant. This is similar to the findings of Bhatt, *et al.* [27] in India who found higher EDV in fetuses of mothers with pregnancy induced hypertension due to brain sparing action. EDV showed significant correlation with systolic BP among hypertensives (p=0.016). However, the correlation with diastolic BP was not statistically significant. (p=0.704). In patients with severe systolic hypertension; and diastolic BP≥160 mmHg, there was also statistically significant correlation with systolic BP (p=0.008) and no statistically significant correlation was seen with diastolic BP (p=0.257).

RI was abnormal in 30.8% of patients in the study group. This was lower than 58% found by Yakasai, *et al.* [26] The lower findings recorded by this study could be attributed to lower sample size of the study by Yakasai et al. [26] and conduct of their study in patients with pregnancy induced hypertension alone excluding other forms of hypertension. Mean RI was lower in patients with hypertensive disorders in pregnancy when compared to normotensive patients with mean of 0.70 and 0.77 respectively. The difference in mean RI between hypertensive and normotensive patients was statistically significant (p<0.001). This is similar to the findings of Gupta, *et al.* [28] and Khalid, *et al.* [29] who found statistically significant reduction in mean RI in patients with pregnancy induced hypertension. RI showed significant correlation with systolic and diastolic BP (p=0.011 and 0.023 respectively). In patients with severe systolic hypertension; and diastolic BP≥100mmHg, RI also showed statistically significant correlation with both systolic and diastolic BP (p=0.01 and 0.02 respectively)

The patients in the study group also showed lower PI when compared with the patients in the control group with mean of 1.35 and 1.49 respectively. The difference in mean PI between the study and control groups was statistically significant (p<0.001). This is similar to the findings of Gupta, *et al.* [28] and Khalid, *et al.* [29]. PI did not show statistically significant correlation with systolic and diastolic BP among hypertensive group (p=0.069 and 0.326) respectively. However, in patients with severe systolic hypertension; and diastolic BP≥160mmHg, there was statistically significant correlation of PI with diastolic and systolic BP (p=0.05 and 0.03 respectively).

Among hypertensive patients, 56.9% of showed abnormal S/D ratio which was lower than the 88% recorded by Yakasai, *et al.* [26] This could be attributed to the lower sample size of Yakasai, *et al.* [26] and selection of patients with pregnancy induced hypertension alone excluding other forms of hypertensive disorders of pregnancy. There was also lower S/D ratio among hypertensive patients when compared with normotensives with mean of 3.64 and 4.53 respectively. The difference in mean S/D ratio between the study and control groups was statistically significant (p=0.03). This was similar to the findings of Gupta, *et al.* [28] and Khalid, *et al.* [29]. The S/D ratio did not show statistically significant correlation with systolic and diastolic BP among hypertensive patients (p=0.095 and 0.099 respectively). However, in patients with severe systolic hypertension; and diastolic BP≥100mmHg, there was statistically significant correlation with systolic and diastolic BP (p=0.025 and 0.042 respectively).

The general pattern of abnormalities of fetal MCA Doppler indices in patients with hypertensive disorders of pregnancy is statistically significant decrease in PSV, RI, PI and S/D ratio while the EDV increases. Similarly, there was statistically significant correlation between maternal increase in systolic and diastolic BP; and abnormalities of Doppler indices.

Fetal MCA demonstrates high resistant waveforms (high systolic velocity and low or absent diastolic velocity) throughout pregnancy. The mean values of indices (PI, RI and S/D ratio) showed decline with increasing gestational age due to decrease resistance of the vessel to meet the oxygen demand of the growing fetus while PSV and EDV increase with advancing gestational age. In hypertensive disorders of pregnancy, due to chronic hypoxia, there is redistribution of blood flow to the essential organs such as the heart and the myocardium [29,30]. This study found significant reduction of fetal MCA Doppler indices (PSV, RI, PI and S/D ratio) in patients with hypertension disor-

ders of pregnancy similar to other studies [26,29], while the fetal MCA EDV increases due to cerebral redistribution of blood.

The study also found a statistically significant relationship between increase in blood pressure with abnormalities of fetal MCA Doppler indices.

Conflicts of interest:

There are no conflicts of interest.

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