Outcomes among term infants when two-hour postnatal pH is compared with pH at delivery

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OBJECTIVE: This study was undertaken to measure infant outcomes when pH at birth was compared with neonatal pH determined within 2 hours of age.

STUDY DESIGN: We retrospectively studied term infants born between January 1, 1988, and August 31, 1998, who had umbilical artery blood pH measured at birth and again from the radial artery or umbilical artery within 2 hours after birth. Statistical significance was determined with the χ² test. Odds ratios and 95% confidence intervals were calculated by means of the Mantel-Haenszel method.

RESULTS: Data from a total of 1691 infants were analyzed: 178 (11%) had acidemia at birth (pH of <7.20) that persisted through the first 2 hours after birth; 110 (6%) had development of acidemia after birth; and 594 (35%) were born with a cord pH of <7.20 that improved after delivery. The remaining 809 infants (48%) did not have acidemia either at birth or during the neonatal period, and these served as the reference group. Seizures during the first 24 hours after birth were more likely among those infants with persistent acidemia (odds ratio, 13.0; 95% confidence interval, 6.3-26.7). The odds ratio for seizures among infants in whom acidemia developed after birth was 5.7 (95% confidence interval, 2.2-14.5). Other than the reference group, the infants who were born with acidemia that was corrected by 2 hours after birth had the lowest risk of seizures (odds ratio, 2.5; 95% confidence interval, 1.2-5.3). Significant differences in neonatal outcomes persisted after correction for anomalies.

CONCLUSION: The direction of pH change from birth to the immediate neonatal period was significantly related to morbidity and mortality among term infants who were ill at birth or became ill shortly thereafter. (Am J Obstet Gynecol 2001;184:447-50.)

Key words: Acidemia, perinatal morbidity, perinatal mortality

Umbilical cord blood pH analysis has become a commonly used measure of infant condition at birth and has been linked to subsequent outcome.1,2 Although there is substantial literature concerning fetal acidemia measured in umbilical cord blood, and it has long been assumed that pH may deteriorate during the neonatal period, there is no current information on the correlation of umbilical artery pH measured at birth with pH values obtained during the ensuing first hours after birth. Indeed, the only English language report we could find was published in 1958 and included only 7 infants with paired delivery and neonatal pH values measured within 3 hours of birth.3 The authors concluded that these infants were subjected to hypoxia, carbon dioxide retention, and acidemia during parturition, which receded rapidly after birth. In no instance did acidemia (defined as a pH value of <7.20) develop in a neonate during the first hours after delivery.3

The purpose of our investigation was to compare pH at delivery with pH measured within 2 hours after birth and to correlate the direction of pH change with markers of perinatal morbidity and mortality among infants born at term. Preterm infants were excluded from this analysis, because the outcomes in these infants were likely to be influenced not only by condition at birth but also by immaturity.

Material and methods

Umbilical artery blood is obtained for acid-base analysis from all live births at our hospital. From January 1, 1988, to August 31, 1998, there were 153,462 live births at Parkland Memorial Hospital, Dallas, and 5465 (3.6%) of these infants also had radial artery or
umbilical artery blood obtained for blood gas analysis within 2 hours after delivery. A total of 1691 of these infants were delivered at term (≥37 weeks’ gestation) and had development of respiratory symptoms during the immediate neonatal period that led to blood gas analysis.

Umbilical artery blood samples were drawn from a doubly clamped segment of cord into heparinized 3-mL plastic syringes, and these specimens were placed in ice for transport to the hospital laboratory. Blood gas analysis was immediately performed. The Corning Biomedical 278 and 288 (Corning Incorporated, Corning, NY); the Nova Biomedical Stat profile 5 and 9 (Nova Biomedical, Waltham, Mass); and the Radiometer ABL 620 (Radiometer America Inc, Westlake, Ohio) were used for blood gas analysis. Similar methods were used for blood gas analysis during the neonatal period. All the blood gas results were entered into a computer and linked into an on-line perinatal database that contained obstetric and neonatal information for all births during the study period.

Categoric data were analyzed with the $\chi^2$ test. Comparisons were performed with a reference group of infants who never had acidemia according to either umbilical artery or neonatal blood gas analysis. Odds ratios and 95% confidence intervals were calculated by means of the Mantel-Haenszel method.

Results

The 1691 term infants with paired delivery and neonatal blood gas analyses included 36 twins (2%) and 77 singleton breech presentations (5%). Fifty-seven percent of the infants (n = 959) were male. Fifty-two percent of the mothers were Hispanic, 32% were black, and 14% were white. Forty-seven percent of the mothers were nulliparous, and the mean (±SD) maternal age was 24 ± 6 years.

