Elevated uterine activity increases the risk of fetal acidosis at birth

P. C. A. M. Bakker, MD; P. H. J. Kurver, MSc; D. J. Kuik, MSc; H. P. Van Geijn, MD, PhD

**OBJECTIVE:** The objective of the study was to assess the role of uterine activity on fetal outcome.

**STUDY DESIGN:** Intrauterine pressure (IUP) recordings from consecutive term singleton, vaginal deliveries collected between June 1, 1993, and July 1, 2004, were analyzed. One thousand four hundred thirty-three recordings were included. IUP data were obtained using HP 8040A and HP M1350 cardiotocographs. For each recording the uterine contraction curve was analyzed, and the following contraction parameters were determined: relaxation time; contraction duration, frequency, amplitude, and surface; Montevideo units; and active planimeter units and contraction frequency. IUP recordings and contraction parameters from deliveries ending with an umbilical artery pH of 7.11 or less were compared with those ending with an umbilical artery pH of 7.12 or greater. Statistical analyses were performed using Student's *t* test and logistic regression.

**RESULTS:** An umbilical artery pH 7.11 or less at birth is associated with significant more uterine activity during the first and second stage of labor.

**CONCLUSION:** Increased uterine activity is significantly associated with a higher incidence of an umbilical artery pH of 7.11 or less.

**Key words:** intrauterine pressure recording, umbilical artery pH, uterine activity

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The standard assessment of the fetal condition during labor and delivery is by means of cardiotocography, also named electronic fetal heart rate monitoring (EFM). EFM enables the obtaining of tracings of the fetal heart rate (FHR) and the uterine contraction curve using 2 methods: external or internal monitoring. With both methods a cardiotocogram (CTG) is obtained for further reading and interpretation.

In spite of its widespread use, EFM is surrounded by controversy. The source of the controversy lies in its limitations. Definitions of FHR patterns are not standardized, which leads to poor reliability of FHR interpretation and results in an increased incidence of obstetric interventions without a significant improvement in fetal outcome. The only clinically significant benefit from the use of continuous EFM has been reduction in the incidence of neonatal seizures.

The discussion of how to read and interpret cardiotocograms is nearly restricted to the FHR patterns. The influence of uterine activity (UA) on the fetal condition is scarcely addressed in literature. Even international guidelines on cardiotocography mention UA summarily or not at all. Freeman et al. and Shenker are among the few authors who suggest that UA may have an effect on the fetus, which is reflected in the FHR pattern as decreased variability, delayed (late) decelerations, or prolonged decelerations. Whereas Freeman et al. mention the importance of the relaxation time, solely based on clinical experience, Shenker states that excessive UA is the most frequent cause of late decelerations.

The purpose of the current study was to determine how UA affects fetal outcome. Cardiotocographic data obtained during labor applying internal UA monitoring were analyzed and compared with the infants’ umbilical artery pH at birth.

**MATERIALS AND METHODS**

Recordings were from consecutive singleton, vaginal deliveries at term in the VU University Medical Center in Amsterdam, The Netherlands, June 1, 1993, until July 1, 2004. All cases with intrauterine pressure (IUP) monitoring (n = 2886) were included for further analysis. An IUP catheter was indicated if labor was induced or augmented and in cases of prolonged labor. Occasionally adequate contraction monitoring was not possible (eg, because of maternal obesity or lateral position and external monitoring had to be replaced by IUP monitoring). The study profile is presented in the Figure, and the study demographics are presented in Table 1. Exclusion took place for the following reasons: IUP monitoring in the first stage of labor was shorter than 1 hour (n = 216), ended more than 15 minutes before delivery of the infant (n = 284), or was not performed during the second stage of labor (n = 65). In 511 cases IUP was either inadequately calibrated (n = 289) or the IUP catheter was not correctly applied (n = 222).
With regard to the umbilical cord blood gases, 377 cases were excluded. Reasons for exclusion were: (1) the difference between umbilical arterial pH and venous pH was less than 0.03 units, suggesting that the same vessel (vein or artery) had been sampled twice; (2) samples were clotted; or (3) the result from the artery or vein was lacking. Finally, the database consisted of 1433 recordings.

Intrauterine tocography data were obtained using HP 8040A and HP M1350 cardiotocographs (Hewlett Packard, Boblingen, Germany). An open-end, fluid-filled intrauterine pressure catheter was used (intrauterine pressure monitoring kit with amnio port/lumen, Utah Medical Products, Midvale, UT). Before insertion, the IUP catheter is filled with saline infusion fluid. The catheter is inserted into the uterus through the applicator and flushed to remove air bubbles. Next, calibration is done on atmospheric pressure. Incorrect IUP reveals itself in the pressure curve as a flat line (IUP not correctly applied) or a baseline tone below the 0 mm Hg line (inadequate calibration).

