Obstructive urolithiasis is a common condition of male goats that is inevitably fatal without medical or surgical intervention. Affected animals may have urethral obstruction alone or develop secondary complications of ruptured bladder and uropertitoneum or ruptured urethra with subcutaneous urine pooling. Laboratory abnormalities associated with obstructive urolithiasis in most nonruminant species include azotemia, hyperphosphatemia, hypokalemia, and metabolic acidosis. Urolithic cattle have similar abnormalities, except that potassium and phosphorus may be either increased or within reference intervals; cattle also may have metabolic alkalosis. Azotemia is the only well-documented serum biochemical abnormality in urolithic goats. Because treatment often includes surgery with general anesthesia, knowledge of expected serum biochemical abnormalities is important in patient care. The purpose of the study reported here was to characterize the serum biochemical abnormalities in urolithic goats to determine whether they are similar to those reported in other species.

Criteria for Selection of Cases

Goats were included in the study if they had urolithiasis and if blood had been collected for serum biochemical analysis on entry to the hospital.

Objectives—To characterize serum biochemical abnormalities in goats with uroliths.

Design—Retrospective case-control series.

Animals—107 male goats with uroliths and 94 male goats with various nonrenal diseases (controls).

Procedures—For male goats, results of serum biochemical analyses collected from 1992 through 2003 were retrieved from computerized records, as were signalment, clinical diagnoses, and discharge status. Results of analyses for BUN, creatinine, phosphorus, calcium, Na, K, Cl, total CO₂, anion gap, and glucose were compared between goats with uroliths and control goats.

Results—Goats with uroliths had higher mean BUN, creatinine, total CO₂, K, and glucose concentrations and lower mean phosphorus, Na, and Cl concentrations than control goats, with no difference in mean calcium concentration and anion gap. Goats with uroliths had higher frequency of azotemia, hypophosphatemia, hypochloridemia, and increased total CO₂ and lower frequency of decreased total CO₂ than control goats. Urolithiasis occurred more frequently in castrated males than in sexually intact males and in dwarf African breeds than in other breeds.

Conclusions and Clinical Relevance—Goats with uroliths often had hypophosphatemia at admission. Hypochloridemic metabolic alkalosis was the most common acid-base disorder. Rupture in the urinary tract system was associated with increased prevalence of hyponatraemia and hyperkalemia. Clinicians should be aware of these abnormalities when determining fluid therapy. (J Am Vet Med Assoc 2007;230:101–106)
Results

Population characteristics—Overall, 68.2% of goats in this study had been castrated. Castrated goats comprised a significantly ($P < 0.001$) greater proportion of urolithic goats (80.4%) than in the population with nonrenal diseases (54.2%). Breed information was available for 185 of the 201 goats. Dwarf African goats were more likely to be evaluated for urolithiasis than either dairy-meat–type breeds or rare breeds ($P = 0.04$). There was no interaction between castration status and the likelihood of a breed type to develop urolithiasis ($P = 0.3$; Table 1). Ninety-six urolithic goats were discharged alive, whereas 11 did not survive (10 were euthanized and 1 died). Survival rate for urolithic goats was significantly ($P = 0.003$) higher than that of the nonrenal diseases population, which had 69 survivors and 25 nonsurvivors.

Ninety-five of the urolithic goats had urethral obstruction alone, whereas 7 also had a ruptured bladder and 5 had a ruptured urethra. Goats with secondary urinary tract rupture were significantly ($P = 0.02$) more likely to have a fatal outcome of their low number. On the basis of medical record information, goats were categorized according to breed type as dairy-meat (eg, Nubian, Alpine, Toggenburg, and Boer), dwarf African (Pygmy and Dwarf Nigerian), various rare breeds (eg, Angora and San Clemente), and unknown.

Serum analytes evaluated included BUN, creatinine, total calcium, inorganic phosphorus, Na, K, Cl, TCO₂, and glucose. Anion gap was calculated according to a formula ($Na + K – Cl – TCO₂$). Analytes of the urolithic and nonrenal disease goats were compared via differences in mean concentrations and the frequency of results outside of reference ranges for healthy goats provided by the UCDVMTH Clinical Chemistry Laboratory.

Statistical analysis—The unpaired $t$ test was used for comparison of means, and the $\chi^2$ test or Fisher exact test was used for comparisons of categoric data. Frequencies of abnormalities among urolithic goats with uncomplicated urethral blockage, ruptured bladder, or ruptured urethra were compared via stepwise logistical regression. Values of $P < 0.05$ were considered significant.

