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Fetal descending aorta/umbilical artery flow velocity ratio in normal pregnancy at 36-40 Weeks of gestational age

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Abstract

Doppler velocimetry studies of placental and aortic circulation have gained a wide popularity as it can provide important information regarding fetal well-being and could be used to identify fetuses at risk of morbidity and mortality, thus providing an opportunity to improve fetal outcomes. Prospective longitudinal study conducted through the period from September 2011–July 2012, 125 women with normal pregnancy and uncomplicated fetal outcomes were recruited and subjected to Doppler velocimetry at different gestational ages, from 36 to 40 weeks. Of those, 15 women did not fulfill the protocol inclusion criteria and were not included. In the remaining 110 participants a follow up study of Fetal Doppler velocimetry of Ao and UA was performed at 36 – 40 weeks of gestation. Ao/UA RI: 1.48±0.26, 1.33±0.25, 1.37± 0.20, 1.28±0.07 and 1.39±0.45 respectively and the 95% confidence interval of the mean for five weeks 1.13-1.63. Ao/UA PI: 2.83±2.6, 1.94±0.82, 2.08±0.53, 1.81± 0.12 and 3.28±2.24 respectively. Ao/UA S/D: 2.14±0.72, 2.15±1.14, 1.75±0.61, 2.52±0.18 and 2.26±0.95. The data concluded that a nomogram of descending aorto-placental ratio Ao/UA, S/D, PI and RI of Iraqi obstetric population was established.

Keywords: Pregnancy; Fetal doppler; Velocimetry; Placenta

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Introduction

The most important is that the placenta venous system. About 20%-30% of the returns to the fetus through the umbilical rather than the lungs is the major source umbilical venous blood, then bypass the of the oxygenation in the fetus, the liver through narrow trumpet–shape oxygenated blood from the placenta vessels, called the ductus venosus [1].

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carried out in the placenta, A large gradient of oxygen partial pressure (PO2) of about 60mm Hg has been found between the maternal arterial blood flow & the fetal umbilical venous flow.

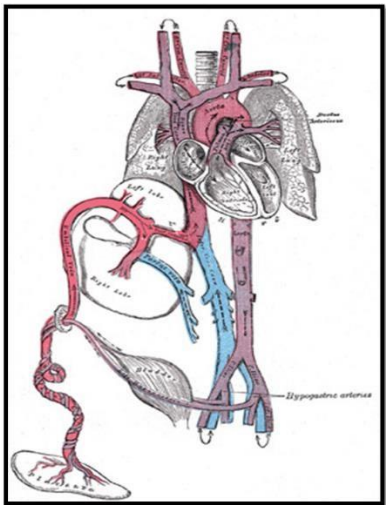

Figure 1. Fetal circulation, the red color representing oxygenated blood, the blue color represent the deoxygenated blood [2].

The umbilical artery was the first fetal vessel to be evaluated by Doppler velocimetry. Flow velocity waveforms from the umbilical cord have a characteristic saw- tooth appearance of arterial flow in one direction and continuous umbilical venous blood flowin the other. Continuous wave Doppler examination of the umbilical artery is simple [3].The total umbilical

During the fetal life the oxygenation is blood flow decreases toward term in human [4, 5].

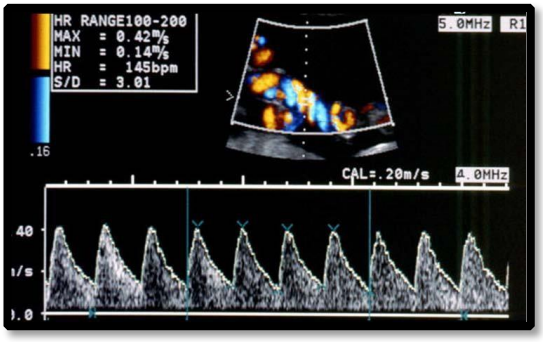

Figure 2. Umbilical artery Doppler waveforms in a normal fetus in the third trimester of pregnancy, shows low impedance circulation with increased end-diastolic velocity [6, 7].

The location of the Doppler sampling site in the umbilical cord affects the Doppler wave form and the impedance indices are significantly higher at the fetal end of the cord than the placental end. A possible explanation for this finding is that the fetal placental vascular bed is a low impedance system associated with minimal reflection, which explain the presence of continuing forward flow in the umbilical artery during diastole [8].

