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Correcting umbilical artery flow velocity waveforms for fetal heart rate is unnecessary

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We prospectively examined 55 normal pregnant women between 32 and 41 ($\bar{x}$ = 37) weeks' gestation. Five measurements of the umbilical artery peak-systolic/end-diastolic frequency ratio were obtained from each patient during one examination. Comparison of the fetal heart rate and the umbilical artery peak-systolic/end-diastolic frequency ratios between pregnancies <37 and >37 weeks' gestation revealed no difference. Subsequently a total of 256 measurements were analyzed as one group. Plotting the individual peak-systolic/end-diastolic frequency ratios against the corresponding fetal heart rates revealed a moderate negative linear correlation: $y = 4.15 - 0.012x$, $r = -0.36$ and $p < 0.04$. When only heart rates between 120 to 160 beats/min were plotted against peak-systolic/end-diastolic frequency ratios, a weaker correlation was found ($r = -0.33$, $p = 0.15$). The difference (mean ± SD) between the obtained and the corrected peak-systolic/end-diastolic frequency ratios was 4.4% ± 3.2%. The 95th percentile of the obtained peak-systolic/end-diastolic frequency ratio was 3.35 and the corrected ratio was 3.27. Averaging of the five measurements obtained from each patient for all 55 patients decreased the 95th percentile value to 3.09 whereas the same procedure for the corrected peak-systolic/end-diastolic frequency ratios decreased it to 3.07. We conclude that although there is a statistically significant negative linear correlation between the fetal heart rate and the umbilical artery peak-systolic/end-diastolic frequency ratio, this relationship is not clinically significant. (AM J OBSTET GYNECOL 1989;160:704-7.)

Key words: Fetal heart rate, umbilical artery S/D ratio, continuous significance, umbilical artery flow velocity waveform, continuous wave Doppler

Fetal umbilical artery flow velocity waveform analysis is considered a useful noninvasive clinical method for the evaluation of fetal well-being. The ratio of the peak-systolic frequency over the end-diastolic frequency (S/D ratio) taken from the umbilical artery flow velocity waveform has been used by several investigators for the evaluation of the fetus at risk in pregnancies complicated by intrauterine growth retardation, preeclampsia, diabetes, etc.[1-6]

S/D ratios > the 95th percentile for the corresponding gestational age are associated with increased perinatal morbidity and mortality.[3, 6, 7] The S/D ratio is considered a measure of placental vascular resistance distal to the point of insonation.[7, 8] However, placental resistance may not be the only factor that affects the S/D ratio. We have observed during the course of the same examination that the umbilical artery S/D ratio was inversely related to the fetal heart rate. Because the fetal heart rate (FHR) may vary widely in normal fetuses in short time intervals, it may increase the variance of the S/D measurements, which in turn may affect the sensitivity and specificity of the test.

The present study was designed to define prospectively the relationship between the umbilical artery S/D ratio and FHR, and to evaluate its statistical and clinical significance.

Material and methods

Fifty-five normal pregnant women between 32 and 41 weeks' gestation were examined only once during their pregnancy. None of the patients developed any complications. All patients were delivered at term of appropriate for gestational age infants, with Apgar scores ≥7 at 1 minute. The study was approved by the Clinical Research Practices Committee and all patients gave written informed consent.

Umbilical artery flow velocity waveforms were obtained by a continuous wave Doppler device operating at a frequency of 4 MHz equipped with a spectrum analyzer (Vasoflo 3, Sonicaid-Oxford Medical Inc., Clearwater, Fla.). The flow velocity waveforms were obtained with the mother lying in a left lateral tilt and

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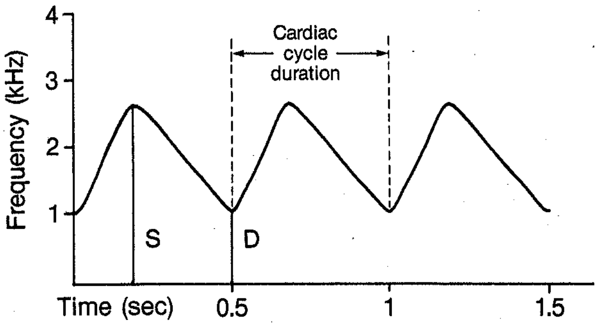

Fig. 1. Method used to obtain cardiac cycle duration and systolic-peak *(S)* and end-diastolic *(D)* frequencies.

