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Original Article

Umbilical Artery Doppler to Determine the Relation between Doppler Indices and Sampling Site in the Third Trimester of Pregnancy: A Prospective Study

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Abstract

Background: The most useful tool for identifying and treating fetal growth restriction is the umbilical artery (UA) Doppler. The components of obstetric Doppler include the middle cerebral artery, UA, uterine artery, and ductus venosus. The optimal site to sample the UA is simultaneously one of the most frequently requested questions, so this study was done to determine the changes in umbilical pulsatility index (PI) and resistivity index (RI) at several sites.

Purpose: The purpose of this study was to ascertain whether the UA's RI and PI values differ at various sample sites during normal third-trimester pregnancy and whether its sampling next to the fetal bladder can be used for serial monitoring of fetal well-being.

Materials and Methods: A prospective observational study was conducted in Kempegowda institute of medical sciences with a study population of 312 third-trimester antenatal cases. All patients who met inclusion criteria underwent UA Doppler sampling at four different sites: At the placental attachment site, free-floating loops, abdominal attachment site, and beside the fetal urinary bladder.

Results: The mean RI and PI value of the UA was highest beside the fetal urinary bladder and lowest at the placental attachment site suggesting a significant difference.

Conclusion: Our findings of different Doppler indices based on the UA sampling site have important implications for the clinical surveillance of the fetus for subsequent care. The site of sample will be a crucial factor in assessing the severity of abnormality whenever UA Doppler indices are aberrant. Whenever we encounter any difficulty in locating a fixed place for monitoring, we can alternatively conduct the UA sampling next to the fetal urinary bladder.

Key words: Intra-uterine growth restriction, Middle cerebral artery, Pulsatility index, Resistivity index, Umbilical artery Doppler

INTRODUCTION

Ultrasound is the modality of choice in pregnancy. It has the most potential impact in managing high-risk pregnancies, including a high risk for fetal intrauterine growth restriction (IUGR) or where IUGR is already established.[1] Two umbilical arteries carry the deoxygenated blood from the fetus to the placenta.[1] The umbilical arteries arise from the fetal internal iliac arteries coursing alongside the lateral walls of the bladder into urachus[1] [Figure 1]. The umbilical artery (UA) measures 55–60 cm in length,[2] and its sampling plays a major role in assessing fetal growth restriction/distress. The Doppler parameters of UA mainly depend on the Doppler angle, sampling site, fetal cardiac, and breathing movements.

Normal waveforms from the UA are unidirectional and demonstrate forward flow throughout the cardiac cycle [Figure 2]. An abnormal waveform shows absent or reversed diastolic flow. Before the 15th week, the absence

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of diastolic flow may be a normal finding.[3] Depending on the fetal gestational age, any of these abnormal/aberrant findings should cause us to be concerned and take the appropriate therapeutic action. An increase in resistivity index (RI) and pulsatility index (PI) values is the early indicator, even when the wave patterns are normal.

Routine sampling of the UA is done at the free-floating loops, because many previous studies have shown to sample at these free loops. It is however challenging when continuous monitoring of intra-uterine growth-restricted fetuses by Doppler is required since the repeat values may be high if sampling is done toward the placental attachment site and less if we measured near the fetal attachment site of the umbilical cord. Therefore, in this study, we are trying to determine the difference in angle-independent indices of fetal Doppler at different sites of the UA and whether a fixed site (beside the fetal urinary bladder) for a sampling of UA can be determined for serial monitoring. Sampling of the UA beside the fetal urinary bladder is straight forward since this site is constant, and not only the number of umbilical arteries can be easily identified in the early pregnancy/NT scan but also effectively sampled in case of oligohydramnios, twin pregnancies, and other conditions where free loops' identification is difficult. Normally absent/reversed end-diastolic flow is likely to be seen first at the fetal end; thereby, we can find whether the Doppler values are statistically significant, which will help in early intervention and reduction of perinatal mortality.[4]

