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Clinical findings, blood chemistry values, and epidemiologic data from dairy goats with pregnancy toxemia

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Abstract

Pregnancy toxemia is one of the most common diseases in sheep and goats occurring during the last month of gestation. Clinical signs and blood chemistry findings from 22 clinical cases of pregnancy toxemia in dairy goats are described. All were maintained on a single farm that used an intensive dry-lot production system. Clinical signs observed most consistently were anorexia, ruminal atony, polypnea, drooping ears, a preference for recumbency with reluctance to stand or walk, swelling (subcutaneous edema) of the limbs, inability to stand or walk, and neurological signs. Major blood chemistry results showed decreased potassium, glucose, pH, bicarbonate, base excess, and partial pressure of carbon dioxide (pCO2). The prognosis was very poor in goats with a case fatality rate of 86%, even though a caesarean section was performed or kidding was induced, and medical treatments were administered in an attempt to correct the underlying glucose deficit and metabolic acidosis. The mortality rate was 100% in 11 does with pregnancy toxemia when the blood pH was 7.122 or lower.

Key words: dairy goats, pregnancy toxemia, hypokalemia, metabolic acidosis.

Résumé

La toxémie de gestation (ou fièvre puerpérale) est l'une des maladies les plus courantes des brebis et des chèvres au cours de leur dernier mois de gestation. Nous décrirons ici les signes cliniques et les résultats de l'analyse sanguine de 22 cas de toxémie de gestation chez des chèvres laitières. Ces dernières provenaient toutes de la même ferme où elles étaient élevées en parc sans pâture. Les signes cliniques les plus souvent observés étaient l'anorexie, l'atonie ruminale, la polypnée, les oreilles tombantes, une préférence à la position couchée avec parfois une incapacité à se tenir debout ou à marcher, des enflures (oedèmes) sous-cutanés sur les pattes et des troubles neurologiques. Parmi les résultats de test sanguin les plus marquants, on note un déficit à plusieurs niveaux : potassium, glucose, pH, bicarbonate, excès de bases et pression partielle du gaz carbonique (pCO_2). La mortalité fut importante (86 %) chez les chèvres sur lesquelles on avait pourtant pratiqué des césariennes, provoqué la mise bas ou administré un traitement médical pour corriger le déficit sous-jacent en glucose et l'acidose métabolique. La mortalité fut de 100 % chez onze (11) chèvres atteintes de toxémie de gestation dont le pH sanguin était égal ou inférieur à 7,122.

Introduction

Pregnancy toxemia (PT), a metabolic disease in sheep and goats caused by negative energy balance, is commonly called pregnancy disease or twinning disease. The disease is commonly associated with rapid growth of multiple fetuses during late pregnancy. Nearly 80% of fetal growth occurs during the last six weeks of gestation.[2,12] During the final month of gestation, the energy requirement of a pregnant doe carrying twins or triplets is 180% or 240% greater, respectively, than that of a doe with a single fetus.[12] Obese ewes and does are at greater risk for developing PT.[12] Hypoglycemia, hyperketonemia, and metabolic acidosis are the primary blood disturbances in PT.[15]

Materials and Methods

This study was done on a 1,700-head dairy goat farm located 30 miles northeast of Lisbon, Portugal. Approximately 1,200 of the goats were adult does that had given birth at least once. Two breeds were represented on the farm, Saanen (1,100 head) and Alpine (600 head).

All goats were continuously housed in confinement, and all adult does had access to free stalls. Three kidding seasons per year were utilized: January, April, and October. Each kidding season began on the first day of the month, and continued for 45 days. Daily milk production in this herd averaged approximately 3.2 quarts (3 L)/doe; does were milked with machines twice daily.

All goats over six to seven months of age were sorted into one of four basic groupings, and fed and managed accordingly. These groupings were: 1) high-producing doe (HPD) groups; 2) low-producing doe (LPD) groups; 3) dry doe (DD) groups; and (4) herd replacement (HR) (young doe) groups. Following parturition, all does were moved to a HPD group where they were kept until individual milk production fell below 3.2 qt (3 L)/day.

At that point, does were moved to a LPD group where they were bred naturally. Does remained in this grouping until the beginning of their final month of gestation. At that time, does producing less than 0.52 qt (0.5 L) were moved to a DD group. Those still producing more than 0.52 qt (0.5 L) remained in a LPD group, and were milked until they gave birth. As young does in the HR group entered their final month of gestation, they were moved into a DD group.