The closer the measurement site is to the placenta, the less is the wave reflection and the greater the end diastolic flow, so the Doppler wave form that represents arterial flow velocity demonstrate progressively declining pulsality indices

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from the fetal to the placental end of the cord [8]. During breathing substantial intrathoracic pressure & central hemodynamic changes are seen, leading to dynamic variation in the umbilical arterial Doppler wave form and Doppler indices (**fig. 3**).

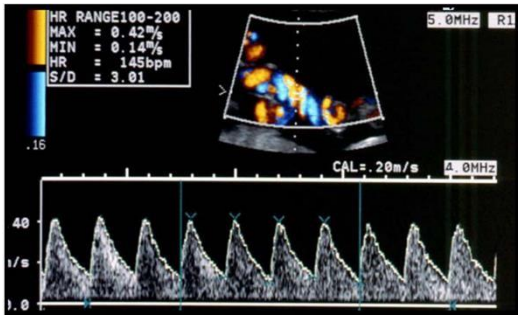

Figure 3. Fetal breathing & umbilical A wave form observe the dynamic variation in the arterial and venous tracing [8].

Fetal Abdominal Aorta the blood flow in the fetal descending aorta is characterized by high blood velocity – higher than that found in the adult descending aorta, and the wave form of the aortic velocity is influenced by the low vascular resistance in the placenta [9]. In the uncompromised fetus during the second half of pregnancy, aortic diastolic velocity is present throughout the cardiac cycle, the proportion of the diastolic flow being higher in the abdominal than in the thoracic descending aorta [10]. The pulsality index (PI) and resistive index (RI) are typically lower in the abdominal than in the thoracic aorta [11].

The aim of the study is to evaluate Doppler flow wave form parameters including resistance and pulsatility indices (RI; PI), systolic/diastolic ratio(S/D) for Fetal abdominal aorta and for umbilical artery, at 36-40 weeks gestational ages in singleton uncomplicated pregnancy with normal maternal and fetal outcomes.

Furthermore, to construct reference ranges of aortic-umbilical artery ratio (APR) in Iraqi obstetric population and to investigate whether or not these parameters correlate with the gestational age.

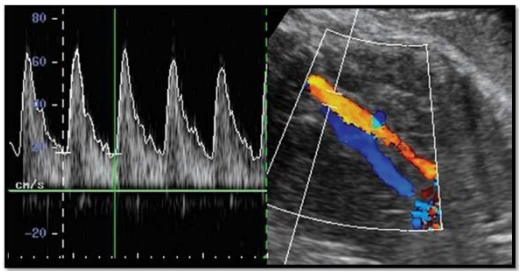

Figure 4. Normal Doppler velocity waveforms obtained from the abdominal aorta [12].

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Method

Study of populations

In the present study, a total of 110 pregnant women were participated as volunteers after obtaining their signed consent and formal approval of the Ethical Committee of the Faculty of Medicine, University of Kufa. The study conducted between September, 2011 and July, 2012 at Al-ameer diagnostic center, all pregnant women have to meet the inclusion and exclusion criteria listed in Tables (8, 9), they had their medical and surgical histories and anthropometric data recorded including age, parity, weight, height, also history of cigarette smoking cardiovascular disease, renal and hepatic disease, hypertension, diabetes mellitus, other medical history and current use of medications.

NO. 110	Mean	Range	SD
Age Y	6.59 2	27	5.92
Height CM	164.7	14	5.72
Mode of delivery	NVD		Cesarean Section
110	80 (88%)		30 (12%)

Table 7. Demographics of the Population and Mode of Delivery.

Each woman underwent physical examination including blood pressure using mercury sphygmomanometer and heart rate measurements using pulse oxymeter, blood sugar test, blood group, Hb and general urine exam. All the examinations performed by single investigator, using advanced ultrasound machine GE Voluson 370 with color Doppler and 4D facilities. The transducer frequency was 3.5-5.0 MHz. The Doppler sample volume was 2 mm, and the wall filter was 50–100 Hz. The spatial temporal average intensity was below 100 Mw /cm2, according to manufactures specification. As part of the pregnancy care protocol at our governorate, Doppler ultrasound measurements were carried out in uncomplicated pregnancies at 36-40 weeks gestation, the gestational age was estimated from the last normal menstrual period and confirmed by the first or second trimester ultrasound reports (crown-rump length, femoral length & bi-parietal diameter records). The technique of imaging and Doppler velocimetry was similar to other investigators [13, 14].