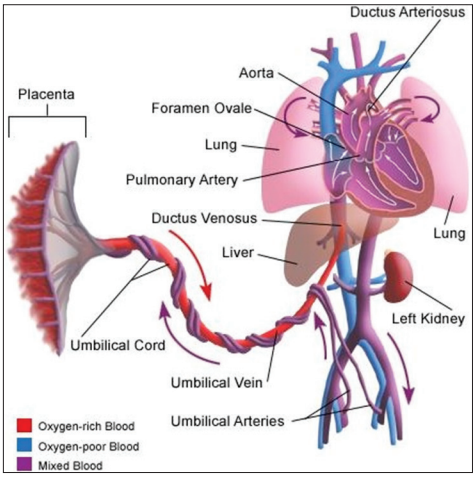

Figure 1: Anatomic image of fetal circulation in oblique view showing umbilical artery origin from internal iliac arteries and carrying deoxygenated blood to the placenta

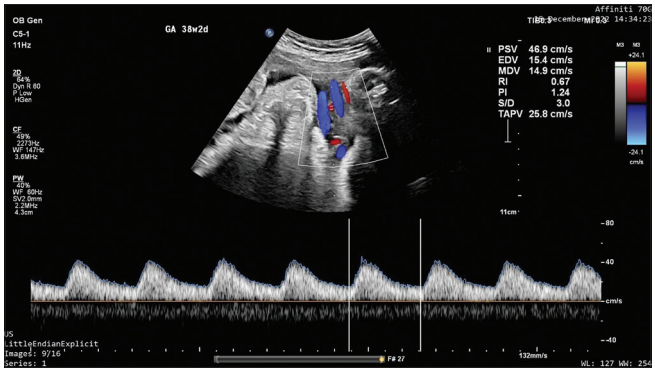

Figure 2: Normal wave pattern of umbilical artery: Duplex ultrasound image of a 38-week 2- day fetal umbilical cord sampled at free loop showing continuous unidirectional and forward flow throughout the cardiac cycle

Aims and Objectives

The aim of the study is to determine the difference in RI and PI values of the UA in different sampling sites along its length in a normal third-trimester of pregnancy.

The main objective is to determine a fixed location, like beside the fetal urinary bladder (Perivesical location) can be used for the UA sampling in serial monitoring.

MATERIALS AND METHODS

Study Design

This study was a prospective study.

Duration

This study was 1 month.

Place

This study was Kempegowda Institute of Medical Sciences (KIMS) hospital, Bangalore.

Sample Size

This study was 312.

Inclusion Criteria

The following criteria were included in the study:

- All normal third-trimester pregnancies.

Exclusion Criteria

The following criteria were excluded from the study:

- High-risk pregnancies
- Complicated pregnancies (GDM, HTN, and pregnancy associated with other maternal conditions)
- Pregnancy with IUGR.

This is a prospective study conducted in the Department of Radiodiagnosis KIMS, Bangalore, over a month in 2023. Normal pregnancies who came for routine antenatal scans and those who agreed to participate in this study were included in the study.

Prior Ethical Committee Clearance and patient consent were taken.

Using an affinity 70 ultrasound machine with all safety precautions and the ALARA principle, obstetric Doppler studies were conducted by a single radiologist with 12 years of experience in fetal ultrasound and obstetric Doppler sonography.

Doppler was performed with the mother in the supine position, and parameters were obtained when the fetus was not Mobile. Using a curvilinear probe (frequency 2–6 MHz) with appropriate Doppler settings, RI and PI values were obtained.

UA Doppler sampling was done at four sites: the placental attachment site, the free loops, the abdomen attachment site, and beside the fetal urinary bladder [Figure 3].

Besides, the bladder's right and left umbilical arteries were sampled separately, and average values were considered for calculation [Figure 4]. Once we obtained the waveforms at these sites, RI and PI values were taken by manual tracing. In this study, we mainly consider RI and PI values, which were angle independent, although the Doppler angle was kept below 30° to obtain more accurate Doppler values.

RESULTS

We enrolled 312 pregnant females who fulfilled the inclusion criteria in the study period.

The maximum number of cases was in 32 ± 1 week of gestation, and the minimum number of patients were 30 ± 1 week of pregnancy [Figure 5].

In our study, we noticed that UA PI and RI gradually reduce as gestation age progressed, which was maximum at 30 weeks and minimum at 40 weeks of gestation in all the sampled sites.