Table 2—Mean ± SD serum biochemical values in 107 goats with urolithiasis and 94 goats with various nonrenal conditions.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Urolithiasis</th>
<th>Nonrenal diseases</th>
<th>$P$ value</th>
<th>Reference range</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUN (mg/dL)</td>
<td>73.2 ± 68</td>
<td>26 ± 68</td>
<td>&lt; 0.001</td>
<td>19–31</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>6.3 ± 6.8</td>
<td>1.3 ± 0.9</td>
<td>&lt; 0.001</td>
<td>0.7–1</td>
</tr>
<tr>
<td>Calcium (mg/dL)</td>
<td>9.1 ± 1.0</td>
<td>8.9 ± 1.2</td>
<td>NS</td>
<td>9.2–11.7</td>
</tr>
<tr>
<td>Phosphorus (mg/dL)</td>
<td>4.0 ± 3.2</td>
<td>6.2 ± 4.8</td>
<td>0.002</td>
<td>4.2–9.1</td>
</tr>
<tr>
<td>Na (mmol/L)</td>
<td>146.6 ± 5.3</td>
<td>146.7 ± 5.5</td>
<td>&lt; 0.001</td>
<td>140–150</td>
</tr>
<tr>
<td>K (mmol/L)</td>
<td>4.5 ± 1.2</td>
<td>4.2 ± 0.7</td>
<td>0.006</td>
<td>3.4–5.7</td>
</tr>
<tr>
<td>Cl (mmol/L)</td>
<td>101.6 ± 9.2</td>
<td>106.9 ± 7.5</td>
<td>&lt; 0.001</td>
<td>101–112</td>
</tr>
<tr>
<td>TCO₂ (mmol/L)</td>
<td>27.8 ± 6.1</td>
<td>22.9 ± 6.1</td>
<td>&lt; 0.001</td>
<td>22–28</td>
</tr>
<tr>
<td>Anion gap (mmol/L)</td>
<td>19.8 ± 7.8</td>
<td>20.0 ± 8.7</td>
<td>NS</td>
<td>11–25</td>
</tr>
<tr>
<td>Glucose (mg/dL)</td>
<td>149.3 ± 62.8</td>
<td>117.3 ± 55.6</td>
<td>0.003</td>
<td>52–81</td>
</tr>
</tbody>
</table>

*$n = 93$ for urolithiasis group and 92 for nonrenal diseases group. NS = Not significant ($P ≥ 0.05$).
(4 dead/12 goats), compared with uncomplicated obstruction (7 dead/95 goats).

**Serum biochemical analysis**—The most striking differences between urolithic goats and goats with nonrenal diseases were the significantly higher mean BUN and creatinine concentrations and lower phosphorus concentrations in urolithic goats (Table 2). Phosphorus concentration was low in many urolithic goats over the whole range of creatinine values, whereas it was often increased along with creatinine in the comparison population (Figure 1). There was no significant difference in mean calcium values, although the means for both populations were slightly below the reference interval. Urolithic goats had slightly lower mean Na and Cl concentrations and higher K and TCO₂ concentrations than control goats, with no difference in mean anion gap. Both populations had mean glucose concentrations much greater than the reference interval, and urolithic goats had significantly higher glucose than goats with nonrenal diseases.

Comparisons of the frequencies of abnormal laboratory results were made (Figures 2–6). Urolithic goats had a higher frequency of hypercreatinemia and high BUN and a lower frequency of hypocreatinemia and low BUN, compared with nonrenal disease goats. Most of the urolithic goats were hypophosphatemic (67%), compared with 38% of nonrenal disease goats. Hyperphosphatemia was uncommon and similar in both populations. Hypocalcemia occurred in most goats without significant differences in prevalence between urolithic goats and the nonrenal disease goats. Hypercalcemia was extremely rare (n = 3 goats), and no statistical comparison was done for that abnormality.

Urolithic goats had a higher frequency of hyperkalemia, hypochloridemia, and high TCO₂ and a lower frequency of low TCO₂, compared with nonrenal disease goats. The frequencies of abnormal results are shown in Tables 3 and 4. Figure 1—Box-and-whisker plots of serum concentrations of phosphorus and calcium in goats. A box-and-whisker plot is a graphical representation of the distribution of a dataset. The box represents the interquartile range (IQR), which is the middle 50% of the data, while the whiskers extend to the adjacent values. The median is indicated by a horizontal line within the box. The outliers are marked with circles. In this case, the phosphorus concentration was low in many urolithic goats over the whole range of creatinine values, whereas it was often increased along with creatinine in the comparison population (Figure 1). There was no significant difference in mean calcium values, although the means for both populations were slightly below the reference interval. Urolithic goats had slightly lower mean Na and Cl concentrations and higher K and TCO₂ concentrations than control goats, with no difference in mean anion gap. Both populations had mean glucose concentrations much greater than the reference interval, and urolithic goats had significantly higher glucose than goats with nonrenal diseases.
disease goats. For Na and anion gap, the frequencies of abnormalities were low and there were no significant differences between the populations. Hyperglycemia was highly prevalent, with equal frequency in both populations, whereas urolithic goats were less likely to be hypoglycemic.

In the urolithic goat population, secondary urinary tract rupture resulted in significant differences in the frequency of abnormalities, compared with goats with uncomplicated urethral obstruction (Table 3). Goats with any type of urinary tract rupture were more likely to have azotemia, hyperkalemia, and hypochloridemia than were goats with uncomplicated urethral obstruction. In addition, goats with ruptured bladder were more likely to have hyponatremia and hypophosphatemia, abnormal TCO₂, and increased anion gap, compared with goats with urethral blockage alone.

