

## Doppler Waveform Analysis of the Umbilical Artery in Normal Pregnancies (Normogram) at Shimla.

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### Summary

A prospective longitudinal study was done on all consecutive normal pregnant women attending the antenatal clinic of Kamla Nehru Hospital, IGMC, Shimla with single fetus at or around 28 weeks of gestation with no high risk factors. Serial Doppler evaluation of umbilical artery blood flow was carried out at 2 weekly intervals starting around 28 weeks of gestation till the time of delivery. A total of 53 women were evaluated out of which 29 were primigravid and 24 were multigravid. All the flow velocity wave form indices showed a gradual fall with the progression of gestation. S/D ratio decreased from  $3.04 \pm 1.3$  at 26-28 weeks to  $2.40 \pm .16$  after 38 weeks. RI decreased from  $0.64 \pm 0.02$  at 26-28 weeks to  $0.60 \pm 0.04$  after 38 weeks. PI also decreased from  $1.01 \pm 0.05$  at 26-28 weeks to  $0.84 \pm 0.06$  after 38 weeks. There was a statistically significant decrease in the S/D ratio, RI and PI with progression of gestation at term as compared to the baseline taken b/w 26 to 28 weeks of gestation ( $P < 0.001$ ,  $< .01$ ,  $< .001$  respectively). There was no significant difference in the various waveform indices between the primigravidae and multigravidae at any period of gestation.

### Introduction

Antepartum detection of fetus at risk of death or compromise in utero remains a major challenge in modern obstetrics. Specific and accurate methods for detection of fetus at risk can result in early appropriate intervention and hence reduce fetal loss. Antenatal tests of fetal well being depend indirectly on changes in fetal physiology, an aspect of the fetus, which, until recently, has been relatively inaccessible to study by the paucity of techniques to measure the placental function – the critical organ through which the transfer of nutrients occur. New technology has now become available in the clinical assessment of placental circulation. Doppler measurement of the pulsatile blood velocity in umbilical artery gives direct information on fetoplacental circulation and hence identifies placental circulatory failure. Recording of umbilical artery waveforms provide

a measure of placental flow resistance. Knowledge gained from the use of Doppler velocimetry of the umbilical artery can distinguish between fetus that can safely be managed conservatively from the fetus really at risk of perinatal morbidity or mortality who is likely to benefit from earlier delivery, thus having a beneficial role in the management of high risk pregnancies. In order to use indices which characterize the maximum frequency outline of the waveform, in clinical management, it is important to establish the normal reference ranges throughout pregnancy.

### Material and Methods

A prospective longitudinal study was done at Kamla Nehru Hospital of the Department of Obstetrics and Gynaecology, and the Department of Cardiology, IGMC, Shimla (H.P.) from 1<sup>st</sup> May, 1996 to 30<sup>th</sup> April, 1997.

## Subjects and Methods

All consecutive normal pregnant women attending the antenatal clinic of Kamla Nehru Hospital, ICMC were screened for possible participation in the present study after explaining about the nature of the study.

### Inclusion Criteria

All the women who fulfilled the following criteria were enrolled for the study.

1. Willingness to participate in the study and to deliver at Kamla Nehru Hospital.
2. Normal accurately dated pregnancy at / or around 28 weeks of gestation with a single fetus and having no high risk factor.

A detailed menstrual, obstetrical, past family and personal history was taken. Thorough general physical, systemic and obstetrical examination was done. The duration of pregnancy at the time of registration to the hospital and the gestational age at first velocimetry study was recorded. Period of gestation was calculated from menstrual history in patients with history of previous regular menstrual cycles with last menstrual date known with certainty. Pregnancy duration was confirmed by an ultrasound examination prior to 20 weeks of gestation. Assessment of growth was done by clinical examination and conventional ultrasonography after 28 weeks.