The CTGs are sampled for the FHR with a frequency of 4 Hz and the uterine pressure at 2 Hz. The status (pen on, pen off) and the mode of the signals (ultrasound/direct fetal electrocardiogram, external/internal pressure) are acquired.

The raw signals in combination with data from mother, fetus, and newborn infant are stored on a network server with the MOSOS centralized monitoring system (BMA Co, Woerclen, The Netherlands). To analyze the signals (tocogram), a special program has been developed written in Fortran IV (P.H.J.K.). This program detects contractions automatically as changes in the uterine pressure curve and distinguishes between artifacts and real contractions. The raw signal (uterine pressure curve) passes a digital band-pass filter followed by a level-crossing technique in the first derivative analyses the uterine contraction curve. On the basis of this contraction detection program, the following parameters for each separate contraction are evaluated: relaxation time, contraction duration, contraction amplitude, and contraction surface. Montevideo units, active planimeter units, and contraction frequency are calculated over a 10 minute period (Table 2). Parameters are computed for each contraction or 10 minute periods for the last hour of the first stage and the entire second stage of labor until the birth of the infant.

Starting time of the second stage was determined by the time written down in the patients’ chart and had to correspond with the start of active pushing visible on the uterine contraction curve. The average duration of the second stage was 37.6 minutes in the acidotic group and 33.5 minutes in the nonacidotic group. For each recording the average and cumulative contraction parameter values were calculated. Because MU, AP, and contraction frequency are already averaged parameters, only mean values have been computed.

Umbilical cord blood gases were routinely collected according to a standardized protocol. Immediately after birth, a segment (10-30 cm) of the umbilical cord is double clamped. The first clamp is placed about 20 cm from the umbilicus and the second near the umbilicus. Samples from the umbilical vein and arteries are drawn in 1 ml dry, nonheparinized, polyethylene syringes and measured with a Rappidlab 840 (Bayer, Germany).
or a Corning 248 (Bayer, Leverkusen, Germany). This machine performs a full blood gas analysis: pH, pCO₂, and pO₂.

Fetal acidosis was considered an umbilical artery pH of 7.11 or less on the basis of the review of 14 studies by Vandenbussche et al. Further classification of the study group was performed according to the definitions by Goodwin et al. Metabolic acidosis was defined as pCO₂ greater than 65 mm Hg and base deficit less than 10 mmol/L. Mixed acidosis was defined as pCO₂ greater than 65 mm Hg and base deficit of 10 mmol/L or greater. The base deficit of blood has been used to determine the different forms of acidosis. It is calculated from the following equation: BD (blood) = (1 - 0.014 × concentration total hemoglobin [ctHb]) [(cHCO₃⁻ - 24.8) + (1.43 × ctHb + 7.7) (pH - 7.40)].

Comparison of contraction parameters during the first and second stage of labor were analyzed by univariate analysis. Statistical analyses were performed with the Student’s t test. Results are presented as means and SDs. The tests were considered statistically significant when P < .05 for a 2-tailed test. To investigate interrelations of the parameters, stepwise logistic regression was performed for 2 models: with and without correction for confounders.

**Results**

Increased uterine activity during the first and second stage of labor is associated with an increased incidence of lower pH values in the umbilical artery (Table 3).

In the first stage of labor, this holds for all contraction parameters. The acidotic group in comparison with the nonacidotic group has a shorter relaxation time and vice versa a longer duration, higher amplitude, and an increased surface of the contractions. The same holds true for the Montevideo units, active planimeter units, and contraction frequency.

Comparison of contraction parameters in the second stage of labor again shows more UA in the group with an unfavorable umbilical artery pH. Although not all differences are significant, results demonstrate a similar tendency as in the first stage of labor. The Montevideo units, active planimeter units, and contraction frequency are significantly increased in the acidotic group.

Logistic regression demonstrates that 4 of the contraction parameters predict an adverse umbilical artery pH best: high cumulative values for first-stage contraction amplitude and surface and a high contraction frequency during the first and second stage of labor. After correction for confounders in the second logistic regression model, a high cumulative first-stage contraction surface and an in-

### TABLE 2

**Definition of contraction parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relaxation time</td>
<td>Time in seconds between the end of a contraction and the beginning of the next contraction</td>
</tr>
<tr>
<td>Contraction duration</td>
<td>Time in seconds between onset and offset of a contraction</td>
</tr>
<tr>
<td>Contraction amplitude</td>
<td>Maximum uterine pressure above basal tone, mm Hg</td>
</tr>
<tr>
<td>Contraction surface</td>
<td>Surface underneath the contraction, compared with the basal tone between onset and offset of the contraction, mm Hg × seconds</td>
</tr>
<tr>
<td>Montevideo units⁶</td>
<td>Average of the intensities of all contractions × the frequency of the contractions in a 10-minute period</td>
</tr>
<tr>
<td>Active planimeter units⁶</td>
<td>Area under the active pressure curve in a 10-minute period</td>
</tr>
<tr>
<td>Contraction frequency</td>
<td>Number of contractions in a 10-minute period</td>
</tr>
</tbody>
</table>
creased first stage contraction frequency persist.

