Reference values for Doppler velocimetric indices from the fetal and placental ends of the umbilical artery in uncomplicated third trimester pregnancy

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Abstract

Introduction: The purpose of this study was to establish new reference ranges for commonly used umbilical artery Doppler indices (Pulsatility Index, Resistance Index, and Systolic: Diastolic ratio) at standardized insonation sites in uncomplicated third trimester pregnancy

Methods: This was a prospective cross sectional study involving 101 singleton pregnancies between 30 and 37 weeks of gestation without any known risk factors. Umbilical artery indices were obtained from fetal end and placental end of the cord. Regression equations were used to construct reference ranges and percentile fitted Normograms were obtained for all the parameters. Paired t test was used to see the difference of different parameters at two different sites of the cord.

Results: Among 101 singleton pregnancies between 30 and 37 weeks of gestation, 65 (64.35%) were primigravida and 36 (34.65%) were multigravida. Mean maternal age was 23.12years (range 16 to 35 years). Maximum number of pregnancies (18.81%) was at 34 weeks of gestation. The established Doppler indices showed a continuous reduction of all the measured indices as

pregnancy increases ($p<0.0001$). Umbilical artery RI, PI and S: D ratio were higher in the fetal end of the cord than in the placental end ($p<0.0001$).

Conclusions: Umbilical artery Doppler parameters vary significantly at different locations. We have established new reference ranges for the UA at fetal end and placental end of the cord which should be useful for the surveillance of fetuses with repeated observations.

Keywords: Doppler study, fetal end of cord, placental end of cord, umbilical artery

Introduction

With introduction of Doppler to obstetrics in 1977, umbilical artery Doppler is one of the most rigorously evaluated and frequently used noninvasive tests of fetal well-being.[1] The combined evidence from several trials[2-5] in high-risk pregnancies (complicated by maternal hypertension and by intrauterine growth restriction) demonstrates that there are fewer stillbirths and neonatal deaths among normally formed babies when the results of the umbilical artery Doppler are made available to clinicians.[6-12] By contrast, the value of Doppler velocimetry in the assessment of low-risk populations has not been proven.[13-16].

The umbilical artery is the longest blood vessel in the human fetus and the umbilical artery Doppler velocimetry parameters are known to vary along the length of the umbilical cord.[17-25] Free loop is the most commonly used site because it is the easiest site to record the Doppler parameters where even less experienced person can easily measure the various parameters accurately. However, in order to reduce methodological variability, it is advisable to use a site of insonation that can be repeatedly and reliably identified. The fetal and placental ends of the umbilical artery are such sites. Such a strategy would be particularly useful in complicated multiple pregnancies since identifying the correct umbilical artery for each fetus is commonly a problem unless the fetal end or intra-abdominal section of the vessel is used.

Furthermore, the variability of umbilical artery blood velocity waveforms along the cord appears to be greater among intrauterine growth-restricted (IUGR) fetuses than normally grown fetuses.[26] As these fetuses usually need monitoring with serial Doppler examinations, a standardized site for repeated measurements would be an advantage.

The reference ranges for umbilical artery Doppler waveforms at the fetal and placental ends of the umbilical artery have been reported previously based on cross-sectional[23] and at the intra-abdominal portion based on longitudinal[27] observations. However, no such reference ranges have been established for Nepalese women.

So this study was conducted in an effort to establish the reference values for Doppler indices of umbilical artery at fetal end and placental end of the cord in uncomplicated third trimester pregnancies in Nepalese population.

Methods

This was a prospective cross sectional study involving 101 singleton pregnancies between 30 and 37 weeks of gestation who were referred for routine obstetric examination. Study was conducted in the department of Radiology & Imaging, Tribhuvan University Teaching Hospital from September 2007 to August 2008.