As shown in Fig 1, the infants with acidemia were divided into groups A through C according to the direction of pH change after birth. Group A included 178 infants (11%) born with a pH of <7.20 and in whom pH remained at <7.20 within 2 hours after delivery. Group B included 110 infants (6%) born with a pH of ≥7.20 but in whom pH decreased to <7.20 during the immediate neonatal period. Group C comprised 594 infants (35%) who had a pH of <7.20 at birth but in whom pH had increased to ≥7.20 by 2 hours after birth. Infants who had pH values that were ≥7.20 at birth and remained so during the early neonatal period were selected for the reference group (n = 819; 48%).

Shown in Table I are intrapartum complications according to the direction of pH change after birth. Complications, which included postterm pregnancy, breech presentation, twin gestation, and chorioamnionitis (maternal fever ≥38°C), were not significantly correlated with the direction of blood pH change. Infants in group A, those who were born with acidemia and continued to have acidemia at 2 hours after birth, had a significantly decreased incidence of oxytocin for stimulation of labor (28% vs 36% in the reference group; $P = .008$). Infants in Group A also had an increased incidence of meconium (55% vs 36%; $P < .001$), and cesarean delivery for nonreassuring fetal heart rate pattern (31% vs 9%; $P < .001$) relative to the reference group. As shown in Table I, deterioration of pH during the neonatal period among infants delivered with pH values ≥7.20 (group B) was unrelated to intrapartum complications. Infants in group C, those who were delivered with acidemia and successfully resuscitated (neonatal pH of ≥7.20) were more frequently born to mothers with pregnancy-induced hypertension. Labor before delivery of infants in group C was also more often complicated by meconium-stained amniotic fluid, a prolonged second stage of labor, and cesarean delivery for nonreassuring fetal heart rate pattern.

Selected neonatal outcomes are shown in Table II. Septicemia, defined by positive results of blood cultures, was not significantly correlated with the pH study groups. Infants from groups A, B, and C were more frequently intubated in the delivery room (39%, 21%, and 19%, respectively, vs 13% in the reference group; $P < .001$) and were more
likely to have seizures during the first 24 hours after birth (15%, 7%, and 3%, respectively, vs 1% in the reference group; \( P < .001 \)). However, the incidence of respiratory distress, defined by mechanical ventilation within 24 hours after birth, was increased only in groups A and B (51% and 57%, respectively, vs 19% in the reference group; \( P < .001 \)). Radiographically diagnosed meconium aspiration syndrome was also found more often among the infants in groups A and B (15% and 10%, respectively, vs 4% in the reference group; \( P < .001 \)). Infants with major anomalies were significantly more common in group B (pH deterioration after delivery) than in the reference group (31% vs 14%, respectively, \( P < .001 \)).

Depicted in Fig 2 are the odds ratios and 95% confidence intervals for respiratory distress, meconium aspiration syndrome, seizures, and corrected neonatal death rates according to the direction of pH change between delivery and 2 hours after birth. Respiratory distress was 4 or 5 times more likely among those infants with a pH of <7.20 in the immediate neonatal period (groups A and B), regardless of the pH at delivery. Similarly, meconium aspiration syndrome was 2- or 4-fold higher in groups A or B relative to infants with a pH of ≥7.20 both at delivery and in the neonatal period (reference group). Seizures were 13 times more likely to occur among those infants who were born with an umbilical artery pH of <7.20 and continued to have acidemia during the neonatal period (odds ratio, 13.0; 95% confidence interval, 6.3-26.7). The incidence of seizures among those infants who were delivered in good condition (umbilical artery pH of ≥7.20 and neonatal pH of ≥7.20) but who had deterioration after delivery (group B) was approximately 6 times higher than in the reference group (odds ratio, 5.7; 95% confidence interval, 2.2-14.5). Those infants from group C who had an umbilical artery pH of <7.20 and were successfully resuscitated were 2.5 times more likely to have seizures during the first 24 hours after birth than were those in the reference group (odds ratio, 2.5; 95% confidence interval, 1.2-5.3). Neonatal death was 10 times more frequent among those infants who were born with acidemia that did not respond to resuscitation than it was in the reference group (odds ratio, 10.7; 95% confidence interval, 3.3-35.3), whereas those infants who had deterioration during the immediate neonatal period (group B) were 7 times more likely to die than were those in the reference group (odds ratio, 7.2; 95% confidence interval, 1.6-32.9). Finally, those infants who were born with acidemia but had a pH of ≥7.20 during the neonatal period (group C) were not at in-

