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ARTICLES

Using S/D Ratios to Predict Fetal Outcome

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The systolic/diastolic (S/D) ratio is a measurement of the umbilical cord artery that compares the systolic with the diastolic flow and identifies the amount of resistance in the placental vasculature. This retrospective study made a direct comparison between the S/D ratios of third-trimester fetuses and their birth weights. Previous studies have reported fetuses with S/D ratios greater than 3.0, after 30 gestational weeks, to be at an increased risk for low birth weight. This study looked at outcomes of fetuses with S/D ratios greater than 3.0, and ratios less than 3.0. One hundred S/D ratios were obtained and divided into three categories: less than 2.0, between 2.0 and 3.0, and greater than 3.0. The collected data showed 35.5% of low-birth-weight neonates had S/D ratios greater than 3.0. Those patients with S/D ratios less than 2.0 had the largest percentage (37.5%) of neonates above the 50th percentile in weight, whereas ratios between 2.0 and 3.0 had the highest percentage (59.46%) of neonates between the 11th and 50th weight percentiles. The S/D ratio is easily obtained and provides important information in conjunction with fetal structural measurements when predicting the outcome of a fetus.

Key words: systolic/diastolic (S/D) ratio, umbilical cord artery

Umbilical cord Doppler ultrasonography is a simple procedure that can be included in every fetal survey. Performing pulsed Doppler on an umbilical cord artery may assist in predicting fetal outcome. A systolic/diastolic (S/D) ratio taken from a free-floating portion of the umbilical cord artery assists in the assessment of fetal blood flow. When there is an increased amount of flow during diastole, the S/D ratio is low, and it is presumed that the fetus is receiving an adequate amount of blood. Decreased diastolic flow results in a high S/D ratio and has been linked to risk of low birth weight and pregnancy-induced maternal hypertension.[1]

This study evaluated Doppler velocity waveforms from one free-floating segment of umbilical artery

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to determine an S/D ratio. The S/D ratios were divided into three categories, with fetal outcome examined at each level. These included S/D ratios of less than 2.0, S/D ratios between 2.0 and 3.0, and S/D ratios greater than 3.0. Previous studies have reported that fetuses with S/D ratios greater than 3.0 are at greater risk for low birth weight, whereas fetuses with S/D ratios less than 3.0 are more likely to be appropriate in weight.[2] This study attempted to confirm these findings as well as examine the outcome of those fetuses with S/D ratios less than 2.0. This study also attempted to determine the prevalence of low birth weight in each of the three S/D ratio categories.

Materials and Methods

A retrospective study was conducted using obstetric data collected between January 1995 and July 1997. Patients ranged from 14 to 42 years of age (average, 27 years) and were from a large variety of ethnic groups. The study included those patients who were greater than 30 gestational weeks according to the dating criteria from their first-trimester ultrasound. If a patient did not have an ultrasound during the first trimester, then gestational age was based on last menstrual period. Each patient had to have had an ultrasound and delivery at Providence Medical Center of Seattle to be included in the study. Patients with multiple gestations were excluded.

All studies were performed using a Diasonics VST Master Series (Diasonics Ultrasound, Santa Clara, CA) or an ATL HDI 3000 (Advanced Technology Laboratory, Inc. Bothell, WA). Each study was performed using either a 3-MHz or a 5-MHz curved array transducer.

Each patient had a complete obstetric study performed, according to American Institute of Ultrasound in Medicine guidelines. The examination also included a pulsed Doppler measurement of a free-floating segment of umbilical artery. Color Doppler imaging was used when necessary to identify umbilical artery. Angle correction was not used when obtaining velocity measurement, because a ratio and not an absolute velocity was the focus of the study. After the velocity waveform was obtained, a caliper was placed at the peak systolic component. A second caliper was placed at the end-diastolic component, and then the S/D ratio was obtained (Fig. 1). The S/D ratio was entered into a computer program along with the fetal measurements.

The patient population data was randomly selected from an obstetric database program. A total of 100 patients were included in the study, 32 with S/D ratios less than 2.0, 37 with S/D ratio between 2.0 and 3.0, and 31 had S/D ratios greater than 3.0.