Singleton pregnancies with period of gestation between 30 to 37 weeks determined by reliable last menstrual period or ultrasound examination before 20 weeks of gestation without any complication in the current pregnancy or known risk factors of adverse pregnancy outcome were included in the study. Pregnancies with undetermined period of gestation, maternal smoking, multiple pregnancies, diagnosed fetal abnormality in current pregnancy, previous history of preeclampsia, intrauterine growth retardation, abruptio placenta or preterm delivery, history of

any pre-existing medical condition (such as hypertension, diabetes mellitus, renal disease), risk of developing fetal anemia including Rh negative women, women not willing to give consent for the examination were excluded from the study.

Umbilical artery was examined with 3.5MHz curvilinear probe in Toshiba color Doppler machine by single examiner. Color Doppler imaging was used to optimize the insonation by the pulsed Doppler examination. The angle of insonation was kept at <20 degrees in all cases. The high-pass filter was set at minimum, and a large sample volume was used for the pulsed Doppler recording. The Doppler velocity waveforms were obtained from the placental attachment site [Fig. 1] and near the abdominal attachment site [Fig. 2] of the umbilical cord during fetal quiescence.

Five to 6 uniform waveforms were obtained and online measurements were performed. The waveform envelope that had the highest measured peak systolic velocity was considered for analysis, assuming that the highest measured velocity represents the lowest angle of insonation. Doppler waveform indices were calculated from the maximum velocity waveform with the following computerized planimetry:

PI = (Peak systolic velocity−end-diastolic velocity)/time-averaged maximum velocity[24]

RI = (Peak systolic velocity−end-diastolic velocity)/peak systolic velocity[25]

S: D ratio = Peak systolic velocity/end-diastolic velocity[20]

Data obtained were compiled and analyzed using standard statistical analysis. SPSS 11.5 and Microsoft Excel were utilized for the data analysis and presentation. Pierson correlation was used to see the relation of Doppler parameters with gestational age. Linear regression equations were calculated and percentile fitted values were obtained for all the parameters at different gestational age. Paired t-test was used to compare the difference in mean at fetal and placental

attachment site of umbilical cord. Normograms and percentile fitted curves were obtained. Skewed data were kept as such without converting into normal distribution.