Does in the HPD and LPD groups were fed different total mixed rations. The two rations contained 46% and 52% roughage as fed, respectively, along with corn silage, chopped alfalfa hay, and ryegrass hay. The remainder of rations contained ground feed grains, by-product feeds, and minerals. Dry does were fed long-stem wheat straw ad libitum, and 2.2 lb (1 kg) of a concentrate mix per head/day, divided into four equal portions offered at 8 am, 12 pm, 2 pm, and 6 pm.

The present study began in January of 2009, ended in February 2012, and spanned seven kidding periods. There were 2,458 parturitions and 3,877 kids born during the study, with 1.58 live kids delivered per doe.

The 22 does with PT in this study were randomly selected, and represented about a quarter of total PT cases diagnosed during the study period. Data from the 22 study does with PT were compared to 22 healthy dry does (controls) that were in the last month of pregnancy.

Seventeen does with PT were Saanens, and five were Alpines. In the control group, 14 does were Saanen and eight were Alpine breed. The distribution of PT cases by kidding season was: January 2009 – 1 doe; April 2009 – 2; October 2009 – 1; January 2010 – 5; April 2010 – 4; October 2010 – 3; January 2012 – 6 does.

At the time each PT doe was diagnosed and enrolled in the study, a physical examination was performed, and clinical signs of disease and vital signs (rectal temperature, heart rate, respiratory rate, and rumen motility) were recorded. Rumen motility was scored on a scale of 1 to 3, where 1 indicated complete absence of contractions, 2 indicated diminished strength and/or frequency of contractions, and 3 indicated normal motility. In addition, a blood sample was collected from the jugular vein, and the following parameters were measured on the farm using a portable analyzer:[a] ions (Na^+, K^+, Cl^-, and $HCO3^-$); glucose; pH; base excess (BE); pCO2; and blood urea nitrogen (BUN). Immediately afterwards, these same procedures were performed on a control doe from the same DD group as the PT doe, selecting a doe that most closely matched the PT doe in breed and age, with the highest priority given to matching for breed.

The decision whether to perform a caesarean section or induce kidding was based primarily on the owner's preferences. Kidding was induced using dexamethasone[b] (1 mg/22 lb or 1 mg/10 kg BW, IM) and dexcloprostenol[c] (125 µl, IM). A caesarean section was performed on eight PT does (36%) and parturition was induced in 14 cases (64%). Supportive medical treatment was also provided, using the following six treatments:

Treatment 1: 30 g of a dry, commercial oral electrolyte product containing 70% glucose, 15% sodium chloride, and 12% sodium bicarbonate (with vitamins C and E) was dissolved in 1.6 to 2.1 qt (1.5 to 2.0 L) of water and administered orally at 12 to 24-hour intervals.

Treatment 2: 50 mL of propylene glycol was administered orally and repeated at 12-hour intervals. It was given only to PT does that had rumen motility.

Treatment 3: 0.52 qt (0.5 L) of 5% glucose in water was administered intravenously and repeated at 12-hour intervals.

Treatment 4: 50 mL of 20% calcium borogluconate solution was administered subcutaneously once daily.

Treatment 5: flunixin meglumine was administered intravenously (1.1 mg/lb or 2.5 mg/kg) once daily. It was used only for PT does with swollen limbs.

Treatment 6: Isotonic sodium bicarbonate solution was administered intravenously; the dose varied with the base deficit.

Farm employees administered Treatments 1 through 5, while the senior author administered Treatment 6. It was not the intent of the attending veterinarian (MSL) that all medical treatments be administered to every PT case; however, several does received more than one treatment. Furthermore, it was not the intent of this study to compare efficacies of these medical treatments. Consequently, this part of the larger study was neither prospective nor controlled.

Statistical Analysis

A one-tailed T test for independent samples[20] was used to compare the number of treatments administered to the three surviving does with the number of treatments administered to eight does that died (Table 5). These 11 does had blood pH values of 7.127 or higher.

The other 11 PT does had blood pH values of 7.122 or less, and all died. A two-tailed T test for independent samples[20] was used to compare the mean values of the data obtained from PT and control does (Tables 1 and 2). A two-tailed Fisher's exact test[20] was used to determine the significance of the difference between the rates of occurrence of PT in the two breeds of goats, and in the rate of rumen atony in PT does and control does.

Results

The age, number of kids carried/delivered, and vital signs in the 22 PT does and 22 control does are summarized (Table 1). The mean values for age, rectal temperature, and heart rate were not significantly different between PT and control does. Rectal temperatures were below the reference range in 19 of 22 PT does and 18 of 22 control does. The heart rate was above the reference range in 18 of 22 PT does and 21 of 22 controls, and were below the reference range in two PT does.

