

## OBSTETRICS

# Umbilical venous flow rate in term fetuses: can variations in flow predict intrapartum compromise?

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**OBJECTIVE:** The objective of the study was to investigate the distribution of umbilical venous flow rates, measured in early labor, in a cohort of normal term pregnancies and to establish the relationship between umbilical venous flow and subsequent intrapartum outcome.

**STUDY DESIGN:** Five hundred eighty-nine women with uncomplicated, term, singleton pregnancies were recruited to this prospective observational study prior to active labor (dilation of 4 cm or less) at Queen Charlotte's and Chelsea Hospital (London, UK). All participants underwent an ultrasound examination, during which fetal biometry, umbilical venous flow velocity, and umbilical vein diameter were recorded. Umbilical venous flow rate was then calculated. Following delivery, intrapartum and neonatal outcomes were correlated with the ultrasound findings. Cases were subdivided according to mode of delivery, and mean umbilical venous flow rates were compared between the groups. Cases were also subdivided according to umbilical venous flow rate (less than the 20th centile, 20th-80th centile, and

greater than the 80th centile), and the incidence of diagnoses of fetal compromise was compared.

**RESULTS:** Fetuses delivered by emergency cesarean for presumed fetal compromise had the lowest umbilical venous flow rates (both corrected for and uncorrected for birthweight) ( $P = .02$  and  $P = .001$ , respectively). Fetuses with the lowest umbilical venous flow rates were significantly more likely to require emergency cesarean for presumed fetal compromise than those with the highest flow rates (15.7% vs 5.6%, relative risk, 2.83; 95% confidence interval, 1.16–6.91).

**CONCLUSION:** Fetuses with the lowest umbilical venous flow rates are at increased risk of a subsequent diagnosis of intrapartum fetal compromise. Measurement of umbilical venous flow could contribute to the risk stratification of pregnancies prior to labor.

**Key words:** fetal compromise, fetal Doppler, labor, umbilical venous flow

Cite this article as: Prior T, Mullins E, Bennett P, et al. Umbilical venous flow rate in term fetuses: can variations in flow predict intrapartum compromise? *Am J Obstet Gynecol* 2014;210:61.e1-8.

Adequate umbilical venous blood flow delivering oxygen and nutrients is essential to support the fetus within the uterine environment. The rate of umbilical venous flow may be considered a direct measure of the delivery of nutrients to the fetus by the placenta, a relationship that is tested to the highest degree in the intrapartum period because fetoplacental blood flow is compromised during periods of uterine contraction.

Despite being first measured in the 1980s,<sup>1</sup> the clinical utility of umbilical venous flow measurement is yet to be established. Studies of umbilical venous flow have demonstrated reduced flow rates in growth-restricted fetuses.<sup>1,2</sup> It is suggested that in cases of growth restriction, umbilical venous flow is reduced prior to changes in umbilical artery resistance.<sup>3</sup> Furthermore, abnormalities in umbilical venous flow have been

associated with an increased incidence of operative delivery for fetal compromise.<sup>4</sup>

The widespread use of electronic fetal heart rate monitoring (EFM) over the last 3 decades has not led to a reduction in the incidence of cerebral palsy<sup>5</sup> but has been associated with a rise in the number of operative deliveries performed.<sup>6</sup> This possibly is due to the poor positive predictive value of EFM for true fetal compromise. Currently, between 8% and 25% of cases of neonatal encephalopathy are believed to be due to intrapartum hypoxia.<sup>7-9</sup> Better identification of fetuses at risk of intrapartum compromise would allow a more targeted approach to intrapartum monitoring as well as allowing more informed decisions to be made regarding place and mode of delivery.

To our knowledge, no studies to date have investigated the value of umbilical venous flow rate, in normal, appropriately grown term pregnancies, as a predictor of a subsequent diagnosis of fetal compromise in labor. As in other studies of fetal hemodynamics, a

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Received June 4, 2013; revised Aug. 5, 2013; accepted Aug. 28, 2013.

T.P. was supported by Moonbeam Trust (Charity number 1110691). All authors were supported by the Imperial College Healthcare National Health Service Trust comprehensive Biomedical Research Centre scheme.

The authors report no conflict of interest.

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0002-9378/\$36.00 • © 2014 Mosby, Inc. All rights reserved. • <http://dx.doi.org/10.1016/j.ajog.2013.08.042>

significant proportion of studies of umbilical venous flow have taken place in cohorts of fetuses known to be growth restricted.

There is very little similar information available from appropriately grown fetuses. In this prospective observational study, we investigated the distribution of umbilical venous flow rates in a cohort of normal, appropriately grown, fetuses at term and correlated the umbilical venous flow rate with intrapartum and neonatal outcomes. We hypothesized that appropriately grown fetuses, with the lowest umbilical venous flow rates, would be at increased risk of a diagnosis of intrapartum fetal compromise and subsequent emergency delivery.