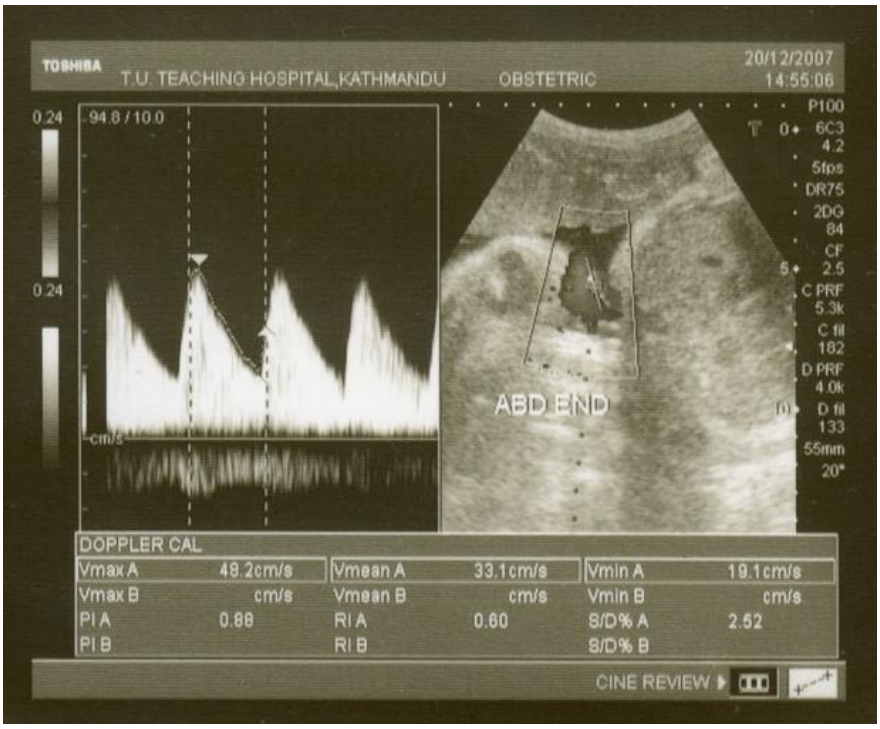

Figure 1: Doppler recording from fetal end of umbilical artery

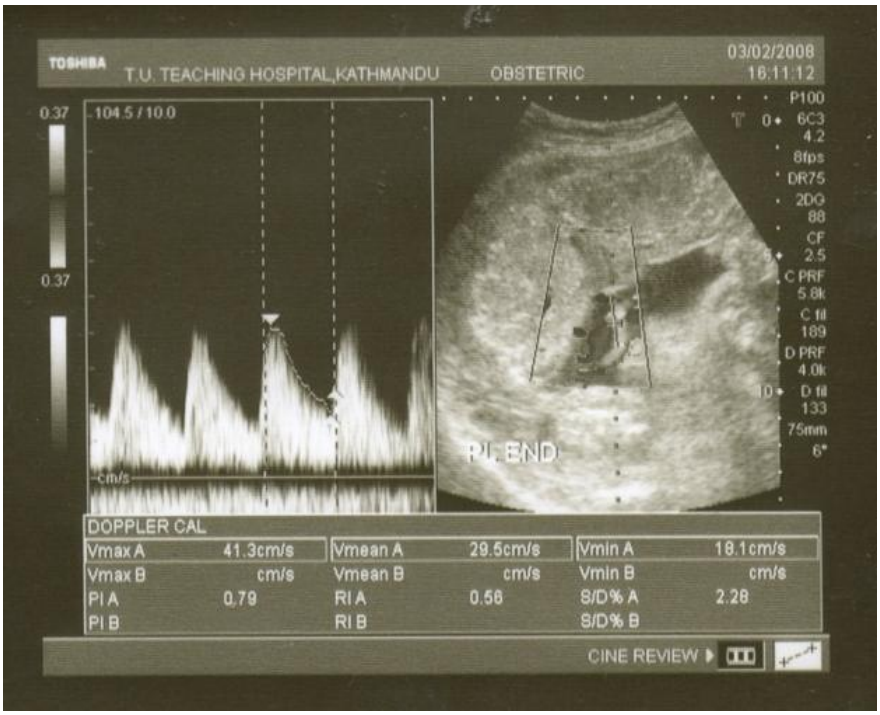

Fig.2: Doppler recording from placental end of umbilical artery

Results

Doppler values were obtained in a total of 101 singleton pregnancies. 48 women (47.5%) had undergone ultrasound examination before 20 weeks of gestation. All were normal. In 12 cases, Doppler parameters could not be recorded from fetal end of the cord and in 11 cases recordings from placental ends could not be obtained. These difficulties were encountered mainly in the late pregnancies because of unfavorable fetal position or posterior location of placenta. A total of 81pairs of Doppler indices were available to compare the difference between fetal end and placental end of the cord.

Maximum number of pregnancies (18.81%) was at 34 weeks of gestation. Minimum number of pregnancies (7.92%) was at 30, 31 and 33 weeks 65 (64.35%) were primigravida women while 36 (34.65%) were multigravida. Maternal age ranged from 16 to 35 years (mean age 23.12years). The youngest age was 16 years. Two patients were of 16 years. The eldest patient was of 35 years.

Doppler Study:

Correlation with period of gestation

All the three parameters showed significant correlation with period of gestation (Table 1). There was equal significant correlation of Pulsatility index and systolic: diastolic ratio ($r = 0.447$) with period of gestation at the fetal end of the cord. At the placental end of the cord, PI showed maximum correlation with period of gestation ($r = 0.435$).