The number of kids born per doe was significantly higher in PT does than in controls ($P < 0.001$; Table 1). One PT doe died prior to giving birth; a necropsy examination was not performed, and the number of fetuses was not determined. Of the remaining 21 PT does, 15 (71%) gave birth to triplets, six gave birth to twins (29%), and none had singles. The mean number of kids born to each PT doe was 2.7 (Table 1). In contrast, 22 control does gave birth to only four sets of triplets (18%), 14 sets of twins (64%), and four singles (18%). The mean number of kids per control doe was 2.0 (Table 1).

The mean respiratory rate was significantly higher in PT does than in controls ($P < 0.05$; Table 1). The respiratory rate was higher than the reference range in 19 of 21 PT does and 18 of 22 controls; the respiratory rate was not recorded in one PT doe.

Rumen atony (complete absence of contractions) was more common in PT does than in controls ($P < 0.001$; Table 1). Rumen motility was absent (atony, a score of 1) in 20 of 22 PT does (91%) and decreased (a score of 2) in two PT does. In controls, rumen motility was absent in four does (18%), decreased in eight, and normal (a score of 3) in 10.

All PT does experienced an abrupt onset of complete anorexia. Drooping ears were present in 12 PT does (55%), and 12 preferred to remain recumbent, but were able to stand and walk when urged to do so. Eight PT does (36%) had swollen (edematous) limbs; all four limbs were affected in six does, while only the two forelimbs were swollen in the remaining two does. Five PT does (23%) were recumbent and could not rise; three laid on their side (14%); and two laid in sternal recumbency (9%). Five PT does (23%) showed evidence of neurological derangement, including muscle tremors of the head (1), blindness (1), head weaving (1), abnormal vocalization (2), head tilt (1), and aggressiveness (1).

Urine was collected from eight PT does and complete urinalyses were performed. Ketonuria and aciduria were the only abnormalities detected, and were present in all eight samples. Blood chemistry results for PT and control does are summarized in Table 2. Mean blood K^+, glucose, pH, $HCO3^-$, BE, and pCO2 values were sig-

Table 1. Ages, numbers of kids, and vital signs in 22 does with pregnancy toxemia and 22 control does.

Parameter studied	PT does Mean ±SD (Range)	Control does Mean ±SD (Range)	Reference ranges*
Age (years)	4.6 ± 1.6 (2 – 9)	3.8 ± 1.3 (2 – 6)	
No. of kids	2.7 ± 0.5[y]	2.0 ± 0.6	
No. of does	n = 21	n = 22	
Rectal temperature (°F)	100.8 ± 1.6 (95.5 – 103.6)	101.3 ± 0.7 (99.9 – 103.6)	102 – 104
Heart rate	115 ± 28 (44 – 173)	123 ± 20 (72 – 154)	70 – 90 per minute
Respiratory rate	48 ± 19[x] (28 – 108)	38 ± 10 (24 – 64)	15 – 30 per minute
Ruminal motility Score (n)	1 (20)[y] 2 (2)	1 (4) 2 (8) 3 (10)	1 – 2 contractions per minute (Score 3)

*Pugh DG. Normal values and conversions. In: Pugh DG, ed. *Sheep and goat medicine*. Philadelphia: WB Saunders Co, 2002;451-455.

[x]$P < 0.05$

[y]$P < 0.001$

Table 2. Blood chemistry values from 22 does with pregnancy toxemia and 22 control does.

Parameter	PT does Mean ± SD (Range)	Control does Mean ± SD (Range)	Reference ranges
Na^+ (mmol/L)	138 ± 4.0 (128 -144)	140 ± 4.1 (128 – 145)	142 – 155*
K^+ (mmol/L)	2.7 ± 0.4[z] (2.0 – 3.3)	3.8 ± 0.2 (3.3 – 4.3)	3.5 – 6.7*
Cl^- (mmol/L)	109 ± 4.0 (103 – 115)	107 ± 2.7 (102 – 112)	99 – 110*
Glucose (mg/dl)	41 ± 16[x] (20 – 76)	50 ± 6.4 (38 – 61)	50 – 75*
pH	7.1 ± 0.2[z] (6.76 – 7.36)	7.4 ± 0.04 (7.31 – 7.45)	7.32 – 7.5*
$HCO3^-$ (mmol/L)***	9.7 ± 4.6[z] (3.5 – 20)	22.9 ± 2.3 (17.9 – 28.5)	20 – 25*
Base excess*** (mmol/L)	-20 ± 7.4[z] (-30 – -5)	-2.0 ± 2.8 (-8 – +4)	0 – 6**
pCO2 (mmHg)	26.8 ± 4.7[z] (16 – 36)	36.8 ± 3.7 (31 – 44)	38 – 45*
BUN (mg/dl)	14.4 ± 7.0 (3 – 33)	12.9 ± 4.2 (6 – 23)	10 – 20*