No	Inclusion criteria
1-	Pregnant women at 36-40 weeks
2-	Singleton , cephalic presentation
3-	Fetal weight 2,700-4,200 grams

Table 8. Inclusion criteria

No.	Exclusion criteria
1-	Twin or triplet
2-	Hypertension
3-	Diabetes mellitus
4-	Intra uterine growth restriction
5-	Protein urea
6-	Oligohydrominous, AFI less than 5cm
7-	Apgar score less than 7at 5 min
8-	Leaking liquor and vaginal bleeding
9-	Post maturity
10-	Congenital abnormality

Table 9. Exclusion criteria [15]

Methods

The examination performed in semirecumbent position to avoid pressure effect upon the inferior vena cava which may lead to hypotension [16]. General Gray scale 2D ultrasound examination was first done for checking fetal anatomy and biophysical profile according to Manning's criteria including abdominal circumference (AC), head circumference (HC), femur length (FL), and bi-parietal diameter (BPD) [17].

Estimated fetal weight according to Shepard and Hadlok formula [18], amniotic fluid volume and placental grade were evaluated. A longitudinal scan to the fetal abdomen and tracing of the abdominal aorta above the renal artery level by gray scale image and then a color Doppler imaging to identify the renal artery level, the pulsed Doppler sample gate is then placed on the aorta below the diaphragm and above the renal artery to obtain flow velocity waveforms. A strip of Doppler spectral waveforms of aorta flow was recorded and the average of three waveforms was calculated. The umbilical artery was also insonated; it was identified first by color Doppler imaging and the pulse wave Doppler recorded at its portion close to the placenta [19, 20]. The average of three waveforms was calculated, from each waveform, different indices were obtained including resistive index (RI) pulsatility index (PI), systolic/diastolic ratio (S/D); the heart rate was also calculated by a software program built in the Ultra Sound Doppler equipment.

Statistical analysis

The 110 participants enrolled in the current study, 110 observations of fetal abdominal Ao and UA velocimetry were calculated as well as APR (Ao/UA). The following statistical analysis was applied: Descriptive statistic, estimation

of 95% confidence interval of the mean, range, standard deviation, standard error of mean, as well as independent T-Test, and least significant difference (L.S.D) to differentiate between means at level of significance α =0.05. P value of ≤ 0.05 was considered as statistically significant. All calculation, tables and graphs were performed by Microsoft SPSS and Excel computerized programs [21].

Result

Of the 125 volunteers pregnant women fifteen participants were excluded from the study due to different causes: fetal congenital anomaly four (spina bifida two, omphalocele one and cervical cystic mass one), Oligohydrominous three, antepartum hemorrhage four, low Apgar score four.

The remaining 110 participants were delivered normal fetuses with Apgar score more than seven in both first and fifth minutes with normal fetal weight.

In the 110 participants fetal gender were males 65(59%) and females 45(41%).

All fetuses had normal outcome.

Ua doppler waveform parameters related to ges. Age (week)

The mean and SD values of RI for the UA at 36, 37, 38, 39 and 40 weeks gestation are 0.52±0.07, 0.56±0.07, 0.54±0.08, 0.54±0.01 and 0.53±0.09 respectively and the 95% confidence interval of the mean for five weeks 0.48-0.60, there is no significant difference among the means of all five weeks gestation (P value more than 0.05), (Tables 10-15).

The mean and SD values of RI for the descending aorta at 36, 37, 38, 39 and 40 weeks gestation are 0.76 ± 0.09, 0.76 ±0.11, 0.74±0.05, 0.75±0.015 and 0.78±0.088 respectively and the 95% confidence interval of the mean for five weeks 0.71- 0.81, there is no significant difference among the means of all five weeks gestation (P value more than 0.05), (Tables 10-15).