Table 1: Correlation of various parameters umbilical artery obtained from different insonation sites of the cord with period of gestation (POG)

Insonation Sites	Parameters	Pierson Correlation (r) with POG	p value
Fetal End	Resistance Index	-0.381	0.0001
	Pulsatility Index	-0.447	0.0001
	Systolic: Diastolic ratio	-0.447	0.0001
Placental End	Resistance Index	-0.367	0.0001
	Pulsatility Index	-0.435	0.0001
	Systolic: Diastolic ratio	-0.423	0.0001

Reference values for the fetal end of the cord

Percentile values (5^{th}, 50^{th} and 95^{th}) of Umbilical Artery obtained from the fetal end of the cord [Table 2]. Since the data were skewed, median was used as center of distribution. Median value of RI at the fetal end of the cord was 0.645 at 30 weeks of gestation and it reduced to 0.575 at 37 weeks. Median PI value decreased from 1.04 at 30 weeks to 0.81 at 37 weeks of gestation. Systolic: Diastolic ratio decreased from median of 2.79 at 30 weeks to median of 2.36 at 37 weeks of gestation.

Table 2: Percentile values (5^{th}, 50^{th} and 95^{th}) of Umbilical Artery obtained from the fetal end of the cord at different weeks of gestation.

Week of Gestation	Resistance Index (RI) Percentile	Pulsatility Index (PI) Percentile	Systolic: Diastolic (S:D) ratio Percentile

	5th	50th	95th	5th	50th	95th	5th	50th	95th
30	0.587	0.645	0.68	0.9045	1.04	1.1395	2.45	2.79	3.1665
31	0.6035	0.63	0.67	0.907	0.975	1.09	2.5785	2.745	2.993
32	0.58	0.625	0.67	0.84	0.96	1.086	2.36	2.705	3.018
33	0.58	0.615	0.643	0.8535	0.935	1.0415	2.46	2.63	2.884
34	0.47	0.6	0.71	0.65	0.9	1.18	1.87	2.56	3.28
35	0.46	0.59	0.69	0.6	0.86	1.07	1.84	2.45	2.837
36	0.509	0.58	0.6355	0.669	0.835	1.01	1.983	2.4	2.803
37	0.5135	0.575	0.6275	0.7235	0.81	0.9765	2.0585	2.36	2.71

Reference values for the placental end of the cord

Reference values with 5th, 50th and 95th percentiles were calculated (Table 3). Median value of RI decreased from 0.62 at 30 weeks of gestation to 0.55 at 37 weeks. Pulsatility index decreased from median of 0.965 at 30 weeks of gestation to 0.79 at 37 weeks. Median values of S: D ratios were 2.725 and 2.28 at 30 and 37 weeks of gestation respectively.

Table 3: Percentile values (5th, 50th and 95th) of Umbilical Artery obtained from the placental end of the cord at different weeks of gestation.

Week of Gestation	Resistance Index (RI) Percentile			Pulsatility Index (PI) Percentile			Systolic: Diastolic (S:D) ratio Percentile		
	5th	50th	95th	5th	50th	95th	5th	50th	95th
30	0.567	0.62	0.666	0.814	0.965	1.076	2.374	2.725	3.029
31	0.567	0.61	0.663	0.8315	0.94	1.059	2.434	2.65	2.885
32	0.54	0.605	0.62	0.8155	0.9	0.949	2.359	2.56	2.649
33	0.5205	0.595	0.6465	0.701	0.885	1.003	2.0605	2.52	2.89
34	0.519	0.58	0.681	0.76	0.84	1.092	1.96	2.43	3.171
35	0.52	0.57	0.617	0.6925	0.825	0.957	2.006	2.37	2.6935

36	0.538	0.565	0.6065	0.698	0.81	0.925	2.005	2.335	2.57
37	0.48	0.55	0.635	0.59	0.79	0.96	1.8	2.28	2.725

Regression Equations

Linear regression equations to obtain the reference values of the umbilical artery Doppler indices are summarized in table 4.

Table 4: Linear regressions for calculating reference values of umbilical artery Doppler indices from the fetal and placental end of the cord.

