ABSTRACT

Ionized Ca in blood, standard ionized Ca, pH, and total Ca in plasma were measured in 33 Holstein-Friesian dairy cows and their calves. Blood was taken immediately postpartum and at 12, 24, 48, and 72 h after calving. Cows and their calves were grouped according to parity. Concentrations of ionized and total Ca consistently were higher in neonates than in the dams. Parity differences were significant for maternal ionized Ca and total Ca. However, parity was not significant for ionized or total Ca in the blood of corresponding calves. Changes in ionized Ca concentration in calves of first lactation cows largely were attributable to perinatal acidosis. In contrast to total Ca concentrations, the ionized Ca and standard ionized Ca concentrations in dams and calves were relatively stable throughout the study, suggesting that ionized Ca concentration in blood is indicative of the Ca status of the dairy animal.

(Key words: calf, ionized calcium, pH)

Abbreviation key: IC = ionized Ca, SIC = standard ionized Ca, TC = total Ca.

INTRODUCTION

Hypocalcemia is one of the most common metabolic disorders affecting dairy cows (7, 12). Most cows experience a transient period of hypocalcemia at the onset of lactation in spite of seemingly adequate parathyroid function and vitamin D status (11, 17). In most instances, this transient hypocalcemia is not severe enough to produce clinical signs, and the concentration of plasma total Ca (TC) returns to normal within 2 to 3 d (10, 12). However, parturient paresis occurs in 5 to 20% of aged dairy cows (10). Hypocalcemia occurs in human neonates (7). Similar reports on the incidence of parturient paresis in newborn calves are not available (8). Even though the importance of the Ca ion for myocardial contraction was known a century ago (21) and the concentration of ionized Ca (IC) in blood has been recognized since 1934 (18) to be the biologically active fraction, the Ca status of an animal presently is assessed based on the TC concentration in blood, primarily because of the lack of reliable and readily available...
TABLE 1. Calculated feed intake before and after calving.

<table>
<thead>
<tr>
<th>Feed parameters</th>
<th>DM (kg)</th>
<th>CP (g)</th>
<th>NE\textsuperscript{2} (M\textsubscript{1})</th>
<th>Ca (g)</th>
<th>P (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake</td>
<td></td>
<td></td>
<td>Precalving\textsuperscript{2}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake</td>
<td>10.6</td>
<td>1036</td>
<td>64.7</td>
<td>33.6</td>
<td>36.5</td>
</tr>
<tr>
<td>Requirement</td>
<td>10-11</td>
<td>984</td>
<td>56.02</td>
<td>1:1</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>0</td>
<td>52</td>
<td>8.68</td>
<td>9:1</td>
<td></td>
</tr>
<tr>
<td>Requirement</td>
<td>22.1</td>
<td>3606</td>
<td>155.5</td>
<td>164.8</td>
<td>96.3</td>
</tr>
<tr>
<td>Difference</td>
<td>.7</td>
<td>46</td>
<td>3.9</td>
<td>4.0</td>
<td>100.5</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Digestible CP.

\textsuperscript{2}Ration consisted of corn silage, alfalfa hay, green alfalfa, milled corn, and mineral premix. Mineral premix fed at the rate of 200 g/d per cow and supplied (per kilogram of premix): 97 g of Ca, 102.7 g of P, 2.42 g of Mg, 126 g of Na, 2.44 g of K, 99.3 g of Cu, 5.16 g of Zn, .33 g of Mn, and 2.28 g of Fe.

Methods for Ca ion determination (13, 16, 22). Direct and accurate measurement of the Ca ion in blood has become practical only during the last two decades with the development of the ion-selective electrode technique (23). Our objective was to study the simultaneous changes in concentrations of IC and TC in the maternal and neonatal circulation during the 72 h postcalving. In addition, the effects of parity on Ca in blood also were examined.