*Pugh DG. Normal values and conversions. In: Pugh DG, ed. *Sheep and goat medicine.* Philadelphia: WB Saunders Co, 2002;451-455.
**Radostits OM, Gay CC, Hinchcliff KW, Constable PD. General systemic states and pregnancy toxaemia in sheep. In: *Veterinary medicine*. 10th ed. Philadelphia: WB Saunders Co, 2007;39-125 and 1668-1671.
***Because published reference ranges for $HCO3^-$ and base excess were not available for goats, values used were for sheep (Pugh) and domestic ruminants in general (Radostits *et al*), respectively.
[x]$P < 0.05$
[z]$P < 0.0001$

nificantly lower in the PT does than in controls. Mean blood Na^+, Cl^-, and BUN values were not significantly different between groups.

Seventeen PT does and 14 control does had blood Na^+ values slightly below the reference range. Blood K^+ values were below the reference range in all PT does, and slightly below the reference range in two controls. Blood Cl^- values were slightly above the reference range in eight PT does and in three controls. Blood glucose values were below the reference range in 16 PT does and 10 controls, and above the reference range in one doe in the PT group. Blood pH values were below the reference range in 18 PT does, and slightly below in one control doe. Blood $HCO3^-$ values were well below the reference range in all but one doe in the PT group; one control doe had $HCO3^-$ levels slightly below the reference range, and three others were slightly above the reference range. BE values were far below the reference range in all PT does, and slightly below the reference range in 15 controls. pCO2 values were below the reference range in all PT does and in 13 controls. BUN levels were slightly above the reference range in one PT doe and one control, and slightly below the reference range in six PT does and five controls.

In an effort to identify biochemical tests or clinical manifestations that might have prognostic value, data from the 19 fatal and three non-fatal PT cases were statistically analyzed. Age, vital signs, blood chemistry values, and the presence or absence of nine different clinical manifestations of PT were examined. No statistically significant differences were found between the fatal and non-fatal PT groups with respect to any of these measurements and observations.

The course of the disease was determined in the 19 fatal cases of PT in the study (Table 3). Fatal cases of PT lived 41 ± 27 hours after clinical signs were first observed. Eleven of 19 (58%) died within 24 hours, and only one lived longer than three days (Table 3). The case fatality rate was 86%.

Cesarean section was performed on eight PT does (36%). Parturition was induced in the other 14 PT does (64%) by injecting a combination of dexamethasone and dexcloprostenol. Seven of eight does in which caesarean section was performed died (88%) and one survived (12%). Twelve of 14 goats (86%) in which kidding was induced died and two survived (14%).

Medical treatments used to manage PT cases on the study farm (whether included in this study or not) are

described in the Materials and Methods section. Medical treatments administered to the PT does in this study, as well as the outcomes, are shown in Table 4.

Among PT cases, the mortality rate was 100% in the 11 does that had a blood pH of 7.122 or lower. In the remaining 11 does, which had a blood pH of 7.127 or higher, the mortality rate was 77.2% (eight of 11 cases). This particular "break point" was chosen because 7.127 was the lowest blood pH value observed in a PT doe that survived the disease.

A retrospective study was conducted in the latter group of 11 PT does. Three medical treatments (Treatments 1, 2, and 4) were significantly associated with survival ($P < 0.05$; Table 5). These treatments provided either glucose or a glucose precursor (propylene glycol). Treatments 1 and 4 also provided bicarbonate and calcium ions, respectively. Because all three of these treatments (except in two cases) were administered simultaneously, it was not possible to determine the specific treatment, or combination of treatments, that provided beneficial results. In general, intensive use of supportive treatments was significantly associated with survival ($P < 0.05$; Tables 4 and 5).

Use of Treatment 3 (intravenous glucose), Treatment 5 (intravenous flunixin meglumine), and Treatment 6 (intravenous bicarbonate administration, according to the base deficit) were not associated with survival. It is interesting that intravenous administration of 5% glucose solution (Treatment 3) was not beneficial. It is conceivable that administration of glucose or glucose precursors by routes that provide more gradual and sustained increases in blood glucose concentration (oral and subcutaneous) than the intravenous route might offer an advantage, at least in certain patients.

Causes of death in adult goats on this farm during 2009 and 2010 are summarized (Table 6). Although

Table 3. The course of pregnancy toxemia in 19 fatal cases.