Regression	β	SE	t value	p value	95% CI	
					Lower bound	Upper bound
Fetal End RI	-0.381	0.003	-3.845	0.0001	-0.015	-0.005
Fetal End PI	-0.447	0.006	-4.663	0.0001	-0.041	-0.016
Fetal End S: D	-0.447	0.015	-4.667	0.0001	-0.101	-0.041
Placental End RI	-0.367	0.002	-3.703	0.0001	-0.012	-0.004
Placental End PI	-0.435	0.005	-4.536	0.0001	-0.031	-0.012
Placental End S: D	-0.423	0.014	-4.384	0.0001	-0.086	-0.032

Normograms

Gestational age specific normograms were obtained by plotting Doppler parameter against age of gestation in a scatter diagram and lines were fitted for the 5^{th}, 50^{th} and 95^{th} percentile values

(Fig.3 to 8). All the plots show continuous reduction of all the Doppler indices with increasing period of gestation.

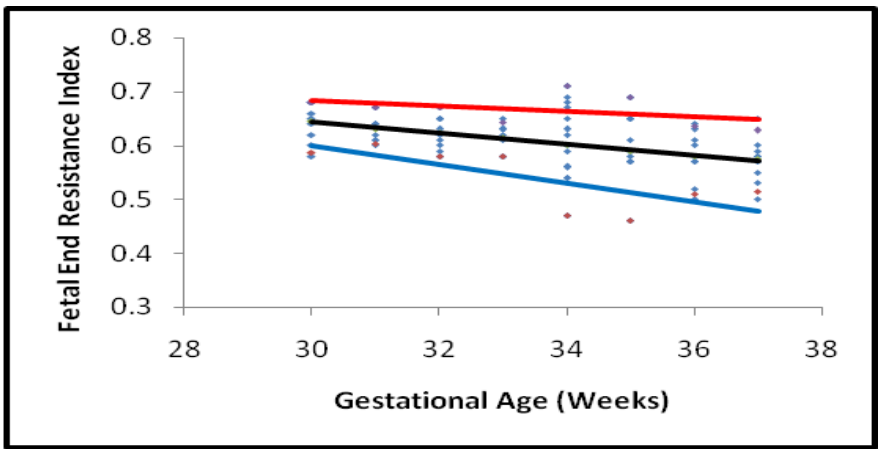

Figure 3: Scattered diagram of Umbilical Artery Resistance Index from the fetal end of the cord against period of gestation with 5th, 50th and 95th percentile lines.

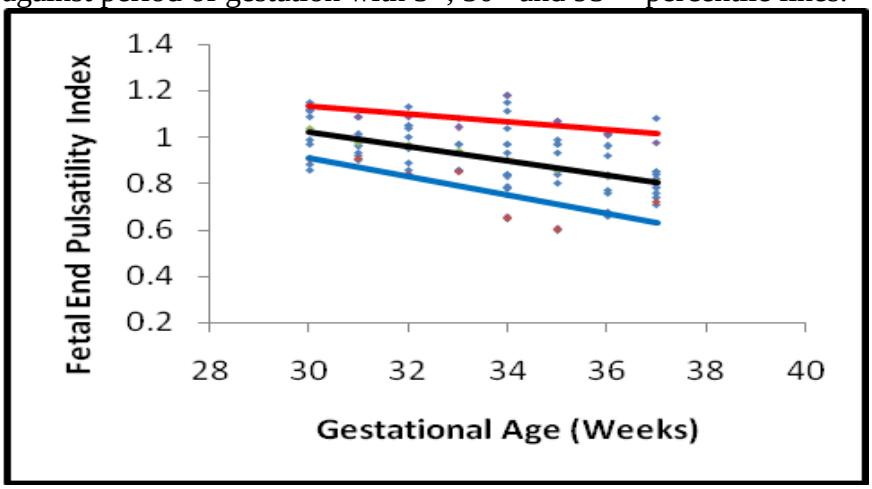

Figure 4: Scattered diagram of Umbilical Artery Pulsatility Index from the fetal end of the cord against period of gestation with 5th, 50th and 95th percentile lines