The average umbilical artery pH in the nonacidoic group was 7.24 with a maximum of 7.41. Base deficit and PCO$_2$ were 5.6 mmol/L and 53.6 mm Hg, respectively. In the acidotic group, the average pH was 7.07 with a minimum pH of 6.89. The average base deficit value was 11.4 mmol/L, the average PCO$_2$ 70.8 mm Hg (Table 1). Thirty-nine percent of these fetuses had respiratory acidosis, 31% mixed acidosis, and 30% metabolic acidosis. A subanalysis demonstrated that there was no difference in uterine activity between those groups.

**COMMENT**

The current study demonstrates that increased uterine activity is significantly associated with a higher incidence of an umbilical artery pH of 7.11 or less.

The choice for this pH value as a threshold for fetal acidosis is based on the review article of 14 studies by Vandenburgsche et al.$^8$ In this review the mean values and the lower limits of statistical normality for arterial cord pH are presented, as reported in the literature. Deriving from this literature ordering of arterial cord blood pH in three categories is recommended: (1) pH greater than 7.11 as normal, (2) borderline if pH is between 7.11 and 6.99, and (3) abnormal if pH is below 6.99. This classification is supported by statistical and physiological evidence.$^5$ Yet the threshold for associated acidemia might be higher. Recent published literature demonstrates that even a small decrease in umbilical cord blood gas pH values is associated with decreased 5-minute Apgar scores, an increased incidence of neonatal intensive care unit admissions and more frequent assisted ventilation.$^{10}$ The clinical implication of this acidosis also depends on whether acidosis is mixed, metabolic, or respiratory. Clinical concerns are much greater with a severe metabolic and mixed acidosis caused by hypoxia during labor than with a pure respiratory acidemia caused by carbon dioxide accumulation. Unfortunately, there is still no universal agreement on the definitions for different forms of umbilical cord blood acidemia.$^{11,12}$

There is physiological evidence for uterine activity induced fetal acidosis at birth. When contractions occur and they exceed 30 mm Hg, the maternal spiral arteries are compressed and placental perfusion is strangled.$^6,13,14$ In labor, mean uterine pressure is 85-90 mm Hg. Maternal pushing causes elevations of IUP, contributing to further compression of maternal spiral arteries.$^6$ Blood

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**TABLE 3**

Umbilical artery pH (means ± SD) in relation to the contraction parameters for the last hour of the first and the full second stage of labor

<table>
<thead>
<tr>
<th>Umbilical artery pH</th>
<th>First stage</th>
<th>Second stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤7.11 n = 77</td>
<td>≥7.12 n = 1356</td>
</tr>
<tr>
<td>Relaxation time (sec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative</td>
<td>1261 (398)</td>
<td>1402 (547)</td>
</tr>
<tr>
<td>Average</td>
<td>51 (23)</td>
<td>63 (35)</td>
</tr>
<tr>
<td>Contraction duration (sec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative</td>
<td>2216 (449)</td>
<td>2053 (500)</td>
</tr>
<tr>
<td>Average</td>
<td>87 (9)</td>
<td>87 (10)</td>
</tr>
<tr>
<td>Contraction amplitude (mm Hg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative</td>
<td>1383 (544)</td>
<td>1178 (501)</td>
</tr>
<tr>
<td>Average</td>
<td>54 (16)</td>
<td>51 (19)</td>
</tr>
<tr>
<td>Contraction surface (mm Hg × sec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative*</td>
<td>479 (164)</td>
<td>418 (154)</td>
</tr>
<tr>
<td>Average</td>
<td>1875 (555)</td>
<td>1798 (600)</td>
</tr>
<tr>
<td>Montevideo units*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>261 (86)</td>
<td>236 (97)</td>
</tr>
<tr>
<td>Active planimeter units*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>9014 (2461)</td>
<td>8379 (2740)</td>
</tr>
<tr>
<td>Contraction frequency per 10 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>5.0 (0.7)</td>
<td>4.8 (0.7)</td>
</tr>
</tbody>
</table>

* Divided by 100.

