UMBILICAL ARTERY DOPPLER INDICES: TRENDS IN APPARENTLY NORMAL GESTATIONS BETWEEN TWENTY TO FORTY WEEKS AGE IN ABUJA, NIGERIA

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ABSTRACT

Background: Umbilical artery Doppler ultrasound is an established and safe tool for quantitative analysis of feto-placental blood flow in pregnancy which has become vital in foetal medicine. As foetal medicine practice is undergoing marked changes fuelled by vast amount of disease states requiring extensive ante-partum risk-assessment.

Objective: Was to determine the umbilical artery Doppler indices (resistive index (RI), pulsatility index (PI) and systolic-diastolic ratio (SDR)) and assess the trend in normal gestations between 20 and 40 weeks ages with a view to establishing local sonographic reference ranges and to correlate the Doppler indices with gestational age and foetal heart rate.

Materials and methods: A General Electric VOLUSON E8 ultrasound machine with colour Doppler facilities, thermal image printer, external hard drive and electronic medical record system were used in data collection. In this prospective, cross-sectional study, 384 pregnant women at 20–40 weeks gestational ages with no foetal malformation and no maternal medical disease, especially of hypertension and diabetes were recruited. Pulse wave Doppler was used to determine the umbilical artery RI, PI and SDR. Pearson's correlation analysis of the relationship between these parameters and gestational age and foetal heart rate was done. Statistical significance level was set at $P < 0.05$.

Results: All the umbilical arteries were paired. Mean RI, PI and SDR declined with increasing gestational age and decreased from 0.7422 to 0.5338, from 1.2867 to 0.7688 and from 4.0667 to 2.1925, respectively. With regard to correlation between gestational age and Doppler indices, r = -0.600 for RI (p = 0.000), -0.564 for PI (p = 0.000) and -0.596 for SDR (p = 0.000). Conversely, the relationship between Doppler indices and foetal heart rate showed no significant correlation. Hence, r = -0.008 for RI (p = 0.879), -0.025 for PI (p = 0.619) and -0.021 for SDR (p = 0.684). $P > 0.05$ in all cases.

Conclusion: The nomograms of the umbilical artery Doppler indices were constructed which showed that the indices decreased with gestational age. These normative data could serve as reference ranges for evaluation of the umbilical artery circulation in this locality.

Key words: Doppler ultrasound, Umbilical artery, Resistive index, Pulsatility index and Systolic-diastolic ratio.

INTRODUCTION

The primary goal of ante-partum evaluation is to identify foetuses at risk of intrauterine injury and death so that intervention and timely delivery can prevent progression to stillbirth [1]. In the United States, stillbirths accounts for more than 55% of the peri-natal mortality and could potentially be prevented with an effective form of foetal testing [2]. To be successful at preventing death, an ante-partum test needs to identify a compromised foetus in enough advanced time for an intervention or rescue.

The use of Doppler Ultrasound in pregnancy to evaluate the uterine and umbilical artery is an important clinical tool in detecting obstetric complications resulting from utero-placental insufficiency, which may increase the risk of adverse effects on both the mother and the foetus during pregnancy, labour and delivery [3]. Disease entities related to utero-placental deficiency, majorly from haemorrhage (39%) and maternal hypertension (9.1%) have been observed to account for largest proportion of maternal death in developing countries [3]. The maternal mortality rate in Nigeria is among the highest in the world with pre-eclampsia-eclampsia documented as the third largest course of the high maternal mortality [4].

The unique aspect of foetal circulation is the umbilical placental route and the presence of three circulatory shunts, viz; ductus venosus, ductus arteriosus and patent foramen ovale. The iliac arteries give rise to a pair of umbilical arteries which passes in either side of the foetal urinary bladder into the umbilical cord and empty into the placenta [5]. The functions of the placenta in foetal circulation include nutritional, excretory, respiratory, and endocrine roles and the foetal life starts from 9 weeks to term [5].