Time from onset to death (hours)	Number of does
< 12	3 (16%)
> 12 to < 24	8 (42%)
> 24 to < 48	2 (11%)
> 48 to < 72	5 (26%)
> 72 to < 96	1 (5%)

Table 4. Individual identification numbers for does with pregnancy toxemia, blood pH values, medical and surgical treatments administered, and clinical outcomes.

ID #	pH	C/I	T 1	T 2	T 3	T 4	T 5	T 6	L/D
6584	**7.127**	**C**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**L**
6393	7.042	C	Y	Y	Y	Y	Y	Y	D
6231	6.802	C	Y	Y	Y	Y	Y	Y	D
8240	**7.293**	**I**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**L**
6780	7.096	I	Y	Y	Y	Y	Y	Y	D
7106	6.993	I	Y	Y	Y	Y	Y	Y	D
5194	**7.221**	**C**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**D**
6433	**7.308**	**I**	**Y**	**Y**	**Y**	**Y**	**Y**		**L**
8386	**7.347**	**I**	**Y**	**Y**	**Y**	**Y**	**Y**		**D**
8750	**7.131**	**I**			**Y**		**Y**	**Y**	**D**
7365	**7.274**	**I**			**Y**		**Y**	**Y**	**D**
646	**7.361**	**I**			**Y**	**Y**		**Y**	**D**
3833	7.008	C			Y			Y	D
2364	6.900	I			Y			Y	D
6260	6.961	C			Y			Y	D
6766	7.024	I			Y			Y	D
7405	7.122	I			Y			Y	D
5246	6.880	I			Y			Y	D
7673	**7.328**	**I**	**Y**				**Y**		**D**
3042	**7.236**	**C**			**Y**				**D**
366	6.764	C							D
7539	**7.320**	**I**							**D**

C = Cesarean section performed; I = parturition induced; T1 to T6 refers to the medical treatment provided (Y=yes); L = lived; D = died.

Table 5. Medical treatments administered and results observed in 11 does with pregnancy toxemia that had blood pH values above 7.122.

Medical treatments utilized	Number of treatments administered to does that died (Mean +/- standard deviation)	Number of treatments administered to does that lived (Mean +/- standard deviation)
Treatment 1: oral glucose, salt & bicarbonate solution	0.375 ± 0.52 (n = 3)	1.000 ± 0.00[x] (n = 3)
Treatment 2: oral propylene glycol	0.250 ± 0.46 (n = 2)	1.000 ±0.00[x] (n = 3)
Treatment 3: intravenous glucose	0.750 ±0.46 (n = 6)	1.000 ±0.00 (n = 3)
Treatment 4: subcutaneous calcium borogluconate	0.375 ±0.52 (n = 3)	1.000 ±0.00[x] (n = 3)
Treatment 5: intravenous flunixin meglumine	0.625 ±0.52 (n = 5)	1.000 ±0.00 (n = 3)
Treatment 6: intravenous bicarbonate	0.500 ±0.52 (n = 4)	0.667 ±0.00 (n = 3)
Total number of treatments administered to all eight does that died and to all three does that lived	2.875 ±0.53 (n = 8)	5.667 ±0.58[x] (n = 3)

[x]$P < 0.05$; n indicates the number of does.

PT was clearly the most important identifiable cause of adult goat mortality on this farm, more adult goats died of unknown causes during this two-year period than died of PT. A total of 2,001 does gave birth and 55 does died of PT during the two-year study period, therefore the morbidity and mortality rates for PT on this farm during 2009-2010 were 3.2% and 2.3%, respectively, assuming a case fatality rate of 86%. In addition to the deaths shown in Table 6, an additional 67 goats were culled because of health problems that included dental disease, lameness, chronic respiratory disease, and unexplained weight loss.

Discussion

Pregnancy toxemia results from competition for glucose between the doe (or ewe) and fetuses during rapid fetal growth in the third trimester of pregnancy.[3] In the present study, there were significantly more fetuses per doe in the PT group than in the controls. PT occurs most commonly in sheep and goats of the "improved" breeds, which are genetically programmed to become pregnant with multiple fetuses.