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**Table I. Intrapartum complications among term infants in relation to paired delivery and neonatal pH groups**

<table>
<thead>
<tr>
<th>Complication</th>
<th>Group A (n = 178)</th>
<th>Group B (n = 110)</th>
<th>Group C (n = 594)</th>
<th>Reference group (n = 809)</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>Hypertension</td>
<td>31</td>
<td>17</td>
<td>15</td>
<td>14</td>
<td>137</td>
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<tr>
<td>Oxytocin</td>
<td>49</td>
<td>28*</td>
<td>36</td>
<td>33</td>
<td>243</td>
</tr>
<tr>
<td>Meconium</td>
<td>98</td>
<td>55*</td>
<td>33</td>
<td>30</td>
<td>279</td>
</tr>
<tr>
<td>Cesarean delivery for nonreassuring</td>
<td>55</td>
<td>31*</td>
<td>8</td>
<td>7</td>
<td>140</td>
</tr>
<tr>
<td>2-h second stage of labor</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>38</td>
</tr>
</tbody>
</table>

*Statistically significant, compared with reference group.

**Table II. Outcomes among term infants according to direction of pH change during the neonatal period**

<table>
<thead>
<tr>
<th>Complication</th>
<th>Group A (n = 178)</th>
<th>Group B (n = 110)</th>
<th>Group C (n = 594)</th>
<th>Reference group (n = 809)</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>Intubation in delivery room</td>
<td>69</td>
<td>39*</td>
<td>22</td>
<td>21*</td>
<td>111</td>
</tr>
<tr>
<td>Respiratory distress</td>
<td>91</td>
<td>51*</td>
<td>63</td>
<td>57*</td>
<td>119</td>
</tr>
<tr>
<td>Meconium aspiration</td>
<td>26</td>
<td>15*</td>
<td>11</td>
<td>10*</td>
<td>32</td>
</tr>
<tr>
<td>Seizures†</td>
<td>27</td>
<td>15*</td>
<td>8</td>
<td>7*</td>
<td>20</td>
</tr>
<tr>
<td>Anomalies</td>
<td>23</td>
<td>13</td>
<td>35</td>
<td>32*</td>
<td>43</td>
</tr>
<tr>
<td>Corrected neonatal death rate</td>
<td>9</td>
<td>6*</td>
<td>3</td>
<td>4*</td>
<td>2</td>
</tr>
</tbody>
</table>

*Statistically significant, compared with reference group.

†Seizures during first 24 hours after birth.
among term infants. Similar findings pertained when poor condition at birth that persists into the immediate neonatal period and deterioration of pH after birth had an intermediate risk of seizures with nonacidemic pH values but had deterioration by 2 hours after birth had an intermediate risk of seizures (odds ratio, 5.7). We interpret these findings to indicate that poor condition at birth that persists into the immediate neonatal period and deterioration of pH after birth are both significant correlates of neurologic morbidity among term infants. Similar findings pertained when such other indexes as respiratory distress, meconium aspiration, and neonatal death were examined.

Modanlou et al. described the pH trend during the first hour after birth in term infants born to mothers at normal and high risk. The pH normally increased from 7.20 at 4 minutes after delivery to 7.32 by 1 hour after birth. Similar observations were made by Holmqvist et al., who found that mean umbilical artery blood pH decreased from 7.27 to 7.19 at 4 minutes after birth among preterm infants but subsequently increased to 7.25 by 30 minutes after birth. It therefore seems reasonable to accept a pH value of 7.20 during the first 2 hours after birth as the point below which an infant can be considered to have acidemia. These data were the basis for our selection of this threshold. Indeed, pH in most term infants in our study either improved or remained within the normal blood pH range after birth.

The condition of the neonate has increasingly been scrutinized in attempts to correlate intrapartum events with subsequent outcomes. It has been established that Apgar scores alone are unsatisfactory for defining birth asphyxia or predicting neurologic outcomes. The results that we report here suggest that acid-base balance may deteriorate significantly during the immediate neonatal period and that the prognosis of infants with acidemia at birth is intensified when the acidemia persists through the first hour after birth. Conversely, correction of acidemia after birth seems to greatly improve infant prognosis relative to persistent or new-onset neonatal acidemia. On the basis of these findings, we propose that the direction of pH change from birth to the immediate neonatal period be considered in the evaluation of the prognosis for term infants who appear ill at or shortly after birth.

**REFERENCES**