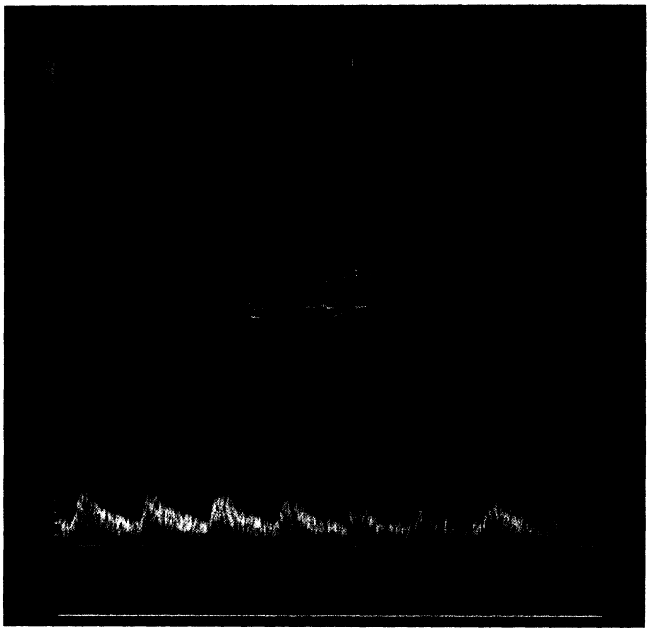

FIG. 1. Pulsed Doppler tracing of umbilical artery showing caliper placement at peak systole and end diastole, to calculate an S/D ratio.

The patients' medical records were reviewed for gestational age at delivery, fetal weight, and Apgar scores. The neonate weights were converted to weight percentiles according to gestational age and Hadlock's sonographic weight standards.[3] By converting weights to percentiles according to their gestational age, it was possible to evaluate the status of the newborns. The well-being of the neonates was determined by their weight percentiles and Apgar scores. Those neonates in the tenth weight percentile or lower were classified as having low birth weights and at risk for adverse outcome.

The collected data were charted to show a comparison between the S/D ratios and the neonates' weight percentiles (Table 1). This direct comparison determined the percentage of low birth weights versus normal birth weights for each of the three S/D categories. Because S/D ratios were known for each patient, the study was also able to determine at what value on the S/D ratio scale there was an increased risk for low birth weight. Hadlock's standards were only carried out to 40 gestational weeks, so the chart was extrapolated to 42 weeks to account for all deliveries.

Analysis of variance was used to compare the neonates' weight percentiles across the three S/D

TABLE 1
Gestational Age at Time of Ultrasound, S/D Ratios, Age at Delivery, and Estimated Weight at Delivery for Study Participants

Patient Information				
Patient	Age at S/D Ratio (wks)	Cord S/D Ratio	Age at Delivery (wks)	Estimated Weight (%)
1	34.7	1.77	40.9	<3
2	38.5	1.78	39.0	<3
3	32.5	1.88	38.4	<3
4	39.2	1.80	41.5	6
5	40.8	1.50	41.4	9
6	38.9	1.80	40.9	9
7	39.4	1.80	39.4	14
8	35.7	1.86	39.6	16
9	38.9	1.70	39.9	23
10	40.3	1.86	41.0	26
11	39.7	1.87	41.4	28
12	37.5	1.80	40.7	33
13	36.3	1.80	37.4	37
14	35.9	1.80	37.3	38
15	38.7	1.77	39.0	40
16	36.9	1.85	39.0	40
17	34.0	1.80	40.1	45
18	41.0	1.70	41.1	48
19	35.8	1.78	40.9	49
20	41.2	1.80	41.7	50
21	40.0	1.80	38.1	54
22	39.0	1.85	41.9	57
23	35.4	1.70	37.7	59
24	38.6	1.80	40.0	66
25	40.3	1.71	41.1	72
26	37.7	1.80	39.0	73
27	37.1	1.80	39.4	85
28	36.2	1.80	38.0	93
29	36.0	1.80	40.0	93
30	40.9	1.77	41.1	94
31	31.4	1.80	36.9	95
32	37.1	1.80	38.0	96
33	37.2	2.30	39.0	<3
34	32.6	2.38	35.3	<3
35	36.0	2.50	40.1	<3
36	31.5	2.58	38.9	<3
37	39.0	2.40	39.7	6
38	37.9	2.70	40.7	9
39	39.0	2.70	39.1	10
40	35.2	2.30	39.0	13
41	38.0	2.34	35.0	16
42	35.8	2.70	39.3	16
43	33.2	2.42	38.4	17
44	35.5	2.50	40.1	17
45	34.7	2.54	38.5	17
46	36.9	2.60	40.3	18
47	36.5	2.47	39.1	19
48	35.4	2.30	38.4	23
49	36.2	2.50	38.6	25
50	32.6	2.30	39.6	26
51	37.9	2.46	40.3	27
52	30.1	2.60	39.7	32
53	32.2	2.55	39.1	38
54	32.3	2.60	39.1	38
55	34.7	2.37	36.4	40
56	36.8	2.33	39.9	41
57	33.8	2.78	39.3	41
58	34.2	2.60	39.1	42
59	36.3	2.30	37.0	43