### Doppler Evaluation of Umbilical Artery Blood Flow

Serial Doppler evaluation of umbilical artery blood flow was carried out at 2 weekly intervals starting around 28 weeks of gestation till delivery. Doppler examination was carried on ATL Ultramark -7 Echomachine. Pulsed Doppler signals were recorded from umbilical artery using 2.5 MH phased array probe with a 200Hz high pass filter. With the patient in supine position with slight lateral tilt, umbilical artery in the amniotic fluid was located by 2D image with superimposed colourflow doppler imaging. Pulsed doppler signals were obtained by positioning the sample volume over the umbilical artery until an ideal signal was obtained. Doppler signals were obtained simultaneously both from the umbilical artery and umbilical vein during periods of fetal apnoea which was recognized by fluctuations in normal steady nonpulsatile flow in the umbilical vein. Waveforms with the maximum frequency i.e. highest systolic peak were selected. When three waves of equal height were visualized, the image was frozen on the display screen and measurements taken. The average of all the three was taken and analysed for the various doppler derived indices. For each study 3

different readings at different locations were taken and average value obtained.

Various doppler derived waveform indices were:

1. S/D Ratio =  $\frac{\text{Maximum Systolic Velocity}}{\text{End Diastolic Velocity}}$
2. Resistance Index (RI) =  $\frac{S-D}{S}$
3. Pulsatility Index (PI) =  $\frac{S-D}{M(\text{Mean})}$

Study population were managed according to the standard protocol of antenatal care and delivery. Doppler derived information did not affect the management. The further management of pregnancy, treatment given and complication if any during pregnancy and labour were noted. The period of gestation at delivery was recorded. Method of termination of pregnancy, period of gestation at delivery, mode of onset of labour, progress of labour and fetal condition was monitored closely and details of complications if any were recorded.

A detailed examination of the new born was done. The APGAR score at 1 and 5 minutes of birth, the resuscitation required, the sex and the birth weight of the baby and the congenital anomalies, if any, were noted. Maturity assessment of the new born was done.

### Exclusion Criteria

1. Women developing complication of pregnancy during the course of study leading to poor perinatal outcome.
2. Delivery at <37 and > 42 weeks of gestation and patients undergoing caesarean section for fetal distress.
3. Birth weight <2.500 Kgms and APGAR score of < 7 at 5 minutes of birth.

Routine haematological and urine examination along with blood grouping, RH factor and VDRL of the couple were done. Conventional ultrasound examination, biophysical profile and any other special investigation if and when required, were done and recorded.

### Statistical Analysis

Results were expressed as mean + 1SD. Statistical analysis was done by the student t-test.

### Observations

#### Clinical Characteristics of Study Population

A total of 53 women who fulfilled the inclusion and exclusion criteria were studied. Mean age was 25.12 ± 4.07 years with a range of 19 - 34 years. 29 were

**Table – I**  
U.A Flow velocity waveform indices in relation to gestational age  
N-53

S.No.	Gestational Age in weeks	No. of Cases	S/D Ratio	RI	PI
1.	26-28	22	3.04±0.13	0.64±0.02	1.01±0.05
2.	28-30	49	2.92±0.02	0.64±0.04	0.95±0.11
3.	30-32	44	2.79±0.24	0.62±0.04	0.94±0.10
4.	32-34	47	2.72±0.29	0.61±0.05	0.89±0.11
5.	34-36	53	2.53±0.31	0.59±0.05	0.89±0.11
6.	36-38	48	2.48±0.30	0.59±0.05	0.88±0.09
7.	>38	25	2.40±0.16*	0.60±0.04**	0.84±0.06*

\* P<0.001 HS \*\* P<0.01 Significant

**Table – II**  
S/D Ratio in Relation to Parity  
N-53

S.No.	Gestational Age in Weeks	Primigravida		Multigravida		T Value	Significance
		No. of Cases	S/D Ratio	No. of Cases	S/D Ratio		
1.	26-28	13	3.10±0.18	09	3.02±0.12	1.1622	NS
2.	28-30	27	3.04±0.28	22	2.97±0.18	1.0133	NS
3.	30-32	25	2.84±0.23	19	2.72±0.22	1.7464	NS
4.	32-34	27	2.74±0.33	20	2.68±0.22	0.7044	NS
5.	34-36	29	2.56±0.37	24	2.50±0.27	0.6615	NS
6.	36-38	26	2.60±0.36	22	2.43±0.24	1.8869	NS
7.	> 38	15	2.40±0.16	10	2.41±0.15	0.1516	NS