Excessively thin or obese pregnant does are most susceptible in late pregnancy. Obese does are at greatest risk of developing PT when pregnant with twins or triplets.[14,15,19] In addition to greater prolificacy, improved breeds tend to accumulate more abdominal fat than traditional breeds.[15,19] In obese does, the intra-abdominal cavity becomes filled with accumulated fat and an ever-expanding uterus during late gestation. This reduces space available for ruminal expansion, therefore these animals are unable to consume sufficient quantities of feedstuffs to satisfy energy requirements.[12,14] The seven PT does necropsied in this study were Saanens, and all had increased abdominal fat, a small rumen, and a fatty liver. Fatty infiltration and degeneration of the liver is almost always associated with fatal PT. Ruminants do not efficiently transport lipoproteins from the liver back into adipose tissues.[12]

Pen space provided for DD groups (21.5 square feet or 2 square meters per doe) was double the amount provided for other doe groupings on this farm. The intent of providing additional pen space was to encourage these does to exercise more. The importance of increased exercise to prevent PT in pregnant sheep has been reported.[3,11,14,18] Forced exercise in pregnant sheep was associated with reduced blood concentration of free fatty acids, presumably resulting from increased utilization.[3]

Seventeen does (77%) with PT were Saanens and five were Alpines, a breed discrepancy that was not significant ($P \geq 0.05$). Prior to this study, we have not observed greater abdominal fat deposition in Saanens during necropsy examinations than in Alpines. For this reason, we suspect that the predominance of PT in Saanen goats in this study was at least partially related to increased fetuses.

PT is typically limited to older does and ewes, more commonly occurring during the second or subsequent pregnancies.[14] The age of 21 of the does with PT were

Table 6. Causes of mortality in a group of 1,200 adult dairy goats during 2009-2010.*

Causes of mortality	Numbers of deaths	Proportion of all deaths (%)	Annual mortality rate (%)**
Unknown	87	29.3	3.6
Pregnancy toxemia	55	18.5	2.3
Dystocia	47	15.8	2.0
Weight loss	27	9.1	1.1
Respiratory disease	26	8.8	1.1
Metritis	19	6.4	0.8
Diarrhea disease	14	4.7	0.6
Mastitis	10	3.4	0.4
Trauma	6	2	0.3
Enterotoxemia	4	1.3	0.2
Heat stress	2	0.7	0.1
Totals	297	100	12.4

*Only deaths in animals that were 12 months of age or older are shown.
**Calculated by dividing the number of deaths over two years by 1,200, and dividing that by 2.

as follows: 2 years of age (2), 3 years (2), 4 years (7), 5 years (5), 6 years (3), 7 years (1) and 9 years (1). The age of the remaining affected doe was unknown, and the age distribution of does within the herd was also unknown.

There is increased demand for metabolites in pregnant animals that accompanies fetal growth, especially glucose and amino acids.[2] Studies in sheep have shown that ewes normally synthesize about 100 grams of glucose/day. However, during late pregnancy, this basal rate can increase to about 180 grams/day.[2] When the rate of glucose synthesis is too low to provide for combined requirements of the dam and the fetus(es), the dam can become hypoglycemic and ketotic.[2]

The ovine fetus has two mechanisms to insure survival and continued growth at the expense of the dam. First, the ovine placenta can transfer glucose to the fetus, even in the presence of very low maternal blood glucose concentrations. This is because the ovine fetus maintains a very low plasma glucose concentration (about 8 mg/dl), which facilitates transfer of glucose from maternal plasma. Secondly, the ovine fetus maintains a relatively high plasma fructose concentration (80-100 mg/dl), which functions as a carbohydrate reserve for fetal tissues. The fructose is synthesized entirely from glucose by the placenta, and cannot readily pass back through the placenta into maternal circulation. However, even though fructose is more abundant than glucose in the plasma of fetal sheep, the fetal tissues utilize approximately twice as much glucose.[2]

The increased demand for metabolites by the fetus in late gestation can overwhelm maternal capacity for mobilizing metabolic fuels, and can result in severe hypoglycemia, ketosis, and metabolic acidosis.[2] Ketone bodies (beta-hydroxybutyrate and acetoacetate) are strong acids,[2,5,18] and their accumulation in blood causes metabolic acidosis (ketoacidosis). This situation can progress to an irreversible stage, accompanied by dehydration and increased BUN.[18] Increased BUN can be caused by increased protein catabolism, decomposing fetuses or terminal kidney failure.[1] Experimental models of ketonemia show that systemic hypertension can occur in pregnant ewes, after as little as 24 hours of food deprivation. Renal dysfunction begins with the onset of hypertension, and may result in up to a 51% decrease in glomerular filtration, a rise in BUN values, and proteinuria.[3] During the present study, BUN was not significantly elevated (Table 2), and urine from eight of the 22 PT does did not contain abnormal amounts of protein. Perhaps pregnant does are not as susceptible to hypertension as pregnant ewes following food deprivation, or it is possible that does were observed in an earlier stage of the disease than ewes studied by Bulgin.[3]

Mortality from PT often exceeds 80% in untreated animals.[15] The course of untreated PT has been reported to range from 12 hours to one week,[19] typically between three and four days.[11] In this study, the case fatality rate for PT was 86% and fatal cases survived 41 ± 27 hours (Table 3).