Hypertensive disorders in pregnancy lead to impairment of normal physiological vascular modifications resulting in abnormal hemodynamic and obstetric complications of impaired placentation. These complications are foetal growth restriction, pre-eclampsia, intrauterine death and placenta abruption [6]. Doppler Ultrasound provides a non-invasive method for the study of maternal and fetal hemodynamic in pregnancy. Doppler interrogation of the umbilical artery gives information on the perfusion of the feto-placental circulation [7].

There are other options for assessment of foetal wellbeing but the current practice involves a combination of methods which may reduce the relevance of the effectiveness of single testing [8][1]. Among many indices possible in Doppler studies, resistive index (RI), pulsatility index (PI) and systolic-diastolic ratio (SDR) are the most commonly used in obstetric application [9]. A high mean resistance greater than 95th percentile for RI or PI, absent or reversed end-diastolic flow will indicate abnormal Doppler blood flow, an indicator that the pregnancy may be at high-risk of developing the complication of impaired placentation [10][6][2]. Early detection of the above vascular changes can enhance peri-natal outcome. But there is perceived poor awareness of the gains of foetal Doppler ultrasound amongst clinicians and no established normative data on the umbilical artery Doppler indices in our environment to guide interpretation of Doppler studies. The importance of the normative data is underscored by the fact that vascular changes pre-date other factors in the case of foetal compromise [11].

The review of the related literature reveals all studies on umbilical artery Doppler indices (RI, PI and SDR) with a uniform result of gradual decrease in the indices with increasing gestational age [12][10][13][14][15][16]. But the actual mean Doppler indices values remained varied presumably due to different designs and racial differences. Therefore, the establishment of normative data of umbilical artery RI, PI and SDR in Nigerian population is what this study was set to address. The regression equation and correlation of the indices with gestational age and foetal heart rate were also derived. The results shall serve as a reference material and a guide in early detection of foetal abnormal hemodynamic status.

MATERIALS AND METHODS

The study employed a prospective cross-sectional design. It was carried out between May and August, 2018 at NISA Premier Hospital Abuja, Nigeria, which is an Obstetrics and Gynaecology Specialist Hospital. Ethical approval was obtained from the Ethics Committee of Health and Human Services Secretariat, Federal Capital Development Authority, Abuja. Written informed consent was obtained from the pregnant women used for the study.

The ultrasound machine used was a General Electric (GE) manufactured colour Doppler machine: Voluson E8 Expert with broad band convex volume probe, manufactured in 2014 and installed in October 2016. A Sony thermal printer and paper, an external hard drive, ultrasound gel and the hospital electronic medical record system were other accessories utilized. The sample size of 384 was determined by the infinite population formula at 5% level of significance and all pregnant women within 20 – 40 weeks gestational age formed the population for the study. The inclusion criteria were singleton gestation, known last menstrual period or first trimester scan, maternal blood pressure below 140/90 and no history of diabetes or intra-uterine growth restriction (IUGR). A sonographer with over ten years experience was involved in the data collection using the same ultrasound machine. Prior to the data collection, pilot studies of ten normal pregnancies were scanned by the sonographer and two sets of data generated from each subject. The data was used to test for the intra-observer variation using the student's t-test statistic. There was no significant difference in the means of the indices obtained by the sonographer. The procedure was clearly explained to the patients, after which their informed consent was obtained. The patients' data input into the ultrasound machine captures the LMP, hospital ID etc. Confidentiality of the

subjects were maintained throughout the study. The routine obstetric scan was carried out which served as a baseline for inclusion and exclusion. A free loop of the umbilical cord was identified and enhanced by a colour Doppler mode. Then pulse wave Doppler mode was activated, the sample gate adjusted to 2 mm, wall filter to 50Hz and insonation angle to less than 60 degrees. The pulse repetition frequency adjusted to remove aliasing, if any. The spectral Doppler was captured during foetal quietness for a distortion free and clear wave signal. Then the image was frozen and the umbilical artery was selected from the calc panel followed by auto measurement of the spectral trace to calculate the Doppler indices. The spectral image was printed and saved as well. The obstetric report page was also printed and the pictures filed for the purpose of the research work. The statistical analysis was performed with the Statistical Package for Social Sciences (SPSS) version 23. Descriptive statistics were obtained.