The mean and SD values of PI for the UA at 36, 37, 38, 39 and 40 weeks gestation are 0.80± 0.13, 0.86± 0.16,

The mean and SD values of PI for the descending aorta at 36, 37, 38, 39 and 40

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0.83± 0.23, 0.83± 0.023 and 0.78±0.16 weeks gestation are 2.23± 1.92, 1.56± 0.65, 1.67± 0.42, 1.55±0.08 and 1.75± 0.44 respectively and the 95% confidence interval of the mean for five weeks 0.71-0.95, there is no significant difference among the means of all five weeks gestation (P value more than 0.05), (Tables 10-15).

UA S/D

The mean and SD values of S/D for the UA at 36, 37, 38, 39 and 40 weeks gestation are 4.74± 1.58, 5.11±2.58, 4.18±0.92, 4.48±0.28 and 5.27±1.91 respectively and the 95% confidence interval of the mean for five weeks 1.98-3.34, there is no significant difference among the means of all five weeks gestation (P value more than 0.05), (Tables 10-15).

Ao /UA RI

The mean and SD values of Ao/UA RI at 36, 37, 38, 39 and 40 weeks gestation are 1.48±0.26, 1.33±0.25, 1.37± 0.20, 1.28±0.07 and 1.39±0.45 respectively and the 95% confidence interval of the mean for five weeks 1.13-1.63, there is no significant difference among the means of all five weeks gestation (P value more than 0.05), (Tables 10-15).

Ao/UA PI

The mean and SD values Ao/UA PI at 36, 37, 38, 39 and 40 weeks gestation are 2.83±2.6, 1.94±0.82, 2.08±0.53, 1.81± 0.12 and 3.28±2.24 respectively and the 95% confidence interval of the mean for five weeks 1.32-4.34, there is no significant difference among the means of all five weeks gestation (P value more than 0.05), (Tables 10-15).

Ao /UA S/D

The mean and SD values Ao/UA S/D at 36, 37, 38, 39 and 40 weeks gestation are

2.14±0.72, 2.15±1.14, 1.75±0.61, 2.52±0.18 and 2.26±0.95 respectively and the 95% confidence interval of the mean for five weeks 1.44-2.64, there is no significant difference among the means of all five weeks gestation (P value more than 0.05), (Tables 10-15).

The least significant difference between descending aorta, umbilical artery and APR indices related the gender as illustrated below in (Table 16) there is no significant difference between the male & female in all these indices.

Parameter NO:15	Range	Mean	Std. Error	Std. Deviation	95% confidence interval of the mean	
					lower limit	upper limit
Ao RI	0.32	0.762	0.025	0.095	0.70	0.81
Ao PI	7.92	2.237	0.514	1.924	1.12	3.34
Ao S/D	5.26	4.748	0.424	1.586	3.83	5.66
UA RI	0.29	0.528	0.020	0.077	0.48	0.57
UA PI	0.50	0.802	0.037	0.139	0.72	0.88
UA S/D	0.97	2.218	0.080	0.301	2.04	2.39
Ao / UA RI	0.96	1.481	0.070	0.263	1.32	1.63
Ao / UA PI	10.45	2.835	0.700	2.621	1.32	4.34
Ao / UA S/D	2.76	2.142	0.193	0.722	1.72	2.55

Table 10. Descending aorta (Ao), Umbilical Artery (UA) and APR (Ao/UA) Doppler Wave form Parameters at 36 Weeks Gest. Age

Parameter NO:23	Range	Mean	Std. Error	Std. Deviation	95% confidence interval of the mean	
					Lower limit	upper limit
Ao RI	0.46	0.761	0.024	0.118	0.71	0.81
Ao PI	2.65	1.682	0.136	0.653	1.40	1.96
Ao S/D	9.34	5.117	0.539	2.587	3.99	6.23
UA RI	0.33	0.569	0.015	0.074	0.53	0.60
UA PI	0.60	0.866	0.034	0.164	0.79	0.93
UA S/D	1.79	2.399	0.083	0.400	2.22	2.57
Ao /UA RI	1.01	1.340	0.052	0.250	1.23	1.44
Ao /UA PI	3.76	1.950	0.173	0.829	1.59	2.30
Ao/AU S/D	4.85	2.152	0.238	1.144	1.65	2.64

Table 11. Descending aorta (Ao), Umbilical Artery (UA) and APR (Ao/UA) Doppler Waveform Parameters at 37 Weeks Gest. Age