Does at risk for PT should be closely observed at feeding time. Early PT cases tend to isolate themselves from pen mates, and do not come to the feed bunk when fresh feed is offered because of ketosis.[11,19] Helpful diagnostic aids include a strong ketone-positive reaction to urine ketone test strips, and a "fruity" ketone odor to the breath.[15] Unfortunately, it is much more difficult to obtain urine samples from does than from cows or ewes. However, a doe that has been recumbent will often urinate when forced to rise.[7]

In this study, complete anorexia was observed in all affected PT does, and ruminal atony occurred in 20 of 22 (91%) of cases. Polypnea was the next most frequently observed clinical sign, being present in 19 of 21 affected does (90%). Other clinical signs observed, in decreasing order of frequency, were drooping ears (12 of 22 does-55%), reluctance to walk (12 does-55%), swelling of the limbs (eight does-36%), inability to rise, stand and walk (five does-23%), and neurological signs (five does-23%).

Clinical findings most frequently associated with an unfavorable outcome were: neurological signs (5 of 5 died-100%), being able to stand up and walk normally (5 of 5 died-100%), lateral recumbency and unable to rise (3 of 3 died-100%), drooped ears (11 of 12 died-92%), polypnea (17 of 19 died-89%), and swollen limbs (7 of 8 died-88%).

Other clinical findings were also associated with a poor prognosis: sternal recumbency and unable to rise (1 of 2 died-50%), normal ear carriage (6 of 8 died-75%), absence of neurological signs (14 of 17 died-82%), prefer recumbency but able to stand and walk with urging (10 of 12 died-83%), and ruminal atony (17 of 20 died-85%). Others have reported that recumbency is considered to be indicative of a poor prognosis.[15] Because of the small number of surviving cases available for comparison, none of these observations reached statistical significance.

Subcutaneous edema of the limbs, which was present in eight PT does, has been reported by others.[19] On this farm, the condition occurred most often in conjunction with PT, but sometimes occurred as a primary disease problem in pregnant does without PT. Either both forelimbs, both hind limbs, or all four limbs have been affected. During the early stages of this problem, animals walked with varying degrees of difficulty. When affected limbs were closely examined, pitting edema extended from the coronary band up to the junction of the limbs with the body. Affected animals experienced varying degrees of discomfort or pain when edematous areas were compressed. Most clinical cases responded well to treatment with flunixin meglumine and/or induction of parturition. The etiology or pathogenesis of this condition is unknown, but the authors hypothesize that the edema in the PT cases in the present study was not caused by hypoalbuminemia.

Although mean blood pH was significantly lower in PT does than in controls, there was considerable variation in individual pH values in PT does, ranging from 6.764 to 7.361. Four with fatal PT had blood pH values within the reference range (7.32 to 7.500), while three PT does that survived had blood pH values of 7.127, 7.293, and 7.308. The mortality rate was 100% in 11 PT does with pH values between 7.122 and 6.764. In the other 11 PT does, which had blood pH values between 7.127 and 7.361, the mortality rate was 73%.

Compensated metabolic acidosis was present (as indicated by decreased blood pH, $HCO3^-$, BE, and pCO2) in does with PT (Table 2). In general, changes in pH of the extracellular fluid produces reciprocal H^+ and K^+ shifts between cells and the extracellular fluid. As a result, K^+ tends to move into the cells with alkalosis and out of the cells with acidosis. These pH-induced effects, however, are transient and frequently overridden by concurrent variations in other mechanisms that influence K^+ transport.[16]

All does with PT in this study were hypokalemic (Table 2). Reductions in blood K^+, Mg^{++}, and Ca^{++} values have been reported in ewes with PT;[11] however, to the best of our knowledge this is the first report where hypokalemia has been recognized as a consistent feature of naturally occurring PT in goats. Hypokalemia has been described in human patients with acute liver failure, including acute fatty liver of pregnancy.[10] In human patients with ketoacidosis and ketonuria, there is marked loss of K^+ in the urine leading to hypokalemia.[17] It seems logical that hypokalemia observed in PT does in the present study could have resulted from the same mechanisms that causes hypokalemia in human patients. On the other hand, goats with PT in the current study were not eating, and a reduction in dietary K^+ intake might have been at least partially responsible for the hypokalemia. This seems unlikely, however, in light of a recent study in which normal, non-lactating dairy goat does in advanced pregnancy with multiple fetuses were fasted for 72 hours in an attempt to experimentally reproduce PT. Although food deprivation resulted in modest reductions in blood pH, $HCO3^-$, and BE, blood K^+ levels were not affected.[9]