RESULTS

Three hundred and eighty four (384) pregnant women were recruited for the study. The frequency distribution of the subjects according to gestational ages shows that the highest number of subjects come from 36 weeks (n = 57: 14.8%) while the least of the subjects come from 25 weeks (n = 5: 1.3%), (Table 1). The researchers assumed normal distribution of the Doppler indices on the account of the large sample size, the central limit theorem holds and most previous literature did same. Hence, Pearson's product moment correlation was employed in the analysis. The scatter plots showing the relationship of RI, PI and SDR with gestational age demonstrated moderate negative linear correlation in all the indices (Figures 1 - 3). Conversely, the scatter plots of the relationship between the RI, PI and SDR with foetal heart rate demonstrated non linear correlation in all the indices (Figures 4 - 6). The mean umbilical artery RI, PI and SDR by weeks of the foetuses were 0.7422 to 0.5338, 1.2867 to 0.7688 and 4.0667 to 2.1925 respectively (Tables 2 - 4). These Tables represent the nomogram values at 95% confidence interval of the various indices studied in this work. The graphical representations of the nomograms were also shown in Tables 7 – 9 respectively. Each graph demonstrates a negative trend with advancing gestational age at 95% confidence interval.

Table 1: Frequency distribution of the subjects according to gestational ages by weeks. Total number of subjects = 384.

GA (weeks)	Frequency	Percent	Cumulative Percent
20	9	2.3	2.3
21	13	3.4	5.7
22	11	2.9	8.6
23	10	2.6	11.2
24	10	2.6	13.8
25	5	1.3	15.1
26	6	1.6	16.7
27	22	5.7	22.4
28	38	9.9	32.3
29	28	7.3	39.6
30	11	2.9	42.4
31	15	3.9	46.4
32	13	3.4	49.7
33	8	2.1	51.8
34	20	5.2	57.0
35	28	7.3	64.3
36	57	14.8	79.2
37	33	8.6	87.8
38	19	4.9	92.7
39	12	3.1	95.8
40	16	4.2	100.0
Total	384	100.0	

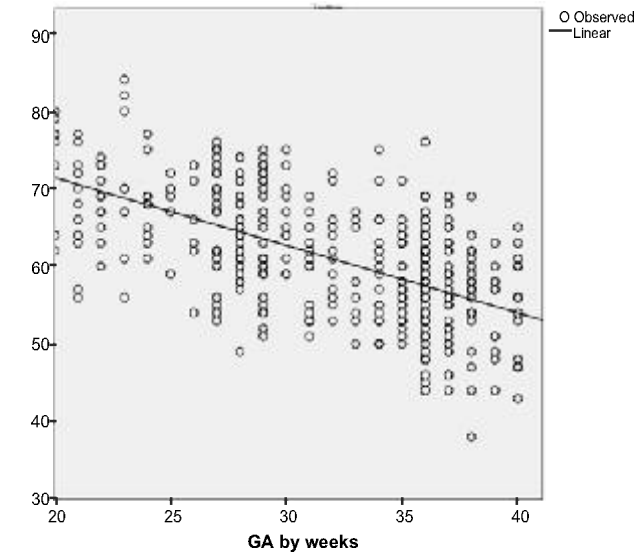

Figure 1: Scatter diagram showing the relationship between the resistive index and the gestational age (weeks)