### Discussion

The high prevalence of hypophosphatemia in urolithic goats was an unexpected finding because hyperphosphatemia is the expected result of postrenal obstruction or ruptured bladder in most domestic species. Only horses are similar to goats, with hypophosphatemia being characteristic of postrenal obstruction. The high prevalence of hypophosphatemia in these urolithic goats (67.3%) appeared to be associated with the condition because it was significantly higher than the prevalence in male goats that were ill from other conditions (37%). The hypophosphatemia could not be ascribed to early diagnosis and minimal metabolic derangement because it occurred in many severely azotemic goats, including goats with secondary urinary tract rupture (Figure 1). These results differed from previously published studies that found either no pattern of phosphorus abnormalities in experimental urethral obstruction or hyperphosphatemia in a combined population of goats and sheep with clinical urolithiasis.

Obstructive urolithiasis in most nonruminant species leads to hyperphosphatemia because renal excretion is the primary route for elimination of excess phosphorus. In contrast, healthy ruminants excrete little phosphorus through their kidneys because most excess phosphorus is eliminated through the gastrointestinal tract. Ruminant saliva contains a large amount of phosphorus to ensure sufficient supply of this element to the rumen microflora. Salivary phosphorus loss is balanced by a high rate of intestinal phosphorus absorption, with excess phosphorus lost in the feces. Endogenous phosphorus recycling is facilitated by the salivary glands’ lower threshold for plasma phosphorus uptake, compared with the renal excretory threshold. For many ruminants, almost all phosphorus in the glomerular filtrate is reabsorbed in the proximal tubules. Ingestion of a high-phosphorus diet is 1 cause of increased urinary phosphorus excretion. Decreased saliva production, caused either by ingestion of finely pelleted feeds or ligation of the parotid salivary duct, diverts phosphorus excretion to the kidneys and results in increased phosphaturia.

Although the urinary system is a minor route for phosphorus excretion in healthy ruminants, decreased GFR in cattle and sheep often causes hyperphosphatemia. Apparently, in these situations, less phosphorus is lost through the gastrointestinal tract because de-
creased rumination reduces saliva production. Excess phosphorus is diverted to the kidneys for excretion, but it is retained just as it is in most monogastric animals with decreased GFR. In the present study, hyperphosphatemia was detected in many of the azotemic goats of the comparison group, similar to the situation for cattle with prerenal azotemia. For most of the urolithic goats, however, a different metabolic balance for phosphorus must have occurred, preventing hyperphosphatemia in most of them despite decreased GFR.

Although relative unimportance of renal phosphorus excretion might explain the relative infrequency of hyperphosphatemia in urolithic goats, it cannot explain the high prevalence of hypophosphatemia in these goats. One possibility is that they were being fed a low-phosphorus diet, a known cause of total body phosphorus deficiency and hypophosphatemia in goats. Secretion of corticosteroids, epinephrine, or a combination of both from pain and stress could cause the hypophosphatemia found in this population. Administration of corticosteroids to goats induces hypophosphatemia within 12 hours. In humans, epinephrine causes a rapid decrease in serum phosphorus concentration, probably because of shifts into the intracellular space. The hyperglycemia found in most of the urolithic goats might have triggered hyperinsulinemia, which causes hypophosphatemia because of the phosphorus shift into the intracellular space. We could not eliminate the possibility that an interfering substance caused falsely low phosphorus concentration because specific validation of the laboratory’s phosphorus assay for goat serum was not performed. This possibility was unlikely; few substances are known to interfere with the molybdate technique used by the laboratory. Furthermore, because it is unlikely that any of these possible causes of hypophosphatemia would occur more frequently in urolithic goats than in the control population, the reason for the association between urolithiasis and hypophosphatemia remains unexplained.

Some human patients with recurrent urolithiasis from calcium-containing calculi are hypophosphatemic, yet have inappropriately high concentrations of urinary phosphorus. Prie et al propose that this syndrome is caused by a deficiency in renal reabsorption of phosphorus (ie, renal phosphate leakage). The association between hypophosphatemia and urolithiasis found in the present study raises the possibility of a similar renal phosphate leak that caused at least some instances of urolithiasis. Goats of dwarf African breeds of UCDVMTH. The finding that the most frequent electrolyte abnormalities included hypochloridemic metabolic alkalosis and hyperkalemia should help clinicians determine appropriate fluid therapy.

Results of this study offer some insights into laboratory abnormalities in male goats, irrespective of their disease. Hyperglycemia was the most frequent abnormality and was often quite marked. The high prevalence of hypocalcemia was an unexpected finding. Recently, hypocalcemia has been recognized as a frequent abnormality in hospitalized humans, cats, and dogs that are severely ill with numerous diseases. It may be that hypocalcemia is a fairly frequent complication of severe illness in goats.

Although this retrospective case-control series identified hypophosphatemia as a common abnormality in caprine urolithiasis, it was limited by lack of information on the phosphorus status of the goats prior to developing clinical urolithiasis. Prospective studies that include serum and urinary phosphorus measurements and determination of dietary phosphorus content are needed to determine the relationship between phosphorus balance and development of uroliths in goats.

References