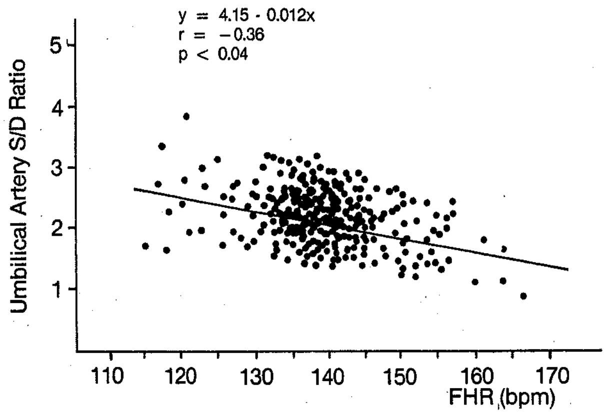

Fig. 2. Relationship of umbilical artery S/D ratio and FHR when the individual measurements are plotted (weighted linear regression).

the transducer placed on the maternal abdomen overlying the area of fetal small parts. The fetal position was defined by Leopold's maneuvers. When an appropriate flow velocity waveform was obtained with forward arterial flow and reverse continuous nonpulsatile venous flow, the transducer was kept in the same place to eliminate regional variability. Measurements were obtained only in the absence of fetal breathing as determined by continuous nonpulsatile umbilical venous flow. Five frames, each containing four similar flow velocity waveforms, were obtained. In 15 patients only four frames were obtained and in 2, only three frames were obtained because of extended periods of fetal breathing.

Measurements were obtained from the frozen frame with the use of electronic calipers. The peak-systolic (S) and least-diastolic (D) frequencies were measured and the S/D ratio was calculated. The FHR was calculated by dividing the number 60 by the duration of the cardiac cycle. The cardiac cycle was measured from the beginning of one waveform to the beginning of the next one (Fig. 1).

Because multiple measurements were taken from each patient and because the number of measurements varied among patients, statistical inference was based on weighted analyses of intrasubject means. For comparing pregnancies that were <37 weeks' gestation vs ≥37 weeks' gestation, this approach led to a repeated measures analysis of variance. For examining the relationship between FHR and observed S/D ratio, this approach led to a weighted linear regression. Corrections of S/D ratio for FHR were made using the standard formula:

$$\text{Corrected S/D ratio} = \text{Observed S/D ratio} + \text{Regression slope} \times [\text{FHR} - \text{Mean (FHR)}]$$

Results

All patients ($N = 55$) were placed in one group because comparison of the umbilical artery S/D ratio and FHR between pregnancies ≥37 weeks' gestation and those <37 weeks' gestation showed negligible differences (Table I). A total of 256 measurements was analyzed. The mean gestational age was 37 weeks, the mean umbilical artery S/D ratio was 2.43 ± 0.46 (SD), and the mean FHR was 140.9 ± 11.7 beats/min (SD).

Table I. Comparison of umbilical artery S/D ratio and FHR between pregnancies ≥37 weeks and <37 weeks of gestational age

Gestational age	*Umbilical artery S/D ratio (mean ± SD)*	*FHR (beats/min) (mean ± SD)*
>37 wk ($N = 156$)	2.40 ± 0.50	140.70 ± 12.50
<37 wk ($N = 100$)	2.45 ± 0.38	141.30 ± 10.50
Significance*	$p = 0.37$	$p = 0.68$

*Based on repeated measures analysis of variance.

Weighted linear regression of the individual umbilical artery S/D ratios on the corresponding FHRs revealed a moderate negative linear correlation: $y = 4.15 - 0.012x$, $r = -0.36$, $p < 0.04$ (Fig. 2). Plotting only S/D ratios corresponding to heart rates within the normal range (120 to 160 beats/min) revealed a weaker negative linear correlation $r = -0.34$, $p = 0.15$).