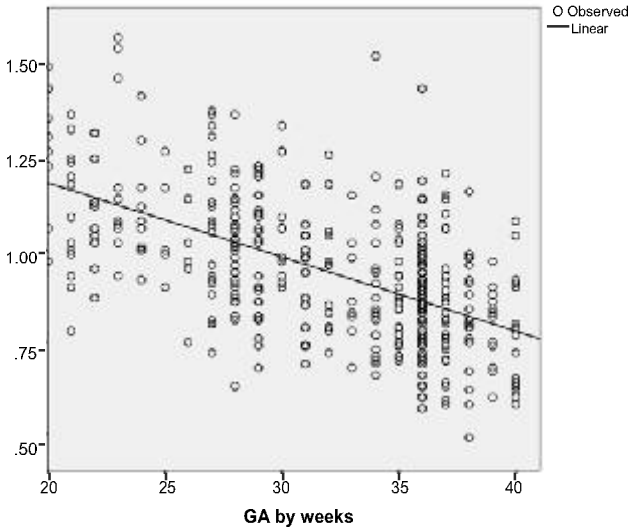

Figure 2: Scatter diagram showing the relationship between the pulsatility index and the gestational age (weeks).

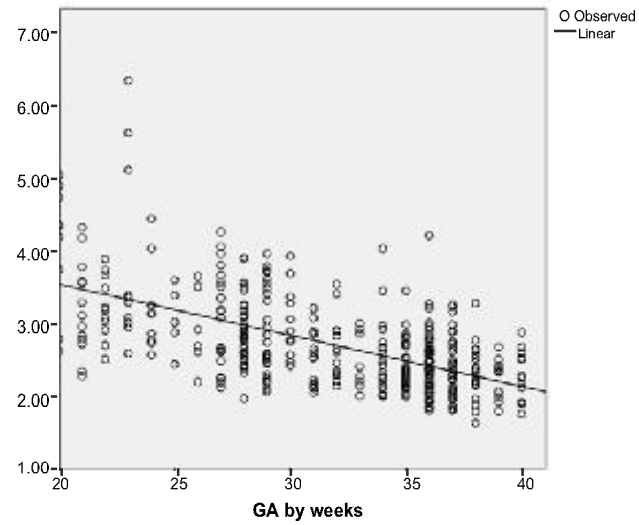

Figure 3: Scatter diagram showing the relationship between the systolic-diastolic ratio and the gestational age (weeks)

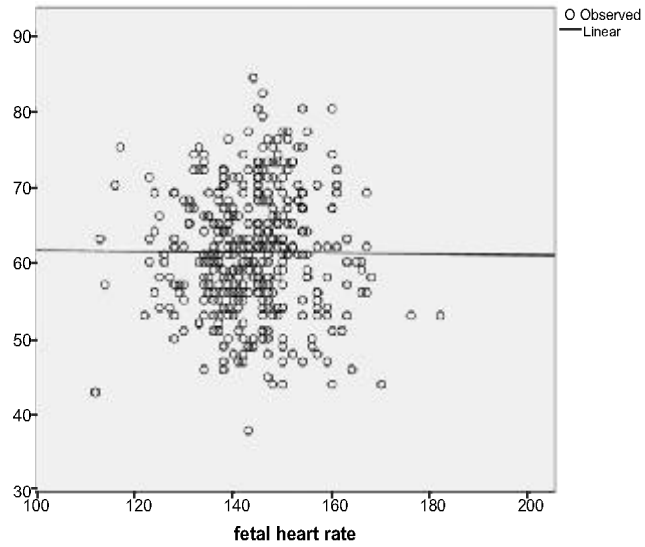

Figure 4: Scatter diagram showing the relationship between the umbilical artery resistive index and the fetal heart rate (bpm).