Parameter NO: 18	Range	Mean	Std. Error	Std. Deviation	95% confidence interval of the mean	
					Lower limit	upper limit
Ao RI	0.18	0.743	0.013	0.057	0.71	0.77
Ao PI	1.70	1.679	0.099	0.421	1.46	1.88
Ao S/D	2.82	4.183	0.217	0.924	3.72	4.64
UA RI	0.31	0.547	0.020	0.085	0.50	0.59
UA PI	0.91	0.838	0.054	0.230	0.72	0.95
UA S/D	2.21	2.305	0.131	0.557	2.02	2.58
Ao /UA RI	0.79	1.370	0.049	0.208	1.26	1.47
Ao /UA PI	1.94	2.084	0.125	0.532	1.81	2.34
Ao /UA S/D	2.62	1.756	0.145	0.615	1.44	2.06

Table 12. Descending aorta (Ao), Umbilical Artery (UA) and APR (Ao/UA) Doppler Wave form Parameters at 38 Weeks Gest. Age

Parameter NO:27	Range	Mean	Std. Error	Std. Deviation	95% confidence interval of the mean	
					Lower limit	upper limit
Ao RI	0.29	0.754	0.015	0.081	0.72	0.78
Ao PI	2.01	1.550	0.083	0.435	1.37	1.72
Ao S/D	6.78	4.489	0.287	1.493	3.89	5.07
UA RI	0.30	0.547	0.013	0.069	0.51	0.57
UA PI	0.40	0.830	0.023	0.120	0.48	0.87
UA S/D	1.63	2.208	0.072	0.374	2.06	2.35
Ao /UA RI	2.18	1.300	0.076	0.397	1.13	1.44
Ao / UA PI	3.53	1.816	0.127	0.663	1.55	2.07
Ao /UA S/D	4.61	2.055	0.184	0.957	1.67	2.43

Table 13. Descending aorta (Ao), Umbilical Artery (UA) and APR (Ao/UA) Doppler Waveform Parameters at 39 Weeks Gest. Age

Parameter NO: 27	Range	Mean	Std. Error	Std. Deviation	95% Confidence interval of the mean	
					Lower limit	upper limit
Ao RI	0.29	0.754	0.015	0.081	0.74	0.81
Ao PI	2.01	1.550	0.083	0.435	1.57	1.92
Ao S/D	6.78	4.489	0.287	1.493	4.51	6.02
UA RI	0.30	0.547	0.013	0.069	0.49	0.56
UA PI	0.40	0.830	0.023	0.120	0.71	0.84
UA S/D	1.63	2.208	0.072	0.374	1.98	2.25
Ao /UA RI	2.18	1.287	0.076	0.397	1.21	1.57
Ao /UA PI	3.53	1.816	0.127	0.663	1.98	2.50
Ao/UA S/D	4.61	2.055	0.184	0.957	1.89	2.64

Table 14. Descending aorta (Ao), Umbilical Artery (UA) and APR (Ao/UA) Doppler Waveform Parameters at 40 Weeks Gest. Age

Variable dependent	Gest. Age	Gest. age	P value
Ao RI	36	40	0.52
Ao PI	36	40	0.077
Ao S/D	36	40	0.38
UA RI	36	40	0.90
UA PI	36	40	0.68
UA S/D	36	40	0.44
Ao/UA RI	36	40	0.44
Ao/UA PI	36	40	0.11
Ao/UA S/D	36	40	0.68

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Table 15. The least significant difference of the means

Parameters	gender	Number	Mean	SD	P value
Ao RI	Male female	65 45	0.763 0.762	0.09 0.09	0.78
Ao PI	Male female	65 45	1.83 1.64	1.05 0.45	0.18
Ao SD	Male female	65 45	4.81 4.76	1.94 1.68	0.60
AU RI	Male Female	65 45	o.54 0.55	0.07 0.09	0.29
AU PI	Male female	65 45	0.820 0.821	0.15 0.17	0.99
AU SD	Female Male	65 45	2.23 2.25	0.33 0.48	0.15
Ao/UA RI	Male female	65 45	1.43 1.41	0.25 0.26	0.72
Ao/UA PI	Male female	65 45	2.26 2.06	0.45 0.66	0.22
Ao/UA SD	Male female	65 45	2.163 2.168	0.89 0.88	0.97