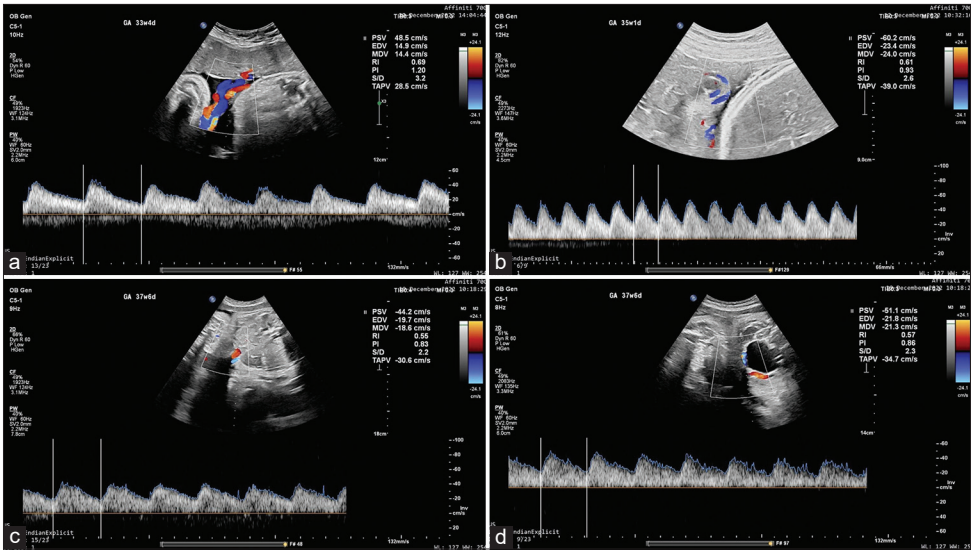

Figure 3: Umbilical artery Doppler wave pattern at different sites. (a) Duplex Doppler ultrasound image of 33-week 4-day fetal umbilical artery sampled at placental attachment site showing normal wave pattern. (b) Duplex Doppler ultrasound image of 35-week 1-day fetal umbilical artery sampled at free loop showing normal wave pattern. (c) Duplex Doppler ultrasound image of 37-week 6-day fetal umbilical artery sampled at abdominal attachment site in axial section showing normal wave pattern. (d) Duplex Doppler ultrasound image of 37-week 6-day fetal umbilical artery sampled beside the bladder in axial section showing normal wave pattern

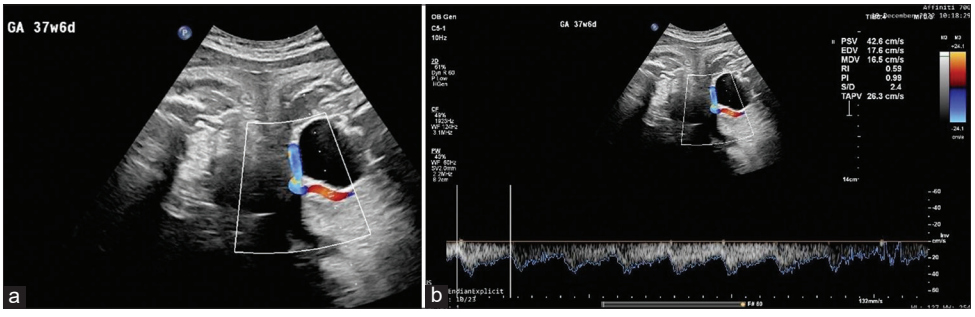

Figure 4: Umbilical artery Doppler sampling beside the fetal urinary bladder. (a) Color Doppler ultrasound image in 37 weeks 6 days fetus in the axial section at the level of bladder showing typical appearance of umbilical artery beside the bladder. In this image, the right uterine artery appears blue, whereas the left umbilical artery is seen in red. (b) Duplex ultrasound demonstrates the umbilical artery wave pattern in the same fetus

In the study, there was a significant difference in the mean RI of the UA with respect to its site. The mean RI of the UA was highest for the left UA beside the urinary bladder (0.68885 ± 0.0815) and lowest for UA at the placental attachment site (0.634 ± 0.0763) [Figure 6].

Bonferroni Test

Umbilical artery RI sampling site	Group based on site of umbilical artery	*P*-value
Umbilical artery RI at placental attachment site	Umbilical artery RI in free loop	0.845
	Umbilical artery RI at abdominal attachment site	0.961
	Right umbilical artery RI at bladder	<0.001*
	Left umbilical artery RI at bladder	<0.001*
Umbilical artery RI in free loop	Umbilical artery RI at abdominal attachment site	1.000
	Right umbilical artery RI at bladder	<0.001*
	Left umbilical artery RI at bladder	<0.001*
Umbilical artery RI at abdominal attachment site	Right umbilical artery RI at bladder	<0.001*
	Left umbilical artery RI at bladder	<0.001*
Right umbilical artery RI at bladder	Left umbilical artery RI at bladder	1.000

There was significant difference in mean RI between the placental and both umbilical arteries beside the bladder.