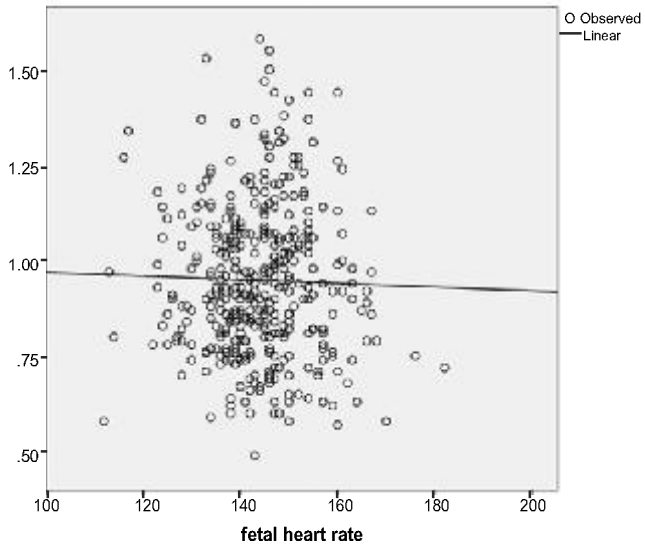

Figure 5 : Scatter diagram showing the relationship between the umbilical artery pulsatility index and the fetal heart rate (bpm).

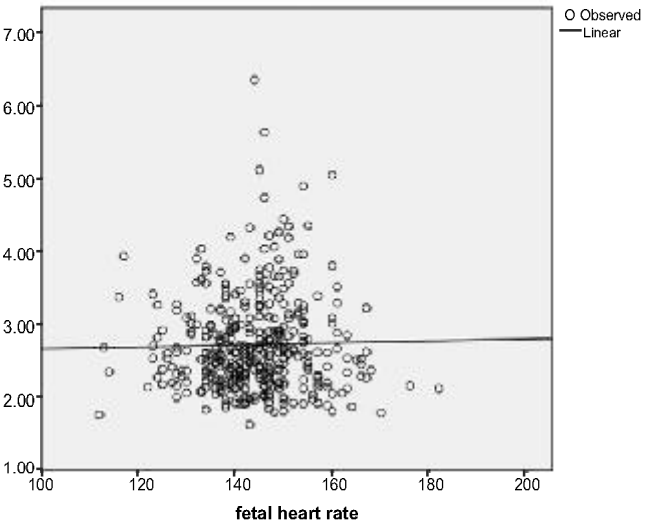

Figure 6 : Scatter diagram showing the relationship between the umbilical artery systolic-diastolic ratio and the fetal heart rate (bpm).

Table 2: Table showing the nomogram values for resistive index (RI) and the upper bound and lower bound 95% confidence limits.

95% Confidence Interval for Mean Resistive Index			
Gestational Age (weeks)	Lower bound	Mean ± SD	Upper bound
20	0.6904	0.7422 ± 0.0674	0.7940
21	0.6353	0.6754 ± 0.0664	0.7155
22	0.6350	0.6827 ± 0.0443	0.7125
23	0.6426	0.7070 ± 0.0900	0.7714
24	0.6428	0.6790 ± 0.0507	0.7152
25	0.6115	0.6740 ± 0.0503	0.7365
26	0.5768	0.6483 ± 0.0683	0.7203
27	0.6277	0.6605 ± 0.0736	0.6931
28	0.6270	0.6445 ± 0.0531	0.6619
29	0.6081	0.6368 ± 0.0738	0.6654
30	0.6239	0.6600 ± 0.0536	0.6961
31	0.5617	0.5940 ± 0.0584	0.6263
32	0.5765	0.6131 ± 0.0606	0.6497
33	0.5315	0.5863 ± 0.0655	0.6410
34	0.5522	0.5860 ± 0.0722	0.6198
35	0.5616	0.5814 ± 0.0513	0.6013
36	0.5613	0.5786 ± 0.0652	0.5959
37	0.5450	0.5694 ± 0.0688	0.5938
38	0.5234	0.5589 ± 0.0738	0.5945
39	0.5082	0.5442 ± 0.0566	0.5802
40	0.4966	0.5338 ± 0.0697	0.5709