Table 16. The least significant difference between the means of male and female

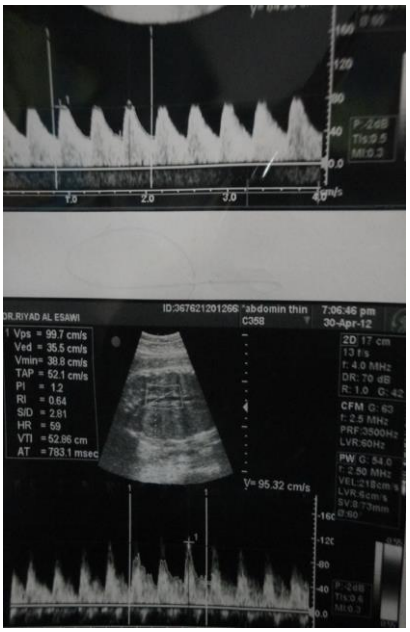

Figure 5. Doppler wave forms of AU (above) & Ao (below) at 36 weeks of gestation

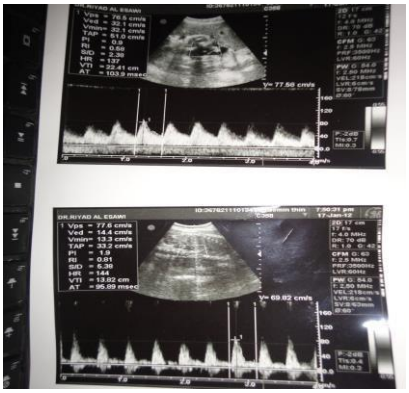

Figure 6. Doppler wave forms of AU (above) & Ao (below) at 37 weeks of gestation

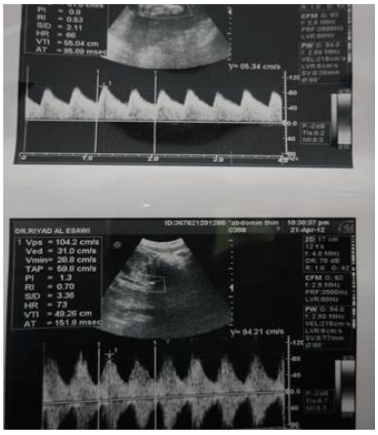

Figure 7. Doppler wave forms of AU (above) & Ao (below) at 38 weeks of gestation.

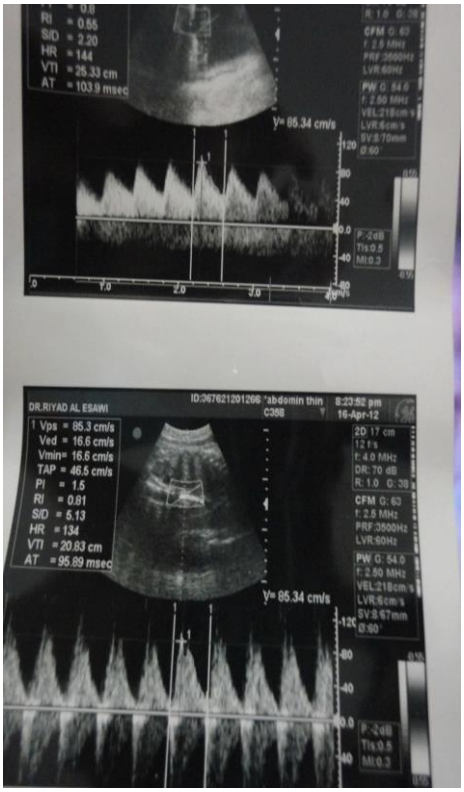

Figure 8. Doppler wave forms of AU (above) & Ao (below) at 39 weeks of gestation.

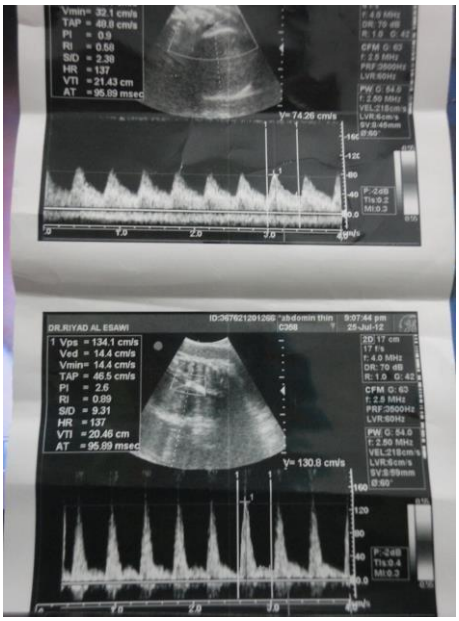

Figure 9. Doppler wave forms of AU (above) & Ao (below) at 40 weeks of gestation).