The mean obtained S/D ratio and the mean corrected ratio were similar, as would be expected, because the least-squares principle always produces residuals that add to 0 (2.43 ± 0.46 and 2.43 ± 0.42). The mean percent difference (mean ± SD) between obtained and corrected S/D ratios was 4.4% ± 3.2%. The coefficient of variation changed to 17.3% from 19% after correction but decreased to 13.6% when all individual measurements from each patient were averaged (Table II). The R^2 value was 0.13, indicating that only 13% of the

Table II. Comparison of obtained S/D ratios with corrected ratios*

	Single S/D ratios (N = 256)		*Average S/D ratios (N = 55)*	
	Obtained S/D	*Corrected S/D*	*Obtained S/D*	*Corrected S/D*
Mean ± SD	2.43 ± 0.46	2.43 ± 0.42	2.43 ± 0.33	2.43 ± 0.32
Coefficient of variation	19%	17.30% (NS)	13.60%	13.14% (NS)

*Single and average measurements were analyzed.

overall variability in the umbilical artery S/D ratio can be accounted for by the changes in the FHR.

Comment

The findings in this article confirm that a moderate negative linear correlation exists between the FHR and the S/D ratio: the S/D ratio decreases when the FHR increases. One could speculate that as the time interval between successive cardiac cycles decreases, the same volume of blood (fraction of the combined stroke volume) travels down the vessel at higher velocities during end diastole. When the cardiac cycle is prolonged, the end diastole velocities are lower. This may be a simplistic explanation, however, because it is based on the assumption that placental resistance, stroke volume, and blood pressure remain unchanged.

Mires et al.[9] have reported on the same subject. They obtained their data from 25 women who were examined on 34 occasions during the third trimester; their results were similar to ours ($y = 4.32 - 0.014x$, $r = -0.49$, $p < 0.04$). It is not clear from their report whether all five recordings from each patient were obtained from the same location. This distinction is important because the resistance is proportionately related to the length of the vessel under examination. Signals obtained from various locations during the same examination may introduce additional variability in the S/D ratio value, which will not be accounted for by the changes in the FHR.[10] Unlike Mires et al.,[9] we did not use any intrapartum data because we believe that factors such as uterine contractions, cord compression, and temporary hypoxia may influence the fetal cardiovascular responses, producing misleading data. The mean heart rate in our study was 140 beats/min; the corrected S/D ratio value can be obtained by the formula corrected S/D = obtained S/D + 0.012 (FHR − 140).

There is no doubt that there is some degree of negative linear correlation between the FHR and umbilical artery S/D ratio. On the contrary, the clinical significance of this finding *is* doubtful. Similar S/D ratio values can be obtained from several fetuses with a wide range of FHRs. This introduces *inter*subject variability that influences the *intra*subject variability, resulting in a weaker relationship between FHR and umbilical artery S/D ratio. Ideally, a large number of measurements should be obtained from the same patient at different heart rates during the same examination; then calculation of the individual slope could be used to correct the obtained S/D ratios. This, however, is cumbersome and of doubtful clinical value. We can only explain 13% of the variability in the S/D ratio measurements in the study group by the changes in the heart rate. The mean difference between obtained and corrected S/D ratios was 4.4%. When considered, the difference does not change the clinical interpretation of the results. In fact, only one value from all 256 recordings would be clinically different after correction. The obtained S/D ratio exceeded the 95th percentile after correction for heart rate. However, this was only one of five measurements; as such, it did not have any effect on the average S/D ratio for the given patient. Averaging of the five obtained measurements from each patient decreased the 95th percentile to 3.09; this provides a narrower 95% confidence interval. In turn, this eliminates the gray areas of the spectrum, in which normal and abnormal results can coexist, and makes the clinical interpretation of the results easier.

In conclusion, this study demonstrates a negative linear relationship between the FHR and umbilical artery S/D ratio and confirms previously published data. However, a critical view of the data indicates that this relationship is clinically insignificant. Our findings also indicate that the average of four to five measurements during an examination decreases the variability and thus provides a narrower 95% confidence interval that facilitates clinical interpretation of the results. Based on the above data, there is no need for mathematic correction of the obtained S/D ratios for the heart rate.

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