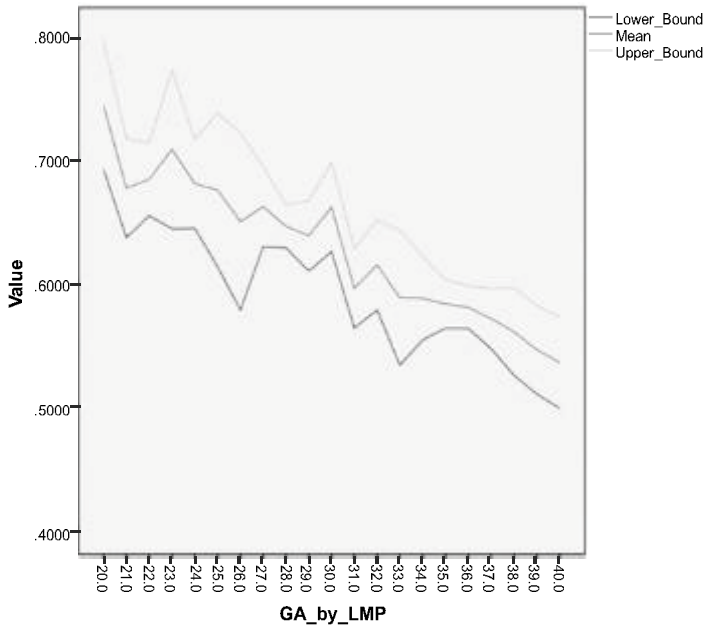

Figure 7: Graph showing the nomogram values for the mean umbilical artery resistive index and upper bound and lower bound 95% confidence limits.

Table 3: Table showing the nomogram values for umbilical artery pulsatility index (PI) and the upper bound and lower bound 95% confidence limits.

95% Confidence Interval for Mean Pulsatility Index			
Gestational Age (weeks)	Lower bound	Mean ± SD	Upper bound
20	1.1498	1.2867±0.1780	1.4235
21	0.9903	1.0985±0.1789	1.2066
22	1.0133	1.1100±0.1440	1.2067
23	1.0384	1.2070±0.2357	1.3756
24	0.9988	1.1080±0.1526	1.2172
25	0.8796	1.0660±0.1501	1.2524
26	0.8366	1.0083±0.1636	1.1801
27	0.9741	1.1064±0.2020	1.1532
28	0.9558	1.0018±0.1402	1.0479
29	0.9249	0.9904±0.1688	1.0558
30	0.9656	1.0709±0.1568	1.1762
31	0.8282	0.9100±0.1478	0.9918
32	0.8378	0.9369±0.1640	1.0360
33	0.7643	0.8900±0.1503	1.0157
34	0.7979	0.8965±0.2106	0.9951
35	0.8167	0.8650±0.1247	0.9133
36	0.8284	0.8709±0.1603	0.9134
37	0.8016	0.8515±0.1691	0.9215
38	0.7468	0.8253±0.1627	0.9037
39	0.7263	0.7950±0.1083	0.8638
40	0.6834	0.7688±0.1601	0.8541

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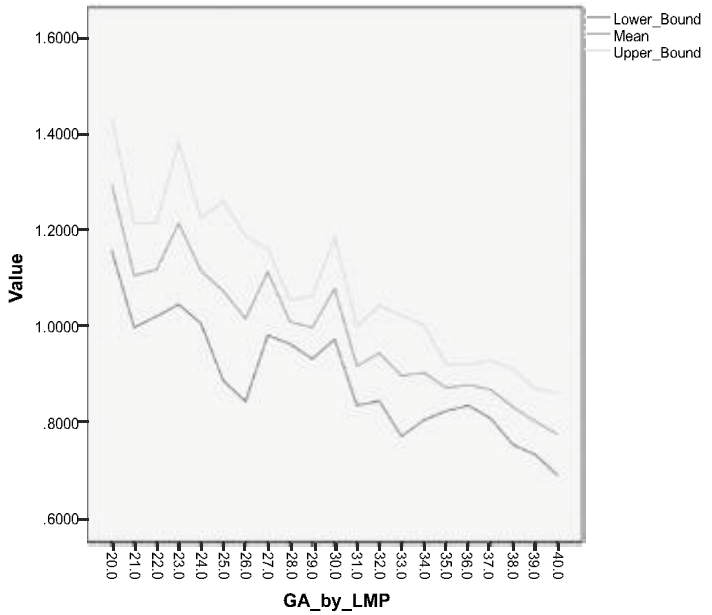