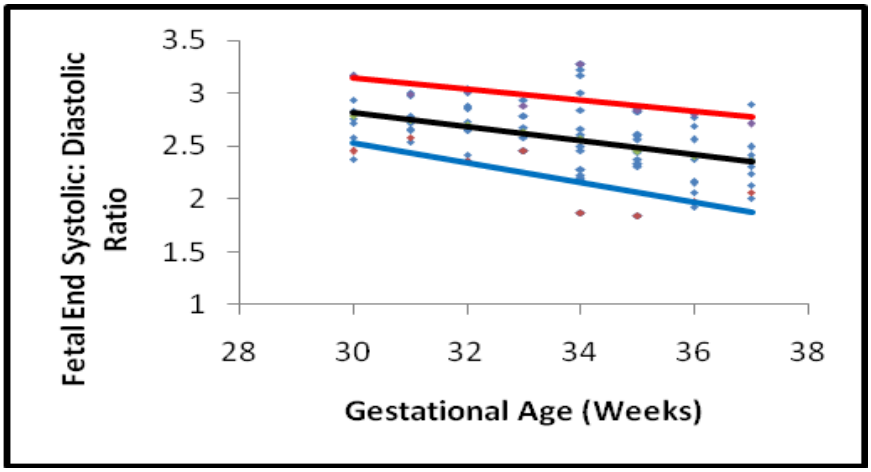

Figure 5: Scattered diagram of Umbilical Artery Systolic: Diastolic ratio from the fetal end of the cord against period of gestation with 5th, 50th and 95th percentile lines

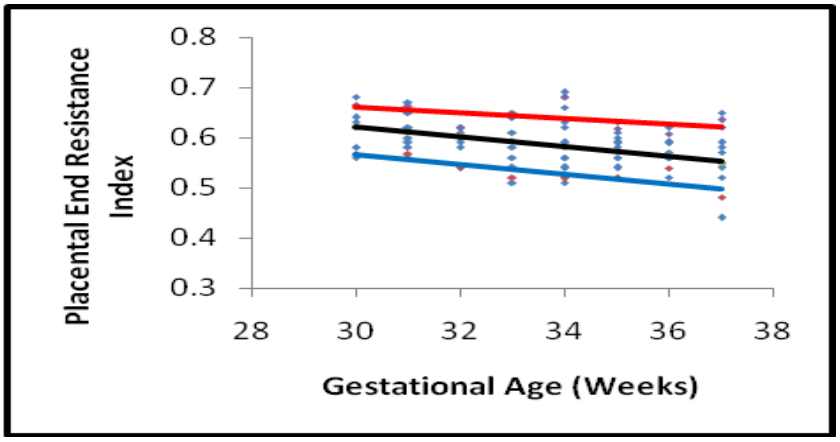

Figure 6: Scattered diagram of Umbilical Artery Resistance Index from the placental end of the cord against period of gestation with 5th, 50th and 95th percentile lines.

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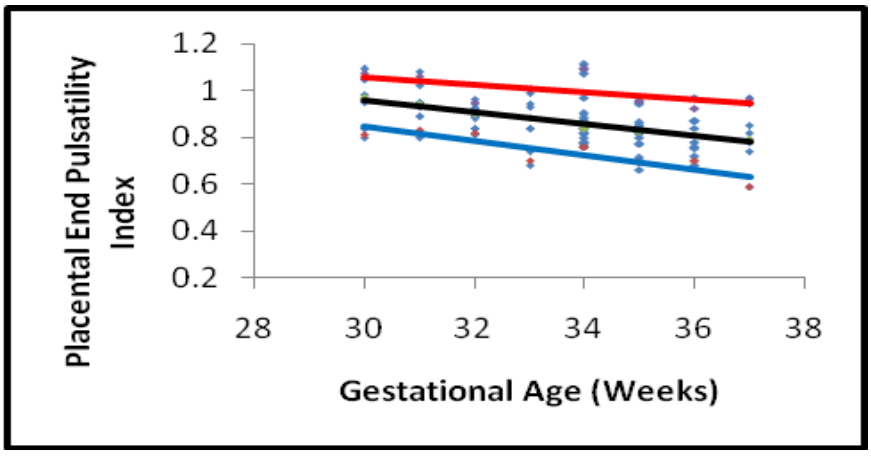

Figure 7: Scattered diagram of Umbilical Artery Pulsatility Index from the placental end of the cord against period of gestation with 5th, 50th and 95th percentile lines.