A significant difference was observed in mean RI between UA in free loop and both umbilical arteries beside the bladder.

There was also a significant difference in RI between UA at abdominal attachment and both umbilical arteries sampled beside the bladder.

In the study, there was a significant difference in the mean PI of the UA with respect to its site. The mean PI of the UA was highest for the right UA beside the fetal urinary bladder (1.072 ± 0.232) and lowest for UA at the placental attachment site (0.975 ± 0.189) [Figure 7].

Umbilical artery sampling site.	Group Based on Site of Umbilical artery	P value
Umbilical Artery PI at Placenta	Umbilical Artery PI in Free Loop	0.328
	Umbilical Artery PI at Abdominal Attachment Site	1.000
	Right Umbilical Artery PI at Bladder	<0.001*
	Left Umbilical Artery PI at Bladder	<0.001*
Umbilical Artery PI in Free Loop	Umbilical Artery PI at Abdominal Attachment Site	1.000
	Right Umbilical Artery PI at Bladder	<0.001*
	Left Umbilical Artery PI at Bladder	0.001
Umbilical Artery PI at Abdominal Attachment Site	Right Umbilical Artery PI at Bladder	<0.001*
	Left Umbilical Artery PI at Bladder	<0.001*
Right Umbilical Artery PI at Bladder	Left Umbilical Artery PI at Bladder	1.000

*--- P-value is statically significant.

There was a significant difference in mean PI between the placental attachment site and both umbilical arteries beside the bladder.

A significant difference was observed in mean PI between UA in free loop and both umbilical arteries beside.

There was also a significant difference in PI between UA at abdominal attachment and both umbilical arteries beside the bladder.

DISCUSSION

The present study was a prospective study which was carried out at the KIMS in Bangalore on 312 pregnant females. Maximum numbers of cases were in 32 ± 1 weeks of gestation, and the minimum number of cases was 30 ± 1 week of gestation.

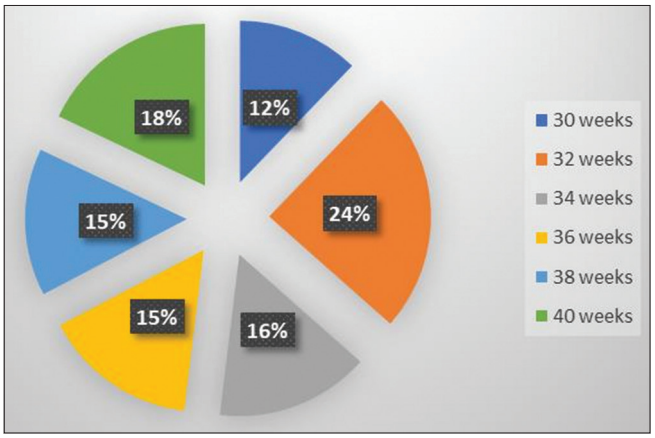

Figure 5: Distribution of gestational age

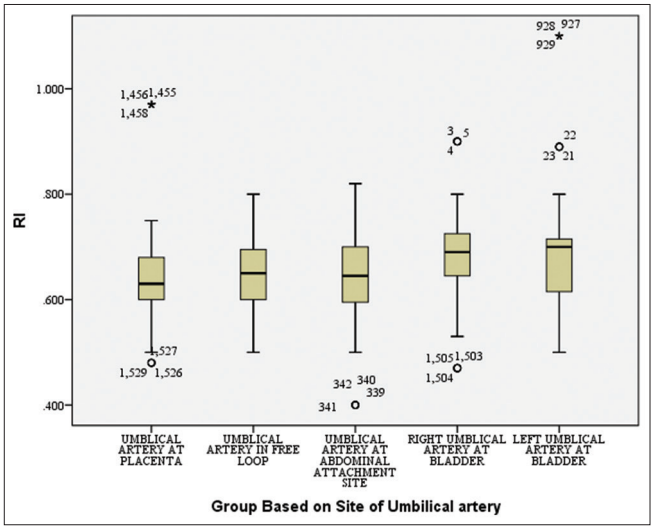

Figure 6: Box plot showing RI of umbilical artery with respect to different sites

In our study, the UA PI and RI values showed a gradual decline throughout the gestation [Table 1].