Figure 8: Graph showing the nomogram values for the mean umbilical artery pulsatility index and upper bound and lower bound 95% confidence limits.

Table 4: Table showing the nomogram values for umbilical artery systolic-diastolic ratio (SDR) and the upper bound and lower bound 95% confidence limits.

95% Confidence Interval for mean systolic diastolic ratio			
Gestational age (weeks)	Lower bound	Mean ± SD	Upper bound
20	3.3974	4.0667 ± 0.8706	4.7359
21	2.8089	3.2000 ± 0.6473	3.5911
22	2.9163	3.2100 ± 0.4372	3.5037
23	2.9290	3.8640 ± 1.3071	4.7990
24	2.7834	3.2070 ± 0.5921	3.6306
25	2.4943	3.0560 ± 0.4524	3.6177
26	2.3361	2.9200 ± 0.5564	3.5039
27	2.7889	3.0759 ± 0.6473	3.3629
28	2.7359	2.8805 ± 0.4401	3.0252
29	2.6518	2.8875 ± 0.6078	3.1232
30	2.6772	3.0109 ± 0.4968	3.3446
31	2.3152	2.5280 ± 0.3843	2.7408
32	2.3834	2.6515 ± 0.4438	2.9197
33	2.1391	2.4663 ± 0.3914	2.7934
34	2.2603	2.5055 ± 0.5241	2.7508
35	2.2983	2.4289 ± 0.3369	2.5596
36	2.3224	2.4321 ± 0.4133	2.5418
37	2.2415	2.3864 ± 0.4086	2.5312
38	2.1318	2.3147 ± 0.3796	2.4977
39	2.0582	2.2275 ± 0.2665	2.3968
40	2.0100	2.1925 ± 0.3432	2.3754

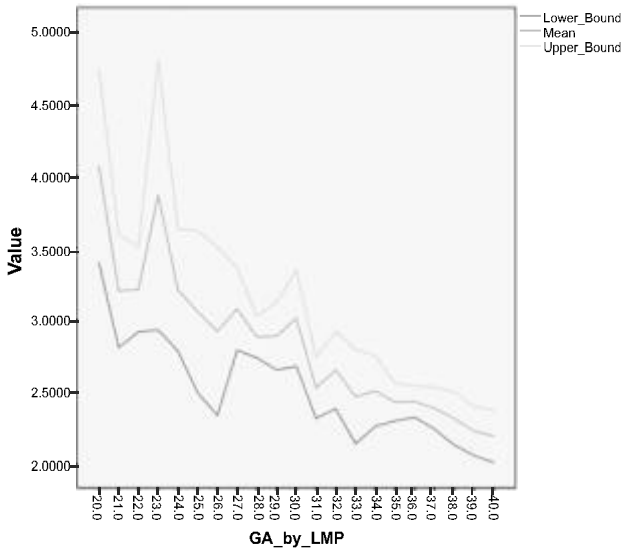

Figure 9: Graph showing the nomogram values for the mean umbilical artery systolic-diastolic ratio and upper bound and lower bound 95% confidence limits.

DISCUSSION

Doppler ultrasound is an established, easily accessible and cheap non-invasive method for the study of feto-placental circulation in pregnancy. Umbilical artery ultrasound has been used in the detection of complications of pregnancy and foetal abnormality [6][3][7][1].