(*Table continues on p. 62.*)

TABLE 1
Gestational Age at Time of Ultrasound (*continued*)

Patient Information				
Patient	Age at S/D Ratio (wks)	Cord S/D Ratio	Age at Delivery (wks)	Estimated Weight (%)
60	37.2	2.40	39.9	43
61	33.1	2.60	38.0	49
62	30.4	2.57	35.9	53
63	38.8	2.30	41.0	59
64	38.1	2.30	39.0	63
65	38.1	2.67	39.9	69
66	30.2	2.49	38.0	70
67	38.4	2.50	38.5	70
68	34.5	2.50	40.1	91
69	32.4	2.77	38.3	>97
70	34.6	3.13	37.0	<3
71	40.1	3.29	41.4	<3
72	37.1	3.30	37.7	<3
73	35.4	3.30	38.0	<3
74	36.4	3.58	39.9	<3
75	35.6	8.50	35.6	<3
76	32.3	3.21	32.6	3
77	33.2	3.54	37.1	5
78	38.3	4.30	39.1	5
79	32.6	3.26	40.3	7
80	35.0	4.40	36.9	8
81	32.8	3.80	40.7	17
82	32.0	3.13	40.0	18
83	31.7	3.42	36.6	19
84	31.6	3.30	37.3	20
85	32.9	3.20	40.1	22
86	36.5	3.60	40.3	22
87	36.4	3.50	37.3	23
88	32.1	3.30	39.7	28
89	31.8	3.50	39.0	28
90	38.6	4.54	39.9	30
91	31.5	3.26	38.1	35
92	32.8	3.20	38.6	37
93	33.5	3.57	39.0	37
94	32.6	3.21	40.4	39
95	34.6	3.33	40.3	42
96	32.2	3.59	41.1	43
97	34.1	3.16	37.9	47
98	34.6	3.16	37.0	54
99	39.0	3.15	39.4	64
100	33.6	3.90	39.9	92

NOTE. Data are gestational age at the time of ultrasound; S/D Ratio; age at delivery; estimated weight at delivery.

ratio categories. Correlation coefficient analysis was also used to examine the relationship between weight percentiles and S/D ratios.

Results

Patients with S/D ratios greater than 3.0 had the largest percentage of low-birth-weight neonates (35.48%) (Table 2). Of neonates in the 2.0 to 3.0 classification, 18.92% and 18.75% of those with S/D ratios less than 2.0 were classified as low birth weight (Fig. 2).

An interesting finding was the percentage of neonates within the 2.0 S/D ratio category who were above average (>50%) in weight. There were 37.50% neonates in the less than 2.0 classification who were above average in weight. This is compared with 21.62% of the S/D group between 2.0 and 3.0 and only 9.68% of the greater than 3.0 neonates who were above average in weight.

The percentage of neonates born with weights between the 11th and 50th percentile was similar among the three categories. The 2.0 to 3.0 S/D ratio category had 59.46% of neonates delivered in

TABLE 2
Outcomes of Study Participants

	Weight Percentiles at Birth			
S/D Ratios	<10%	11% to 50%	>50%	Total
> 2.0	6 (18.75%)	14 (43.75%)	12 (37.50%)	32 (100%)
2.0 to 3.0	7 (18.92%)	22 (59.46%)	8 (21.62%)	37 (100%)
< 3.0	11 (35.48%)	17 (58.84%)	3 (9.68%)	31 (100%)

this weight percentile range, whereas 54.84% of the neonates in the less than 2.0 group and 43.75% of the greater than 3.0 were between the 11th and 50th percentiles. As would be expected, the group with S/D ratios greater than 3.0 had the most low-birth-weight neonates, the group with S/D ratios less than 2.0 had the most above average weight deliveries, and the 2.0 to 3.0 group had the greatest number of delivery weights between the 11th and 50th percentiles.

The less than 2.0 S/D ratio group had the highest mean weight percentile (mean = 45.5), and the greater than 3.0 S/D ratio group had the lowest mean weight percentile (mean = 26.5). The mean differences were statistically significant ($P = 0.02$ from analysis of variance). The finding of weight percentile decrease when the S/D ratio increased was also supported by the correlation analysis ($r = 0.3$, $P = 0.004$).

In all three categories, the Apgar scores were 7 or above at 5 minutes. Ten subjects had Apgar scores of 5 or below at 1 minute, but a trend correlating S/D ratios and Apgar scores could not be found among these few patients.