Srikumar *et al.*[4] (2017) study showed that fetal middle cerebral artery (MCA) and UA Doppler indices followed a definite pattern depending on the gestational age. The UA PI and RI showed a gradual decline throughout the gestation, likely due to a decrease in placental resistance as the pregnancy progressed.

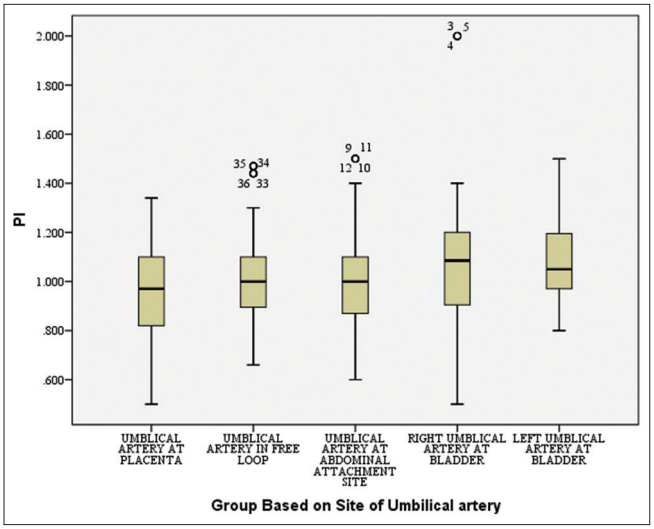

Figure 7: Box plot showing PI of umbilical artery with respect to different sites

Our study showed a significant difference in the mean RI of the UA with respect to its site. The mean RI of the UA was highest for Left UA beside the urinary bladder (0.68885 ± 0.0815) and lowest for UA at the placental attachment site (0.634 ± 0.0763) [Table 2].

There was a significant difference in mean RI and PI between the placental attachment site and both (right and left) umbilical arteries beside the fetal urinary bladder; UA RI in free loops and both (right and left) umbilical arteries beside the fetal urinary bladder; UA at abdominal attachment; and both (right and left) umbilical arteries beside the fetal urinary bladder.

Our study showed a significant difference in the mean PI of the UA with respect to its site. The mean PI of the UA was highest for the right UA beside the fetal urinary bladder (1.072 ± 0.232) and lowest for UA at placental attachment (0.975 ± 0.189) [Table 3].

Trudinger attributed the difference in a gradient from the fetal to the placental ends of the cord entrance region phenomenon.[5] The decrease may also be because of the

Table 1: RI and PI values with respect to gestational age at different sites

Umbilical artery sampling site	Gestational age											
	30 weeks		32 weeks		34 weeks		36 weeks		38 weeks		40 weeks	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Umbilical artery RI at placental attachment site	0.64	0.06	0.65	0.09	0.63	0.08	0.64	0.08	0.62	0.06	0.62	0.08
Umbilical artery RI in free loop	0.67	0.06	0.65	0.06	0.65	0.07	0.64	0.06	0.65	0.05	0.63	0.07
Umbilical artery RI at abdominal attachment site	0.65	0.09	0.65	0.07	0.64	0.09	0.63	0.08	0.66	0.06	0.64	0.07
Right umbilical artery RI at bladder	0.69	0.09	0.69	0.07	0.68	0.08	0.69	0.08	0.69	0.07	0.67	0.08
Left umbilical artery RI at bladder	0.70	0.11	0.69	0.08	0.70	0.10	0.67	0.10	0.71	0.11	0.67	0.08
Mean RI of right and left umbilical artery	0.69	0.09	0.69	0.06	0.69	0.08	0.68	0.07	0.70	0.08	0.67	0.06
Umbilical artery PI at placenta	1.00	0.19	0.99	0.18	0.98	0.18	0.98	0.18	0.96	0.22	0.94	0.19
Umbilical artery PI in free loop	1.05	0.17	1.03	0.17	1.03	0.20	0.98	0.17	1.02	0.18	0.95	0.17
Umbilical artery PI at the abdominal attachment site	1.03	0.24	1.00	0.17	0.98	0.16	0.98	0.14	1.02	0.16	0.97	0.15
Right umbilical artery PI at bladder	1.12	0.24	1.08	0.24	1.05	0.22	1.09	0.27	1.05	0.17	1.05	0.23
Left umbilical artery PI at bladder	1.09	0.19	1.08	0.17	1.09	0.18	1.04	0.19	1.05	0.14	1.06	0.17
Mean PI of right and left umbilical artery	1.10	0.18	1.07	0.15	1.06	0.15	1.05	0.17	1.05	0.14	1.04	0.15