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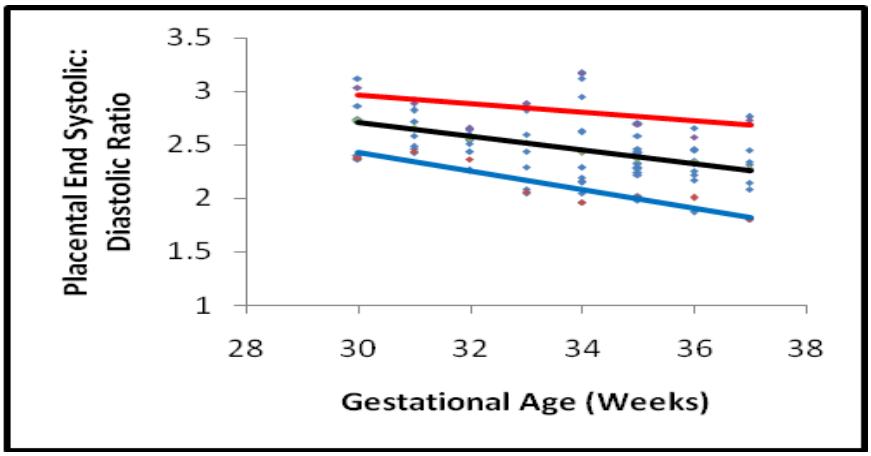

Figure 8: Scattered diagram of Umbilical Artery Systolic: Diastolic ratio from the placental end of the cord against period of gestation with 5th, 50th and 95th percentile lines

Site specific variation of umbilical cord indices

All the three Doppler indices were higher at the fetal end of the cord than at the placental end. Paired t-test was used to compare the means between two ends of the cord (Table 5). Mean difference of RI, PI and S: D were 0.0204 ± 0.03989, 0.056 ± 0.09683 and 0.1321 ± 0.2309 respectively.

Table 5: Difference of Doppler indices between fetal end (FE) and placental end (PE) of the umbilical artery.

Pairs	Sample size (n)	Paired Differences				t	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		

					Lower	Upper		
FE RI - PE RI	81	0.0204	0.03989	0.00443	0.0116	0.0292	4.596	0.0001
FE PI - PE PI	81	0.056	0.09683	0.01076	0.0346	0.0775	5.209	0.0001
FE S/D - PE S/D	81	0.1321	0.2309	0.02566	0.081	0.1832	5.149	0.0001

Difference of Doppler indices between fetal end and placental end were calculated separately for different gestational age groups (Tables 6, 7 & 8).

Mean difference of Resistance index between two ends of the cord was highest at 32-33 weeks (0.0245 ± .04861). Minimum difference of 0.0121 ± 0.03286 was obtained for 36- 37 gestational week group.

Mean difference of Pulsatility index between two ends of the cord was highest at 32-33 weeks (0.0705 ± .11812). Minimum difference of 0.0464 ± 0.07417 was obtained for 36- 37 gestational week group.

Mean difference of Systolic: Diastolic ratio between the two ends of the cord was 0.1362 ± 0.21282 for 30-31 weeks group while it was 0.1179 ± 0.20158 for 36-37 week group.