Discussion

Doppler velocimetry examination of descending aorta and umbilical artery to assess APR is the most rigorously evaluated test throughout the past two decades; it is considered as safe, easy and cheap technique. However the European committee for ultrasound radiation safety stated that routine examination by pulsed Doppler measurement in fetuses during the period of organogenesis is considered inadvisable, at present [22]. In this context, the protocol adopted in the present study was to commence Doppler velocimetry examination at the 36 weeks onward, most of the available studies started with second and third trimesters, to our best knowledge only one study performed by Jittima and Vapropong from Thailand started with 11 weeks of gestation [23].

In this study we found that the descending abdominal aorta indices in form of means and SD including RI, PI and S/D remain constant at 36-40 weeks of gestation , RI= 0.76± (0.09), 0.76± (0.11), 0.74± (0.057), 0.75± (0.081) , 0.75± (0.081) , PI= 2.23 ± (1.92), 1.68± (0.65), 1.67± (0.42), 1.55± (0.43) , S/D

4.74± (1.58), 5.11± (2.58), 4.18± (0.92), 4.48± (1.49) and 4.48± (1.49) respectively for 36, 37, 38, 39 and 40 weeks of gestation, this finding consistent with Masashi Akiyama et al;1999 [24] regarding PI, Yasemin TASCT et al; 1999 [25]. Concerning umbilical artery indices in this study regarding mean and SD including RI, PI and S/D these indices decline with advancing gestational age, the RI=0.52 ± (0.07), 0.56± (0.07), 0.54± (0.08), 0.54± (0.01) and 0.53± (0,09), PI= 0.80± (0.13), 0.86± (0.16), 0.83± (0.23), 0.83± (0.023) and 0.78 ± (0.16), S/D = 2.21± (0.30), 2.39± (0.40), 2.30± (0.55), 2.20± (0.07) and 2.11± (0.34) for 36, 37, 38, 39 and 40 weeks respectively, these finding are consistent with Sunesh, Kumar et al; [26]. Furthermore, our result were consistent with the finding of Pharuhas Champrapah et al; [27] regarding mean and 95% CI for RI, PI and S/D.

The current study showed that the APR for the RI was more than one and the 95% CI =1.13-1.63. PI was almost more than 2 and the 95% CI= 1.32-4.34, while the APR of S/D was around 2 and the 95% CI= 1.44-2.64, unfortunately there was no available literature discussed APR at present at least to our best knowledge.

Concerning gender of the fetus (male and female), we found there was no significant difference between the means of all indices in both descending aorta and umbilical artery and this consistent with many literatures. **In conclusion**; firstly, a nomogram of descending aorto-placental ratio Ao/UA, S/D, PI and RI of Iraqi obstetric population was established.

Secondly, it is believed that the points of strength of present study is that it is a longitudinal study with reference ranges found to be identical with nomograms of other studies worldwide.

Thirdly, the current study provided reference ranges regarding descending aorta and UA PIs, RIs,

S/Ds at 36-40 weeks gestational ages which including Ao/UA ratio are suitable for single and serial studies.

Recommendations

First, launch further study to construct reference ranges of Ao/UA ratio and descending aorta, UA Doppler parameters at weekly interval though out gestational age progress.

Second, to compare the presently constructed reference ranges with changes of Ao/UA and Doppler parameters which could be associated with pregnancy such as pregnancy with anemia, extremes of obesity, heart diseases, diabetes and/or with hypertension.

Third, to compare the presently constructed reference ranges with Ao/AU ratio changes which may occur with various drug administration throughout pregnancy, e.g., giving insulin to a diabetic pregnant woman or antihypertensive drugs or anti-failure drugs, etc.

Competing interests

Author declare that I have no competing interests.

Authors Contributions

All authors wrote, read and approved the final manuscript.

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