PI: Pulsatility index, RI: Resistivity index

Table 2: Mean RI of umbilical artery at different sites

Umbilical artery sampling site	*n*	Mean	SD	95% Confidence interval for mean		Minimum	Maximum	*P*-value
				Lower bound	Upper bound			
RI								
Umbilical artery RI at placenta	312	0.63415	0.07638	0.62563	0.64267	0.480	0.970	<0.001*
Umbilical artery RI in free loop	312	0.64500	0.06327	0.63795	0.65205	0.500	0.800	
Umbilical artery RI at abdominal attachment site	312	0.64462	0.07702	0.63604	0.65320	0.400	0.820	
Right umbilical artery RI at bladder	312	0.68481	0.07811	0.67611	0.69351	0.470	0.900	
Left umbilical artery RI at bladder	312	0.68885	0.09432	0.67834	0.69935	0.500	1.100	
Total	1560	0.65950	0.08157	0.65545	0.66355	0.400	1.100	

PI: Pulsatility index, RI: Resistivity index, * P-value is statically significant

Table 3: Mean PI of umbilical artery at different sites

Umbilical artery sampling site	*n*	Mean	SD	95% Confidence interval for Mean		Minimum	Maxim um	*P*-value
				Lower bound	Upper bound			
PI								
Umbilical artery PI at placenta	312	0.975	0.189030	0.95466	0.99685	0.500	1.34	<0.001*
Umbilical artery PI in free loop	312	1.0082	0.177449	0.98850	1.02804	0.660	1.47	
Umbilical artery PI at abdominal attachment site	312	0.995	0.170117	0.97701	1.01491	0.600	1.50	
Right umbilical artery PI at bladder	312	1.0721	0.232838	1.04618	1.09805	0.500	2.00	
Left umbilical artery PI at bladder	312	1.0694	0.173221	1.05013	1.08872	0.800	1.50	
Total	1560	1.0243	0.193731	1.01471	1.03396	0.500	2.00	

PI: Pulsatility index, RI: Resistivity index

dampening and attenuation of the propagated wave. Other suggested possibilities are changes in elasticity in the walls of the vessels or changes in the diameter of these vessels. A computer model used for studying the difference in RI from fetal to the placental site showed that placental resistance was a primary factor determining the differences, whereas the viscosity of the blood and cord length were secondary factors.[6]

The changing gradient along the umbilical cord length means that UA Doppler indices will vary depending on the site of insonation. The free loops are the most commonly used site in clinical practice, as it is technically easier to obtain, but it is likely to have significant inter- and intraobserver variability because sampling could be from very disparate sites. These differences are likely to be more marked where the waveform and indices are abnormal. Abramowicz *et al.*, for example, examined differences in the indices at the two fixed sites (placental and abdominal attachment) and reported that normal values were obtained for S/D at the placental site when simultaneous examination of the fetal abdominal site obtained highly abnormal values.[7]

Friedman *et al.*[8] recommended measuring the S/D ratio at the insertion of the cord to improve reproducibility, but these sites are often technically challenging to insonate, especially at the later stages of pregnancy due to a poor angle of insonation, the relationship of the fetus with the placenta, or oligohydramnios/anhydramnios.

CONCLUSION

Our findings of varying Doppler indices depending on the UA sampling site have significant implications for clinical practice in monitoring fetuses for further management.

Whenever UA Doppler indices are abnormal, the site of sampling will be an essential variable in determining the degree of abnormality and timing of the delivery.

For this reason, it is essential to monitor fetal well-being by assessment at a constant site for UA Doppler so that the variability will be less and can be clinically correlated with different outcomes.

Whenever we encounter any difficulty in locating a fixed place for monitoring, we can alternatively conduct the UA sampling next to the fetal urinary bladder, like in cases of monoamniotic twins where the investigation of individual fetuses can be undertaken confidently; severe growth restriction with severe oligohydramnios or anhydramnios or ruptured membranes with associated oligohydramnios.

It is time for radiologists to consider defining a reference point for the UA Doppler. This will ensure comparisons of results, consistency in interpretation, and further monitoring.

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