MATERIALS AND METHODS

Cows

A field study was performed in a Holstein-Friesian dairy herd in May and June 1992 in Hungary. Dry cows and first lactation cows were confined in a separate stanchion barn and received a mixed corn silage and fodder ration with alfalfa hay. Water was available for ad libitum intake. All rations (Table 1) were fed to meet or to exceed NRC (20) recommendations for essential nutrients. The postpartum ration was fed to all dams and calves immediately after calving. Just before calving (first stage of labor) or after calving, dams were isolated in a separate stanchion barn. Ten randomly chosen primiparous (body condition score, 3.2 ± .2) and 23 pluriparous dams (body condition score, 3.6 ± .4; previous lactational performance, 6700 to 7200 kg) were used in the experiment. Newborn calves were kept with their dams during the first 72 h after birth and were allowed to nurse. The deliveries of all 33 calves, all with normal anterior presentation, were uncomplicated and were completed within 1 h after the appearance and rupture of the fetal membranes. One to three attendants assisted with traction. The duration of traction was measured. No clinical signs of milk fever were observed during the study.

Blood Sampling and Analysis

Immediately after birth, maternal and neonatal blood was collected from the jugular vein. The deadspace (.08 ml) of a 10-ml plastic syringe and attached needle was filled with a Ca-titrated heparin solution (Radiometer, Copenhagen, Denmark), and blood samples were taken anaerobically. Air bubbles in the sample were removed immediately, and the sample was mixed by rolling. The syringe was capped with a rubber cap and was placed on a bed of crushed ice. Additional blood samples were withdrawn from the jugular vein into heparinized evacuated blood collection tubes (Venoject; Terumo N.V., Leuven, Belgium) and placed on a bed of crushed ice. Sampling of maternal and neonatal blood was repeated at 12, 24, 48, and 72 h after calving. Within 30
min of sampling, all blood samples were analyzed at 37°C for IC, standard IC (SIC), and pH using an IC analyzer (ICA2; Radiometer) as described previously (27). The IC analyzer was equipped with two electrodes to allow the simultaneous measurement of IC and pH, which is important because these two measurements are interdependent and because the measured IC can be corrected for normal blood pH (pH 7.4) for calculation of SIC. The instrument calculates SIC using the following equation (25):

\[ \text{SIC} = \text{IC} \times (1 - 0.53 (7.4 - \text{pH})) \]

Plasma was separated (1500 × g for 5 min at 4°C) within 60 min after collection and frozen at −18°C for up to 30 d. For determination of TC, plasma was thawed and analyzed by an atomic absorption spectrophotometer (Perkin-Elmer 5000, Norwalk, CT).

**Statistical Analysis**

Dams were assigned prepartum to one of the following three groups according to parity: group 1, entering first lactation (n = 10); group 2, entering second lactation (n = 11); and group 3, entering third and later lactations (n = 12). Changes in maternal and neonatal blood pH and in concentrations of IC and SIC in blood and in plasma TC were analyzed by multivariate repeated measures ANOVA procedures (24). The statistical model included time of sampling and parity as independent variables. Significance was declared at P < .05 unless noted otherwise.

**RESULTS**

Cows in parity 3 had significantly lower IC concentrations in plasma during the study than those in parities 1 and 2 (Figure 1). The TC in plasma in dams generally decreased by 12 h (groups 1 and 3) or 24 h (group 2) postpartum. Concentrations of TC at 72 h generally were higher than concentrations at 0 h in all cows. Neonatal TC concentrations in plasma were not influenced by the parity of the dam. Compared with IC concentrations, maternal and neonatal TC were more variable throughout the study (Figure 2). Immediately after birth, the concentrations of TC and IC were significantly higher in the calves than in dams. These differences were still evident 72 h postcalving.
Parity (Figure 2) had a significant effect on maternal concentrations of IC that was not evident with IC concentrations in the corresponding calves. Overall, concentrations of IC in maternal blood generally were higher at 72 h postpartum than at 0 h. A significant \( P < 0.0001 \) interaction of time of sampling \( \times \) parity was observed with IC because of low blood pH for calves in group 1 immediately postpartum. Otherwise, neonatal IC concentrations were very stable.