Bolding signifies significant difference between both groups.
flow in compressed spiral arteries is decreased. However, it remains unclear whether oxygen transfer to the fetus is interrupted. There is controversy in literature concerning fetal oxygenation saturation during uterine contractions. McNamara and Johnson found the greatest drop in saturation 92 seconds after the peak of a contraction. Complete recovery occurs after 90 seconds. On the contrary, East et al concluded that fetal oxygen saturation was unaffected by uterine contractions. It is noteworthy that both studies analyzed only a limited number of cases, 18 and 17 cases, respectively.

Excessive UA, by means of hyperstimulation and tachysystole, shortens the relaxation time. This results in higher levels of cerebral deoxygenated hemoglobin, lower levels of oxygenated hemoglobin, and decreased intracerebral saturation. In case of tachysystole, intracerebral saturation can be down to 18%, whereas in normal labor, the mean saturation level drops much less, namely to 54%. The acidotic group in our study had a significantly higher contraction frequency in the first and second stage of labor than the group with a normal umbilical artery pH.

The importance of excessive uterine activity and relaxation time has been acknowledged by other authors as well. However, the primary goal of these studies was not so much to determine the effect of UA on fetal outcome as to determine the influence of UA on the progress of labor. Gee and Beazley found that in patients with fetal distress, UA was more than 2 SD above average. In these cases surprisingly, uterine hyperactivity had not been suspected by the attendant medical staff.

In 1987 Bidgood and Steer examined the rise in uterine activity integral (UAI), representing the mean amplitude and frequency of contractions for a 15 minute window, in response to oxytocin intravenously. They found a logarithmic dose-response relation. However, contraction frequency will double at the expense of the contraction amplitude if the UAI exceeds 1200 kPa per 15 minutes. They consider this an undesirable situation because doubling of frequency may mean less recovery time for fetal oxygenation. Therefore, active management of labor for women undergoing labor induction or augmentation should be used with caution.

In both the acidic and nonacidotic group, approximately 75% of deliveries was augmented or induced. This overrepresentation of labor induction and augmentation relates to oxytocin use as the primary indication for IUP catheter usage. The relation between uterine activity and fetal acidosis holds true for both the first and second stage of labor. This relationship appears to be less strong for the second stage of labor than the first stage. This is, though, the consequence of a shorter period of analyzed contractions in the second stage of labor (33-37 minutes) than in the first stage of labor (60 minutes). The SD and with that the levels of significance are highly influenced by this difference of duration.

The current study has quantified UA parameters of the last hour of the first stage and the complete second stage. This choice is based on research by others. Low et al performed a matched case-control study to determine the predictive value of FHR variables for fetal asphyxia during labor. FHR variables started to discriminate between the asphyxiated and control group during the last 2 hours prior to delivery. Williams and Galerneau showed a narrow 1-hour window in which FHR patterns predict fetal asphyxia/acidosis. The primary goal of our study was to determine whether and how UA affects fetal outcome. We did not perform an extensive analysis on the FHR pattern. However, a subanalysis to establish the incidence of decelerations was performed. In contrast to the results of Shenker, who found more late decelerations in cases of excessive UA, we found no significant difference between the 2 groups!

Analysis of the contraction parameters was performed in case a fluid-filled catheter had been applied. In The Netherlands, the IUP catheter is applied to approximately 20% of deliveries, whereas in the United States, this technique is no longer utilized. However, it is an inadequate method. Deveoe et al and Arulkumaran et al demonstrated that the open fluid-filled catheter detects UA just as well as the electronic microtip.

It is distressing that most international guidelines lack information concerning UA. The evidence-based clinical guideline on EFM by the Royal College of Obstetricians and Gynaecologists does not mention UA at all. The American College of Obstetricians and Gynaecologists likewise provides guidelines for monitoring, interpretation, and management on FHR patterns and none on UA. The International Federation of Gynaecology and Obstetrics gives some attention to the subject of UA. They mention only the contraction frequency. A contraction rate of more than 4 per 10 minutes is considered ominous, leading to insufficient time for placental perfusion and iatrogenic fetal distress. This cut-off value for the contraction frequency is not substantiated by any research.

In discussions on the benefits of EFM, uterine contraction monitoring generally is ignored. On the basis of the results from the current study, it is obvious that contraction monitoring deserves full attention. Elevated UA during the first and second stage of labor increases the risk of adverse fetal outcome. Adequate reading and interpretation of the uterine contraction curve can be one solution to the FHR monitoring debate and may reduce the number of unnecessary obstetric interventions. Uterine activity monitoring deserves a more prominent role in daily obstetric practice.

ACKNOWLEDGMENT
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REFERENCES