Discussion

This study focused on the umbilical cord artery, which transports poorly oxygenated blood from the fetus to the placenta. By evaluating the S/D ratio of an umbilical cord artery, a prediction can be made about the well-being of the fetus, based on the lack of or extent of resistance in blood flow to the placenta.

A careful assessment must be made in determining where and when to obtain the S/D ratio. S/D ratios may have a large variance, depending on the location of the measurement. Those ratios obtained near the cord insertions to the fetus or placenta may reflect the waveform of its origin. A more accurate measurement of cord blood flow should theoretically be obtained in a segment of free-floating cord. When possible, it is best to take the measurement when the fetus is in a resting state. If the fetus is practicing breathing movements, the cardiac cycle can be shortened, resulting in an increased end-diastolic velocity.

The S/D ratio is a relatively angle-independent indicator that quantifies flow velocities. A normal umbilical artery waveform shows a peak in systole with a large amount of end-diastolic flow, indicating decreased placental resistance. An abnormal umbilical artery waveform shows decreased end-diastolic flow, or in severe cases absent or reversed end-diastolic flow, indicating increased placental resistance.

Studies by Friedman et al,[4] Rochelson et al,[5] Skoll et al,[6] Trudinger et al,[7] as well as this study, have shown that increased blood flow resistance to the placenta can lead to adverse outcomes in neonates. This study correlated Doppler measurements of the umbilical cord artery with neonatal birth weights. We found with increased blood resistance (S/D ratio > 3), there was a group of 34.5% who were classified as low birth weight because their birth weights were below the 10th percentile, whereas 94.3% of this population was below average (<50%) in weight. It supports a direct correlation between umbilical artery S/D ratio and low birth weights, where increased blood resistance to the placenta caused a decline of nutrient exchange resulting in an increased number of underweight fetuses.

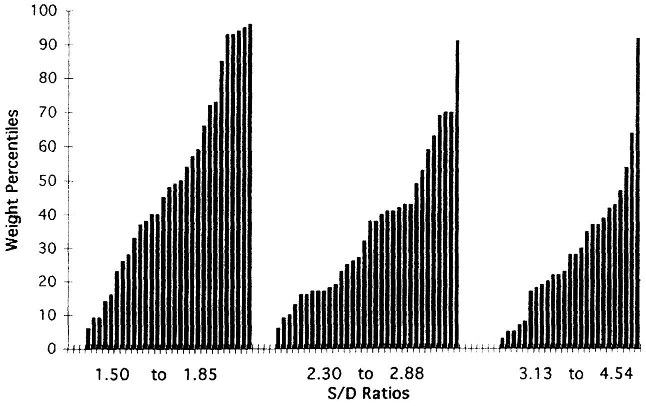

FIG. 2. Weight percentile at birth versus S/D ratio for each study participant.

Because it has been found that an increase in placental resistance can lead to a decrease in birth weight, this study questioned whether a decrease in placental resistance would lead to an increase in birth weight. When the placenta is experiencing little or no resistance an increased blood supply, it provides more nutrients for exchange and thus the possibility for larger neonates. Our findings appear to support this theory, showing a decrease in flow resistance corresponding to an overall increase in neonatal weight. When the S/D ratio was below 2.0, there was a larger population of neonates above the 50th weight percentile.

The weight percentiles for this study were determined using gestational age at birth and Hadlock's weight standards,[3] which poses two separate concerns that need to be addressed. First, Hadlock's chart is based on fetal weight rather than neonatal weight. It is possible that there is a slight variation in weight from the fetal to the neonatal stage. This theoretical difference in weights was not thought to alter any of the results, particularly because all subjects were evaluated by the same criteria. The second concern with using Hadlock's weight standards was that the weight percentiles were only carried out to 40 gestational weeks, and 26% of the population delivered beyond 40 weeks. To account for these subjects, the study extrapolated the weight standards out to 42 weeks. If the fetal weights beyond 42 weeks do not follow the same standards as those between 30 and 40 weeks, the findings may be less accurate.

Conclusion

An S/D ratio measurement should be incorporated into all protocols for obstetric patients greater than 30 gestational weeks. The umbilical cord/artery ratio is an important measurement when taken correctly and can provide valuable information regarding the extent of or lack of placental resistance. The information obtained from this study can assist in the prediction of fetal outcomes. An S/D ratio greater than 3.0 holds an increased risk for low birth weight, and an S/D ratio less than 2.0 usually results in a newborn above average (>50) in weight.

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Answers
SDMS/JDMS CME Test
January/February 1999

1. c	6. b
2. b.	7. d
3. a	8. a
4. d	9. c
5. a	10. a