Sodium Intake by Pregnant Cows and Plasma Aldosterone and Cortisol Concentrations in the Fetus During Late Pregnancy

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ABSTRACT

The purpose of this study was to evaluate the influence of maternal dietary Na intake on the plasma concentrations of aldosterone and cortisol in cows and their fetuses during late pregnancy. Seven cows received a diet with normal amounts of Na (25 g Na per cow/d) and seven others an Na-loaded diet (210 g Na per cow/d) during the last 40 d of gestation. Maternal and fetal blood samples were collected regularly during the last month of gestation through jugular vein puncture and cotyledonary artery indwelling catheters. Serum Na and K concentrations and plasma osmolalities increased, but concentrations of aldosterone decreased in maternal and fetal plasma when cows were fed the Na-loaded diet. Diets did not modify concentrations of cortisol in maternal and fetal plasma. Thus, an increase in Na intake by dams influenced concentration of Na and K in fetal plasma and fetal adrenal secretion of aldosterone.

(Key words: sodium, aldosterone, cattle)

INTRODUCTION

Previous studies (22) demonstrated that plasma aldosterone concentrations in dairy cows were influenced by changes in ionic composition of grass related to the different seasons of the year. However, relationships between plasma ion and aldosterone concentrations could not be established either in perinatal lambs (18), in neonatal guinea pigs (8), in human infants (24), or in calves (23).

The regulation of aldosterone secretion is poorly understood in mammals during the perinatal period and especially during the end of pregnancy. At that time, placental transfer of aldosterone between mother and fetus was very low in several species, such as guinea pig (9) and sheep (18, 27). Furthermore, the ability of the fetal adrenal cortex to secrete aldosterone has been well documented in lambs (2, 26). In sheep, changes in maternal intake of Na had no long-term effect on Na concentrations in fetal plasma or on fetal renal Na excretion (18). The absence of any change in the fetal renin activity indicates that the fetal renin angiotensin system could be controlled by factors other than those influencing the adult renin angiotensin system (25). Furthermore, comparisons between maternal and fetal concentrations of angiotensin and renin activity were conflicting, with higher values either in the fetus (4) or in the mother (13). In the newborn calf, the effect of dehydration has been well documented (21), but nothing is known about the Na-aldosterone relationship in cows in late pregnancy. The objective of this study was to determine the effect of the maternal dietary Na intake on maternal and fetal plasma concentrations of aldosterone.

MATERIAL AND METHODS

Animals and Surgery

Experiments were carried out on 14 Holstein-Friesian pregnant cows, 6 to 8 yr of age (fourth or sixth gestation), weighing 630 ± 20 kg (mean ± SEM). At 250 d after mating, a catheter was fitted into a cotyledonary artery of each animal under halothane anesthesia (5). Ten days were allowed for each cow to recover from surgery before any sampling was undertaken. Maternal blood was obtained by puncture of the left jugular vein. Fetal and maternal blood was collected at 0800 h before feeding,
HORMONE CHANGES WITH CATTLE DIET

TABLE 1. Hematocrit, plasma osmolality, and Na and K concentrations in cows and their fetuses as influenced by maternal dietary sodium intake. (mean ± SEM from d -20 through 0).

<table>
<thead>
<tr>
<th></th>
<th>Control diet</th>
<th>Na-Loaded diet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cows</td>
<td>Fetuses</td>
</tr>
<tr>
<td>Hematocrit, %</td>
<td>32 ± 1</td>
<td>34 ± 1^b</td>
</tr>
<tr>
<td>Osmolality, mOsm/L</td>
<td>290 ± 1</td>
<td>287 ± 2</td>
</tr>
<tr>
<td>Na+, mM/L</td>
<td>144 ± 1</td>
<td>139 ± 1^b</td>
</tr>
<tr>
<td>K+, mM/L</td>
<td>3.8 ± .5</td>
<td>3.7 ± 1</td>
</tr>
</tbody>
</table>

^aSignificant difference between mothers and fetuses (P<.05).
^bSignificant difference between fetuses (P<.05).
^cSignificant difference between mothers (P<.05).

on d 260, 268, 272, 275, 278, and 280 of gestation, defined as -20, -12, -8, -5, -2, and 0 d prepartum.

Fetal arterial blood gases and pH were measured daily; the mean fetal PaO2, PaCO2, and pH were 2.90 ± .05 kPa, 6.03 ± .04 kPa, and 7.39 ± .02, respectively. Thus, these fetuses were neither hypoxic nor acidotic. Each calf was delivered spontaneously at term [280 d of gestation; birth weight was 41 ± 2 kg (mean ± SEM)], and calves remained in good health during the first 2 wk of postnatal life (their mean daily gain was .632 ± .167 kg during this period).