**Table – III**  
Resistance Index in Relation to Parity  
N-53

S.No.	Gestational Age in Weeks	Primigravida		Multigravida		T Value	Significance
		No. of Cases	RI	No. of Cases	RI		
1.	26-28	13	0.64±0.04	09	0.64±0.02	0.000	NS
2.	28-30	27	0.63±0.03	22	0.62±0.03	1.1606	NS
3.	30-32	25	0.63±0.03	19	0.61±0.04	1.8970	NS
4.	32-34	27	0.62±0.05	20	0.61±0.06	0.6255	NS
5.	34-36	29	0.60±0.05	24	0.59±0.05	0.7248	NS
6.	36-38	26	0.60±0.05	22	0.58±0.05	1.3808	NS
7.	>38	15	0.60±0.03	10	0.58±0.04	1.4298	NS

**Table – IV**  
Pulsatility Index (PI) in Relation to Parity  
N-53

S.No.	Gestational Age in weeks	Primigravida		Multigravida		T Vaue	Significance
		No. Cases	PI	No. of Cases	PI		
1.	26-28	13	1.04±0.06	09	0.99±0.06	1.9218	NS
2.	28-30	27	0.97±0.09	22	0.94±0.10	1.1042	NS
3.	30-32	25	0.96±0.07	19	0.93±0.09	1.2447	NS
4.	32-34	27	0.95±0.10	20	0.92±0.12	0.9388	NS
5.	34-36	29	0.90±0.11	24	0.89±0.10	0.3431	NS
6.	36-38	26	0.87±0.17	22	0.87±0.09	0.000	NS
7.	>38	15	0.85±0.06	10	0.84±0.06	0.4083	NS



primigravidae and 24 were multigravidae. First antenatal checkup before 12 weeks was done in 31 cases and 22 women had first antenatal checkup between 12-20 weeks of gestation. Mean gestation at delivery was  $38.41 \pm 1.08$  weeks. Nine patients had caesarean section for indications other than fetal distress and 44 women had normal vaginal delivery. Mean birth weight was  $2.809 \pm 0.273$  Kgms.

Table I shows the values of three doppler derived flow velocity waveform indices recorded sequentially starting from 26 to 28 weeks till the time of delivery. All the doppler derived indices i.e. S/D ratio, RI and PI decreased with the progression of gestation thereby indicating gradual fall in the umbilical artery resistance with the progression of gestation. There was a statistically significant decrease in S/D ratio, RI and PI at term as compared to the baseline taken between 26-28 weeks of gestation. Though when compared over a two weeks period, the decrease in various waveform indices studied, was not found to be significant.

Table II shows S/D ratio for primigravidae and multigravidae at different periods of gestation. In both the S/D ratio showed a decline with increasing gestational age. But there was no statistically significant difference in the S/D ratio between primigravidae and multigravidae at any period of gestation.

Table-III shows declining resistance index with increasing gestation in primigravidae and multigravidae. Again there was no significant difference between the two groups.

Table IV shows pulsatility index in primigravidae and multigravidae with significant decrease with progression of gestation in both the groups but no significant difference between the two at any period of gestation.

## Discussion

Christian Johann Doppler described the "Doppler Effect" in 1842. The use of Doppler ultrasonography to study the flow velocity waveforms in fetal umbilical artery was reported for the first time by Fitzgerald and Drumm in 1977. Because of methodological problems involved in measuring the vessel diameter and in determining the angle of insonation leading to large errors in quantitative volume estimation, interest is turned to indices which measure flow impedance rather than volume flow derived from maximum frequency flow velocity waveforms and are independent of the angle of insonation and the length of cardiac cycle. (Pearce et al, 1988).