Reports on the use of propylene glycol for treatment of PT have not been uniformly favorable.[14] Oral administration of 120 ml of propylene glycol to PT ewes had little effect on blood glucose concentration, when compared with oral administration of 120 ml of glycerol or concentrated glucose solution (44.6 g in 160 mL of water).[4] There are at least two circumstances that could limit the effectiveness of propylene glycol therapy in PT patients. First, absorption of propylene glycol is limited in animals with ruminal atony,[6] which affects most patients with PT. Second, animals with marked steatosis (fatty liver) may be unable to effectively metabolize propylene glycol.[8] Some positive effects of oral propylene glycol administration have been demonstrated in ewes with mild cases of PT when combined with systemic administration of trenbolone acetate.[21] The adequacy of ruminal motility was not assessed in these ewes. It is possible that propylene glycol may be of value in certain PT cases, especially in mild cases, when ruminal function and hepatic metabolism are not yet severely compromised.

All three surviving PT does in this retrospective study had complete ruminal atony. Nevertheless, they

appeared to respond to a combination of three treatments that included oral administration of propylene glycol. However, because propylene glycol therapy was used in combination with other treatments, it was not possible to attribute the favorable results to any single treatment.

Although flunixin meglumine has been highly recommended for treatment of ewes with PT,[22] we have been unable to confirm clinical improvement, except possibly in PT does with swollen limbs.

Conclusions

The prognosis for PT in dairy goats maintained in intensive management systems, such as the one in our study, is very poor in spite of treatment. Consequently, the major focus in dealing with PT must be on prevention. Dairy goat breeds such as the Saanen and Alpine tend to accumulate large amounts of fat in the abdominal cavity, and the subsequent decrease in appetite and caloric intake puts them at higher risk for PT during late pregnancy. Consequently, it is very important to avoid overfeeding does, especially when they are declining in milk production or have been dried-off. Underfeeding during late gestation also increases risk for PT.

When PT occurs, the physical condition of affected does deteriorates rapidly. Consequently, owners of the most susceptible dairy goat breeds should be urged to carefully consider the comparative costs and benefits of all available treatment options, including euthanasia, and adopt a cost-effective plan for dealing with affected individuals that can be quickly implemented.

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Endnotes

[a]i-Stat, Sensor Devices Incorporated, Waukesha, WI
[b]Vetacort®, Vetoquinol, Barcarena, Portugal
[c]Gestavet-Prost®, Hipra, Lisboa, Portugal

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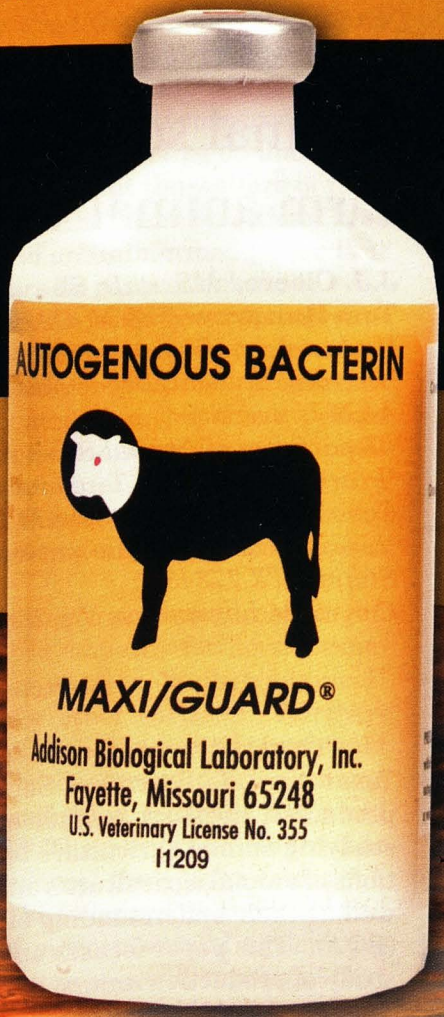

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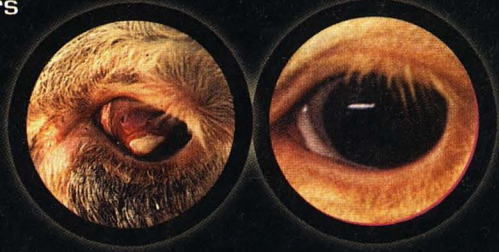

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