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Reference ranges for serial measurements of umbilical artery Doppler indices in the second half of pregnancy

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Doppler index
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Objective: The purpose of this study was to construct new reference ranges for serial measurements of commonly used umbilical artery Doppler indices (pulsatility index, resistance index, and systolic:diastolic ratio).

Study design: This was a prospective longitudinal study of the umbilical artery Doppler indices that were obtained serially at the free-loop of umbilical cord at 4-week intervals at 19 to 42 weeks of gestation in 130 low-risk singleton pregnancies. A total of 513 observations were used to construct the reference ranges with the use of multilevel modeling.

Results: Longitudinally established percentiles of Doppler indices from the present study show a continuous reduction throughout the second half of pregnancy without any plateau or increase near term, as reported previously. There was a significant negative association between Doppler indices and placental weight and neonatal birth weight, but not with gender. The intraobserver coefficients of variation for the umbilical artery pulsatility index, resistance index, and systolic:diastolic ratio were 10.5%, 6.8 %, and 13.0 %, respectively.

Conclusion: New reference ranges for umbilical artery Doppler indices that are based on longitudinal observations appear to be slightly different from cross-sectional studies and are more appropriate for serial evaluation of fetal hemodynamics.

Umbilical artery Doppler velocimetry is one of the most rigorously evaluated and frequently used non-invasive tests of fetal well-being. Although not a good screening tool in the low-risk population,[1] it is a valuable investigation in the surveillance of high-risk pregnancies.[2-5] Several Doppler-derived indices have been used in clinical practice to identify fetuses who are at risk of increased perinatal death and morbidity that may benefit from closer surveillance or elective delivery. Among them umbilical artery pulsatility index (PI), resistance index (RI), and systolic:diastolic (S:D) ratio are used most commonly. The clinical potential of such a tool depends on the availability of suitable reference

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Table I Baseline characteristics of the study population

Parameter	Measure
Maternal	
Age (median, range)	30 Y (18-43 Y)
Nulliparous (n)	60 (46%)
Body mass index at booking (mean ± SD)	25.81 ± 3.98 kg/m^2
Fetal	
Gestational age at delivery (mean ± SD)	39.8 ± 1.36 wk
Birth weight (median, range)	3665 g (1645-4590 g)
Placental weight (mean ± SD)	673 ± 145 g
Umbilical arterial pH (mean ± SD)	7.23 ± 0.148
Umbilical arterial base excess (mean ± SD)	−4.18 ± 3.507 mmol/L
Umbilical venous pH (mean ± SD)	7.33 ± 0.084
Umbilical venous base excess (mean ± SD)	−4.63 ± 3.572 mmol/L

ranges. Several reference ranges of these waveform indices have been published. However, the studies with an adequate number of observations are cross-sectional[6-8] and mostly use routinely collected clinical data.[9,10]

For serial measurements, appropriate reference ranges must be derived from longitudinal studies rather than cross-sectional studies. However, the few longitudinal studies that have been published in the English language are small[11-14] or use continuous wave Doppler imaging without any knowledge of site or angle of insonation[15,16] and the data are mostly analyzed and presented as if they were derived from a cross-sectional study.

The aim of this study was to establish reference ranges for serial measurements of the umbilical artery Doppler indices in the second half of pregnancy based on longitudinal data. In addition, we wanted to examine the effect of neonatal weight, gender, and placental weight on the Doppler indices.

Material and methods

This was a longitudinal study of 130 low-risk pregnancies that were recruited for a detailed study of the umbilical circulation according to a research protocol approved by the Regional Committee for Medical Research Ethics; written informed consent was obtained from all participants.

Inclusion criteria were gestational age confirmed by ultrasound measurement of <20 weeks and no complications in the current pregnancy before recruitment. Maternal smoking, multiple pregnancy, a diagnosed fetal abnormality before recruitment, previous history of preeclampsia, intrauterine growth retardation, abruptio placenta or preterm delivery, and history of any pre-existing medical condition (such as hypertension, diabetes mellitus, renal disease) were reasons for not being included. Each woman was examined 3 to 5 times at approximately 4-week intervals between 19 and 42 gestational weeks.

Doppler ultrasonography was performed with an ultrasound system with a 2.5- to 6-MHz curvilinear transducer (Sequoia 512; Acuson; Mountain View, Calif). A single operator (G.A.) performed all examinations. Color Doppler imaging was used to optimize the insonation by the pulsed Doppler examination. The angle of insonation was kept at <15 degrees in all cases, and angle correction was used if the angle was not zero. The high-pass filter was set at minimum, and a large sample volume (10-12 mm) was used for the pulsed Doppler recording. The Doppler velocity waveforms were obtained from the free-floating loop of the umbilical cord during fetal quiescence. Five to 6 uniform waveforms were obtained ≥ 3 times in succession, and online measurements were performed. The values that were recorded were an average of 3 consecutive cardiac cycles. 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. The guidelines of the International Perinatal Doppler Society[17] were followed during Doppler sonographic examinations. The mechanical index was kept at <1.9, and the thermal index was kept at <1.5. 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[18]

RI = (Peak systolic velocity−end-diastolic velocity)/peak systolic velocity[19]

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

The outcome of pregnancy was noted and included any complications, gestation at delivery, mode of delivery, neonatal birth weight, sex, Apgar score, umbilical cord blood gases, perinatal complications, and placental weight. All the placentas were collected immediately after delivery and inspected for completeness and any gross abnormalities. The umbilical cord was cut flush with the placental surface, but the membranes were not trimmed. Blood was allowed to drain from the placenta, and the clots were removed. The placenta was weighed on a precision balance by the midwife shortly after delivery. A pediatrician routinely examined the newborn infants on the third postnatal day and noted any abnormalities, if present.

Data analysis was performed with SAS software (version 8.2; SAS Institute Inc, Cary, NC). Normality was checked for each outcome variable, and logarithmic