The application of doppler ultrasonography has now extended from the umbilical cord to maternal vessel supplying the placental intervillous space and other fetal vessels including aorta, cerebral and renal arteries especially since the development of colour flow imaging. In spite of these new developments, the study of the umbilical artery has remained the most widely used approach as even less experienced operators can achieve highly reproducible results with simpler inexpensive continuous wave equipment (Alfirevic and Neilson, 1995).

One of the first objective when introducing a new test, is to establish the reference ranges for normal population. Reference ranges for changes with gestational age for various indices of doppler flow velocity waveform of umbilical artery have been published by several authors.

In a study of 89 normal pregnancies by Schulman et al. (1984), the umbilical artery velocity wave S/D ratio declined from 2.8 at 25 weeks to 2.2 at 41 weeks of gestation. These values were lower than those observed in present study viz  $3.04 \pm 0.13$  at 26-28 weeks declining to  $2.40 \pm 0.16$  after 38 weeks. Trudinger et al (1985) studied 15 normal pregnancies every 2 weekly from 28 weeks until the onset of spontaneous labour after 37 weeks. They reported a declining S/D ratio of 3.15 at 28 weeks to 2.2 at 40 weeks which is similar to the present study.

In the present study RI decreased from  $0.64 \pm 0.02$  at 26-28 weeks to  $0.60 \pm 0.04$  at term and PI decreased from  $1.01 \pm 0.05$  at 26-28 weeks to  $0.84 \pm 0.06$  after 38 weeks. Pearce et al (1988) studied 34 normal pregnant women longitudinally every 4 weekly from 16-18 weeks gestation till delivery. The mean values of all the three indices i.e. S/D ratio, RI and PI fell with increasing gestational age indicating that the fetal-placental circulation expands throughout pregnancy.

The 95<sup>th</sup> percentile at 18, 24, 28 and 34 weeks of gestation for umbilical artery S/D ratio in the pregnancies with normal outcome (n=271) were 5.6, 4.6, 4.88 and 3.91 respectively in a study by Newnham et al (1990). In the present study however these values were lower than the above study i.e. at 28 weeks the maximum S/D ratio was 3.30 (mean  $\pm$  2SD) and at 34 weeks it was 3.15 (mean  $\pm$  2SD). According to Devoe et al (1990) the cutoff for maximum S/D ratio varied with the gestational age and showed a progressive decline from 28 through 42 weeks of gestational age. At 28 weeks the threshold for maximum S/D ratio was 4.15, at 32 weeks 3.70, at 36 weeks 3.50 and at 42 weeks 3.10. The corresponding values were lower in the present study with maximum S/D ratio of 3.30 at 28 weeks, 3.27 at 32 weeks, 3.15 at 36

weeks and 2.72 after 38 weeks.

The S/D ratios were analysed for primigravidae and multigravidae in the present study. In both primigravidae and multigravidae, the S/D ratio showed a decline with increasing gestation but there was no statistically significant difference between the two groups at any particular period of gestation showing that gravidity had no influence over the S/D ratio. Rose et al (1993) also showed the similar results in a longitudinal study done on 19 women every two weekly from 20 weeks of gestation onwards till delivery. They also found no significant difference between the primigravidae and multigravidae in their study.

Although there are minor differences in the values, may be due to different standards employed by different authors and due to different population studied, there is broad agreement amongst various reported reference ranges. The indices show remarkable stability in all studies with all three indices i.e. S/D ratio, RI and PI demonstrating a decrease with advancing gestation in normal pregnancies, indicating a reduction in peripheral resistance probably at the level of arterioles of tertiary stem villi. (McParland & Pearce, 1990). This study establishes a nomogram for various umbilical artery flow velocity waveform indices for the study population. Thus

the doppler evaluation of umbilical artery flow velocity waveform can be explored as an additional diagnostic tool in identifying a fetus at risk in complicated pregnancies and aid in their management.

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