## MATERIALS AND METHODS

This was a prospective observational study based at Queen Charlotte's and Chelsea hospitals (London, UK). All women booked with low-risk pregnancies (those with no maternal or fetal concerns identified in the antenatal period), presenting in early labor, and likely to deliver within 72 hours were considered eligible for inclusion. Early labor was defined as regular, painful contractions associated with cervical effacement and/or dilatation up to and including 4 cm.

Exclusion criteria were multiple pregnancy, known fetal growth restriction/pre-eclampsia, known fetal anomaly, cervical dilatation greater than 4 cm, and ruptured membranes with meconium stained liquor. Women were recruited from the delivery suite and day assessment unit over a 2 year period. Each patient gave written consent for inclusion in the study. Patient demographics such as age, ethnicity, and parity were recorded.

Women then underwent an ultrasound assessment in which fetal biometry (head circumference, biparietal diameter, abdominal circumference, femur length) and umbilical venous Doppler were assessed. All ultrasound scans were performed by a single operator using a Voluson e machine (GE Healthcare, Buckinghamshire, UK), and a trans-abdominal curvilinear transducer (AB2-7-RS). Participants were asked to lie in a supine position, with a slight left lateral tilt to avoid caval compression.

For Doppler assessment, the umbilical vein was imaged at a free loop, and pulsed wave Doppler was used to obtain umbilical vein flow velocities. Time-averaged maximum velocities were recorded, which are reported to show good correlation with actual mean flow velocities in experimental models.<sup>10</sup> The angle of insonation was maintained as close to 0 degrees as possible, and always less than 30 degrees, to ensure accurate assessment of flow velocities. The angle correction function was used when any flow velocities were measured at an angle other than 0 degrees. The umbilical vein was then imaged at a free loop, in gray-scale and in longitudinal section, with the umbilical vein perpendicular to the ultrasound beam. The image was magnified and the internal diameter of the vein measured.

All readings were taken between uterine contractions and were repeated 3 times, with the mean value being used for data analysis. An estimated fetal weight was calculated from fetal biometry using the formula of Hadlock et al.<sup>11</sup>

The umbilical vein flow velocity and umbilical vein diameter were then used to calculate umbilical venous flow rate. For this calculation, the umbilical vein was considered a cylindrical vessel and assumed to have laminar flow. The following formula was used for calculation: umbilical venous flow rate (milliliters per minute) = velocity (centimeters per second)  $\times$  0.3  $\times$  cross-sectional area (square millimeters)

Derivation of the formula is presented in the [Appendix](#).

Doppler assessment of umbilical venous flow rate has been demonstrated to be accurate when compared with the gold standard methods of in vivo flow calculation.<sup>12</sup>

Cases were then managed according to local protocols and guidelines. Staff managing the labor were blinded to the results of the ultrasound scan to ensure that the ultrasound findings did not affect obstetric management.

Power calculations, based on data from a pilot study of 100 cases, suggested a power of 0.8 (to detect a difference in incidence of cesarean section for presumed fetal compromise between fetuses with the lowest and highest umbilical

venous flow rates of 0.15) could be achieved with a sample size of 500 cases.

Following delivery, patient notes and electronic records were reviewed and intrapartum and neonatal outcome details recorded. Cases were subcategorized according to the mode of delivery and corrected umbilical venous flow rate (milliliters per minute per kilogram). Intrapartum cardiotocograph (CTG) recordings were analyzed and classified by an obstetrician blinded to the ultrasound scan results as normal, suspicious, or pathological, based on the National Institutes of Health and clinical excellence guidelines.<sup>13</sup> This is a nationally used classification of electronic fetal heart rate tracings. A diagnosis of intrapartum fetal compromise, and the basis for a delivery performed for this indication, was a pathological CTG or a suspicious CTG combined with a pH less than 7.20 from intrapartum fetal blood sampling.

Ethical approval for this study was granted by the North London Research Ethics Committee (reference number REC 10/H0718/26).

## RESULTS

Five hundred eighty-nine women were recruited to the study over a 2 year period from February 2011 to February 2013. Patient demographics are shown in [Table 1](#). The median interval between the ultrasound scan and delivery was 1 day (range, 0–14). Ninety-six percent of women delivered within 72 hours of the ultrasound scan taking place.

Umbilical venous flow was non-normally distributed in the study population (Kolmogorov-Smirnov, 0.02). The median umbilical venous flow rate in the study population was 213.6 mL/min and the interquartile range was 74.19 mL/min. Umbilical venous flow rate was found to be positively correlated with birthweight ( $R^2 = 0.19$ ) but was not correlated with gestation ( $R^2 = 0.00$ ) in our cohort. Therefore, umbilical venous flow rates in this study are reported as raw values as well as following correction for birthweight. Corrected umbilical venous flow rate also had a nonnormal distribution in the study population (Kolmogorov-Smirnov, 0.01). The median corrected umbilical venous flow rate was 61.1 mL/min per

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