Table 6: Difference of Resistance Index between fetal end and placental end at different gestational ages

Period of Gestation (Weeks)	Mean Difference	Std. Deviation	p value
30 – 31	0.0231	0.03092	0.009
32 – 33	0.0245	0.04861	0.036
34 – 35	0.0200	0.04187	0.012
36 – 37	0.0121	0.03286	0.190

Table 7: Difference of Pulsatility Index between fetal end and placental end at different gestational ages

Period of Gestation (Weeks)	Mean Difference	Std. Deviation	p value
30 – 31	0.0594	0.09889	0.030
32 – 33	0.0705	0.11812	0.015
34 – 35	0.0494	0.09306	0.006
36 – 37	0.0464	0.07417	0.036

Table 8: Difference of Systolic: Diastolic Ratio between fetal end and placental end at different gestational ages

Period of Gestation (Weeks)	Mean Difference	Std. Deviation	p value
30 – 31	0.1362	0.21282	0.022
32 – 33	0.1535	0.32388	0.047
34 – 35	0.1226	0.18703	0.001
36 – 37	0.1179	0.20158	0.048

Discussion

Cross-sectional observations were obtained in 101 uncomplicated singleton third trimester pregnancies between 30 and 37 weeks of gestation. Reference ranges for three Doppler indices (RI, PI and S: D ratio) of the Umbilical artery at the fetal end and placental end of the cord were constructed based on these observations. 81 pairs of observations were used to calculate the difference of Doppler indices between the fetal and placental end of the umbilical artery. Continuous reduction of all the Doppler indices with advancing gestational age was obtained, which confirms previous observations.

The site-dependent variations in the measurement of Doppler indices are well known.[23] Some authors have advised recording the waveforms from the fetal end of the umbilical cord[20] and other authors have advised to record from the placental end.[18] Most of the researchers have calculated the reference values for the Doppler indices of umbilical artery from the free loop of the cord.[28, 29, 30, 31] Free loop of the cord is chosen because it is the easiest site to record the Doppler parameters accurately even by less experienced persons. We recorded RI, PI and S: D from the fetal end and placental end of the cord.

Significant difference of all the three Doppler indices (RI, PI and S: D) was observed between the fetal end and placental end of the cord ($p < 0.0001$). All the Doppler indices were higher at the fetal end of the cord than the placental end. Our findings confirm previous reports from cross-sectional as well as longitudinal studies that the UA Doppler velocimetry parameters are different at the fetal end and placental end, emphasizing the importance of using standardized insonation sites while comparing the clinical data.[17-25, 32]

Mean difference of Doppler indices between the two ends of the cord at different gestational age groups were also compared. Except for RI at 36-37 weeks group, all the Doppler indices were

significantly different at all the gestational age groups. The mean difference of all the Doppler indices was higher at 30-31 weeks than at 36-37 weeks group which confirms previous results.[23, 32] The mechanism for this decrease is not known.[26]

Serial evaluation of fetal hemodynamics by repeated Doppler examination is essential in the management of certain high-risk pregnancies, such as complicated multiple pregnancies, IUGR and oligohydramnios. In such cases more reliable comparisons may be made using the method of standardized insonation sites described in the present study.

Local changes in impedance and reflection of waves are important factors modifying the propagating pulse wave.[121] Therefore, variation in diameter along the cord, together with the continuously shortening distance to the bifurcating vasculature as blood approaches the placenta, may explain some of the difference in UA Doppler parameters between the placental and fetal ends.[32]

Conclusions

A total of 101 uncomplicated third trimester singleton pregnancies between 30 and 37 weeks of gestation were included in this cross sectional study. Reference ranges for three Doppler indices (Resistance index, Pulsatility index and Systolic: Diastolic ratio) of umbilical artery from fetal end and placental end were constructed.

Continuous reduction of all the Doppler indices with advancing gestational age was obtained.

Significant difference of all the three Doppler indices was found between the fetal end and placental end of the umbilical artery. Hence, choosing specific site either placental end or fetal

end of the cord would be better method for the serial recording of Doppler indices in complicated pregnancies.

These percentile fitted values and normograms will be valuable for the serial measurement of the Doppler indices in complicated pregnancies. Small sample size, narrow range of gestational age between 30 and 37 weeks of gestation are some of the limitations of our study.

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