Maternal blood pH in each parity group varied within a very narrow range (<0.05 pH units) during the study (Figure 3). Immediately after birth, 7 out of 10 newborn calves in group 1 had expressed acidosis (blood pH 7.0 to 7.2). The duration of tractions in acidosis cases was between 75 and 186 s compared with <60 s in the normal, nonacidotic cases. Twelve hours after birth, neonatal blood pH in all groups reached the normal range observed in the dams (pH 7.35 to 7.5). Thereafter, blood pH in the neonates remained constant.

The maternal and neonatal SIC concentrations showed profiles similar to those for the maternal and neonatal IC concentrations (Figure 4), as expected, because SIC concentration was corrected for blood pH (pH = 7.4) and because the maternal and neonatal blood pH (except for neonates immediately postpartum) was close to normal. The low variability of SIC in calves in group 1 indicates that this parameter was corrected for the fluctuation in neonatal blood pH immediately after birth.

**DISCUSSION**

Concentrations of IC and TC in blood were in agreement with published values (14, 15, 27). Most dairy cows adapt well to the lactational demands for Ca after calving by increasing Ca absorption and bone resorption. The TC concentration in plasma returns to normal within 24 to 72 h after normal calving and in uncomplicated cases of milk fever. Adequate and rapid adaptations of TC in plasma concentration to the demands of lactation were evident in this study. Maternal IC concentration in blood was very stable and is in agreement with results of others (1). Parity had a significant effect on maternal IC concentrations; older dams had lower concentrations of IC postpartum.

Although the bovine fetus is completely dependent on its dam for its supply of Ca, fetal...
TC concentration in plasma appears to be relatively independent of maternal TC concentration in plasma. The passage of Ca across the placenta is unidirectional; back transfer of Ca is very limited (4). In the present study, concentrations of TC in plasma and IC in blood were higher in the newborn calves than in the dams. Trends were similar for TC concentration in plasma. The passage of Ca across the placenta is unidirectional; back transfer of Ca is very limited (4). In the present study, concentrations of TC in plasma and IC in blood were higher in the newborn calves than in the dams. Trends were similar for TC concentration in plasma. The mechanism by which Ca is transported across the placenta is not fully understood. In sheep, spontaneous long-term maternal hypocalcemia was not reflected in the corresponding changes in the fetus (5), in agreement with our findings, because the slight hypocalcemia in the maternal blood in older cows was not reflected by similar changes in neonatal TC and IC concentrations immediately after birth.

Hypocalcemia, which occurs in human neonates, is uncommon in domestic animals (2, 7, 8). The TC concentration in plasma of newborn calves increased (5 mmol/L) between 0 and 2.5 d after birth and then decreased on d 5 (8). We observed a slight, nonsignificant fluctuation in TC concentration in plasma during the study. This finding agrees with those of others (2). Neonatal IC concentration in blood also was very stable and was not influenced by maternal IC concentration in blood at calving.

Maternal blood pH is in agreement with those previously described (19, 26). The acid-base balance of fetal calves just before birth is very labile. Physiologic respiratory and metabolic acidosis (pH 7.2 to 7.3) that develop during the first lactation often can develop (19, 26). Neonatal acidosis (pH 7.0 to 7.2) in calves from first lactation calves immediately after birth caused a comitant increase in IC concentration in blood. This condition disappeared after the compensation of the acidosis within 12 h of life. As shown earlier in humans (6) and dogs (28), a significant decrease of blood pH accounts for a significant rise in the IC concentration in blood in newborn calves.

CONCLUSIONS

Maternal and neonatal IC concentrations in blood (except for calves with postnatal acidosis) remained relatively stable during the first 72 h after calving. The significant effect of parity of maternal IC concentrations requires further study for possible implications in milk fever. Both TC and IC concentrations were higher in the newborn calves than in their dams. Concentrations of IC and TC in calves at birth were not influenced by the parity of their dams.

REFERENCES

21 Ringer, S. 1883. A further contribution regarding the influence of different constituents of blood on contractions of the heart. J. Physiol. (Lond.) 4:29.