Each cow had free access to tap water and was fed hay (15 kg per cow/d) and grain concentrate (3 kg). Sodium was mixed with concentrate. Seven control cows received daily 25 g Na and 190 g K (Na-normal diet) (11). The seven other cows ingested daily 190 g K and 210 g Na (Na-loaded diet). These diets were given to cows from the 240th d of gestation until parturition.

Assays

Plasma osmolality was determined by freezing point depression (Fiske Os Osmometer, Fiske Associates, Needham Heights, MA). Na and K concentrations were measured by flame photometry (Perkin Elmer 400, Perkin Elmer Corp., Norwalk, CT). Plasma concentrations of aldosterone were measured by radioimmunoassay as previously described (19). The sensitivity was 25 pmol/l and intraassay and interassay variabilities were 9 and 10%, respectively. Plasma cortisol concentrations were determined by radioimmunoassay as described and validated in the bovine species. Interassay and intraassay coefficients of variation were 5 and 3%, respectively (7).

Statistics

Results are expressed as mean ± SEM. The statistical significance of differences observed between Na-normal and Na-loaded groups was calculated using Mann-Whitney U test (15).

RESULTS

Changes from Sodium in Maternal Diets

With the control diet, fetal plasma Na concentrations were lower than the maternal ones. When cows were fed the Na-loaded diet, osmolalities and plasma Na and K concentrations increased in the mother and the fetus, and fetal plasma Na concentrations became higher than those of the mother (Table 1).

Sodium Intake and Hormone Concentrations

Overall plasma aldosterone concentrations were significantly lower in both mother and fetus fed Na-loaded diet compared with concentrations in the control group (Table 2), and these differences were observed during the whole period studied (Figure 1). In fetuses of cows fed the Na-normal diet, plasma aldosterone concentrations increased significantly at birth; the same pattern was observed in fetuses of cows fed Na-loaded diet, despite the signifi-

cantly lower concentrations of plasma aldosterone before birth.

Average plasma cortisol concentrations remained significantly higher in fetuses than in their mothers with both diets (Table 2). Although maternal plasma cortisol concentrations decreased near term, fetal plasma cortisol concentrations significantly increased in the last 12 d of gestation (+100%; *P<.05) (Figure 2).

**DISCUSSION**

When cows were fed the Na-normal diet, Na and aldosterone concentrations in maternal plasma were higher than those in fetuses. However, in cows fed the Na-loaded diet, plasma sodium concentrations of fetuses were significantly higher than in mothers with decreased concentrations of aldosterone in both maternal and fetal plasma.

These results suggest that the fetal renin-angiotensin-aldosterone system could respond to changes in plasma Na concentration, indicating that this system may be operative in the fetus just before birth, as demonstrated in the newborn calf (21). It could be assumed that this decrease in fetal aldosterone concentrations could be due to a lowered fetal adrenal secretion rather than to changes in placental transfer of aldosterone from the mother to the fetus, since it has been demonstrated that placental transfer of aldosterone is negligible in ruminants (18). Furthermore, the fetal calf seemed to be unable to induce natriuresis after experimental hydrosaline expansion as previously demonstrated in newborn of several species [human (3), piglet (16), dog (1, 10, 14), guinea pig (17), and rat (6)]. However, in other species, such as sheep, the infusion of saline to fetal lamb induced an increase in Na excretion (12). The maturation of filtration system and hormonal regulation implicated in the hydromineral metabolism seemed to take place at different periods. We confirmed previous data showing the prenatal rise in fetal cortisol in calves before term (20).

In conclusion, our results indicate that in the fetal calf just before birth, the renin-angiotensin-aldosterone system seemed functional, responding to a simulation by a change in plasma Na concentration. Nevertheless the adaptation of the kidney to this change was not complete.
TABLE 2. Effect of maternal dietary sodium intake on plasma aldosterone and cortisol concentration in cows and their fetuses. (mean ± SEM from d -20 through 0).

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cows</td>
<td>Fetuses</td>
</tr>
<tr>
<td>Aldosterone, pg/ml</td>
<td>X 36 7 25 3*</td>
<td>X 12 3° 10 3b</td>
</tr>
<tr>
<td>Cortisol, ng/ml</td>
<td>2.1 2 2.9 4*</td>
<td>1.6 2 4.0 4a</td>
</tr>
</tbody>
</table>

*aSignificant difference between mothers and fetuses (P<.05).
*bSignificant difference between fetuses (P<.05).
*cSignificant difference between mothers (P<.05).

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