In this study the researchers have documented the normal mean values of the umbilical artery RI, PI and SDR in normal singleton gestation in Abuja, Nigeria. This will be useful in the management of at-risk patients with abnormal vascular changes associated with impaired placentation in pe-eclampsia that is more common among black African women [16].

The normal umbilical artery Doppler indices values were derived by a cross-sectional study of the umbilical arteries at 20 to 40 weeks gestational age of pregnant women during ante-natal tests by trans-abdominal ultrasound. This approach was considered adequate for the study inasmuch as the available clinical records accessed through the electronic medical records (EMR) certify the subjects healthy at the time of scan [17][18][19][20]. Most studies in literature recruited less than 300 cases in their studies [12][17][15][21][13]. This small sample size, the researchers believe, may have limited the generalization of their results. A relatively larger sample size was evaluated in this study to improve generalization of the result. The mean umbilical artery RI, PI and SDR in this study reflect gradual decrease in values as normal pregnancy advances. This is in agreement with findings of all previous researches [12][22][17][18][10][13][14]. The values of the umbilical artery RI, PI and SDR in the Nigerian population under study was generated with pulse wave Doppler mode using automatic trace of the spectral wave form [19][14][16].

The mean umbilical artery RI, PI and SDR obtained in this study were (RI), 0.742, 0.674, 0.660, 0.581 and 0.534; (PI), 1.287, 1.066, 1.071, 0.865, and 0.769 and (SDR), 4.066, 3.056, 3.011, 2.429 and 2.193 at 20, 25, 30, 35 and 40weeks respectively. Chanprapaph , *et al.*, [10] in Thailand reported RI of 0.758, 0.720, 0.679 and 0.620 and PI of 1.270, 1.256, 1.110 and 0.958 and SDR of 3.56, 3.39, 2.94 and 2.53 at 21, 25,31 and 35 weeks respectively. Ayoola , *et al.*, [14] in western Nigeria reported RI, PI and SDR ranges of 0.760 to 0.585; 1.265 to 0.829 4.068 to 2.365 at 15 to 39 weeks gestational age respectively. The above reports compared favourably with the present study. But the study in India by Lakhkar , *et al.*, [15] with RI of 0.53, 0.49 and 0.45 and PI of 0.79, 0.67 and 0.61 and SDR of 2.18, 1.97 and 1.86 at 20, 28 and 34weeks respectively and the study in Switzerland by Kurmanavicius *et al.*, [18] with PI of 0.82, 0.77 and 0.73 at 25, 31 and 35 weeks respectively recorded lower values compared to the present study. While Acharya, *et al.*, [21] in Northern Norway reported PI values of 1.90, 1.67, 1.47 and 1.39 at 21, 25, 31 and 35weeks respectively which were higher than values in this study. The discrepancies in the Doppler indices observed may be related to differences in the number of subjects recruited at these GAs in most of the studies or differences in the technique and equipment employed. However, the significance of the differences was not tested in this study. The possibility of the role of racial differences may need to be verified by future studies.

Correlation of the umbilical artery RI, PI and SDR with foetal heart rate (FHR) showed no associations between the variables (Figures 4 - 6). There is paucity of report in literature in support of the findings.

CONCLUSION

This study has produced nomograms of umbilical artery resistive index, pulsatility index and systolic-diastolic velocity ratio among select population in Abuja, Nigeria. The nomograms showed that at gestational ages of 20, 30 and 40

weeks, the RI values of 0.742, 0.660 and 0.534; the PI values of 1.287, 1.071 and 0.769 ; and the SDR of 4.066, 3.011, and 2.193, respectively are expected. From this study, the relationship between umbilical artery RI, PI, and SDR and GA yielded significant correlation coefficients with R^2 of 0.360, 0.318 and 0.355 respectively. But there was no association of the indices with fetal heart rate.

RECOMMENDATIONS

Replication of this work is desirable in other regions of Nigeria to establish a local reference material and inter-observer variability test is necessary for reproducibility assessment.

Conflict of Interest

There is no conflict of interest in connection with this study.

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