Chapter 15
Diseases of the Urinary Tract and Kidney

John Pringle

Reneal Disease in horses

1. Acute renal failure is a sudden, theoretically reversible inability of the kidney to function in clearing nitrogenous wastes while maintaining fluid and electrolyte homeostasis.

a. Patient profile. Acute renal failure can occur in horses of any age.

b. Clinical findings. Signs of acute renal failure are nonspecific and are often related to concurrent disease (e.g., colitis, diarrhea, exertional rhabdomyolysis). (1) Complaints include anorexia, depression, weakness, and decreased athletic performance. There may be abnormal frequency or volume of urination. Edema and increased water intake can also occur. (2) Oliguria is a characteristic finding with hemodynamic causes, whereas polyuria may be evident with acute renal failure caused by aminoglycosides.

c. Etiology and pathogenesis

(1) Etiology. As in all species, the inciting cause of reduced kidney function in horses can be prerenal, renal, or post renal. (a) Prerenal causes are factors that decrease blood flow to the glomerulus. These factors include severe hypovolemia due to dehydration, endotoxemia, or cardiac failure; vascular injury due to endotoxin; or compromised autoregulation of renal blood flow by prostaglandin synthase inhibitors [i.e., nonsteroidal anti-inflammatory drugs (NSAIDs)]. Many compounds are considered potentially nephrotoxic, but the mechanisms are not well documented. (b) Renal causes directly damage the kidney tissue. Many toxins have a specific site of action, such as the glomerulus or the proximal tubules. However, there are no tests available to diagnose the site of damage, which could then lead to the early recognition and removal of toxin. Renal causes include: (i) Nephrotoxic medications, such as aminoglycosides, certain sulfonamides, polymyxin B, phenylbutazone or other NSAIDs, and menadione sodium bisulfite (vitamin K3). (ii) Endogenous pigments, such as hemoglobin from acute intravascular hemolysis or myoglobin from a large release from muscle. (iii) Substances in various plants (e.g., oak, wilted red maple leaves, wild onion, white snakeroot) and some heavy metals (e.g., mercury), which might be contained in some blistering agents. (iv) Cantharidin, the toxin in blister beetles (signs of intestinal erosive disease overshadows any such accompanying toxicity). (c) Postrenal causes of renal failure impair the animal's ability to rid itself of the urine that has been produced. Postrenal causes in horses include mainly bladder rupture in newborn foals. Although uroliths can develop in adult horses, they less commonly cause urinary obstruction in contrast to other species.

(2) Pathogenesis. Regardless of the cause, the common elements of acute renal failure include the accumulation of nitrogenous wastes in blood, with serum creatinine elevations above 170 mmol/L, and blood urea exceeding 9 mmol/L. These changes do not occur until two-thirds to three-fourths of the nephrons are no longer functioning; therefore, lesser degrees of kidney damage do not result in detectable accumulations of nitrogenous wastes.
d. Diagnostic plan and laboratory tests
(1) Laboratory tests
(a) Elevated creatinine and urea reflect an inability to rid the body of nitrogenous wastes, but these results do not provide the localization of the problem or the cause. Serum electrolytes, including sodium, potassium, and chloride, are initially normal but can all decrease with diarrhea or polyuria.
(b) Urinalysis. A urine sample should be obtained to ensure urine flow.
(i) Urinalysis showing a urine specific gravity of less than 1.02 in the presence of clinical dehydration is suggestive of intrarenal disease.
(ii) The color of urine, the presence of the heme pigments myoglobin or hemoglobin, and the presence of free red blood cells (RBCs) or protein can be used to indicate possible underlying causes.
(iii) Sediment analysis normally reveals considerable mucus and calcium carbonate crystals, and casts are easily overlooked because they dissolve quickly in the normally alkaline urine of herbivores.
(2) Renal ultrasoundography may detect cystic or structural changes in the kidney or renal pelvis.
(3) Nuclear medicine techniques, where available, measure the glomerular filtration rate.
(4) Renal biopsy can be performed with ultrasound guidance or blindly, but, because there is the risk of serious hemorrhage, this test should be reserved for cases in which biopsy is an essential part of determining the prognosis.

e. Therapeutic plan
(1) The correction of fluid, electrolyte, and acid–base disorders is essential. The amount of fluids required should be based on the state of hydration. The packed cell volume (PCV) and total protein (TP) measurements can be used to estimate the fluid deficit.
(a) Oral fluids (e.g., water, isotonic saline, or a balanced electrolyte solution) are usually well tolerated, except in the case of acute renal failure associated with gastrointestinal disease (e.g., colitis). Electrolytes ideally should be tailored to the requirements identified by the serum electrolyte and blood gas analysis. Generally, a balanced electrolyte solution with a bicarbonate source, such as lactated Ringer's solution, is sufficient. Adult horses (400–500 kg) can be given 5–8 L of warm water or electrolytes every 30–60 minutes orally until rehydrated.
(b) Intravenous therapy should be reserved for patients with gastrointestinal problems.
(2) Furosemide, dopamine, or both are indicated in those horses that fail to begin passing urine. These horses have the anuric form of renal failure.
(3) Underlying diseases, such as sepsis or rhabdomyolysis, should be treated.
(4) Potentially nephrotoxic drugs (e.g., NSAIDs, aminoglycosides, sulfonamides), which can be far more nephrotoxic in the presence of dehydration, should be discontinued.

f. Prognosis for recovery is good but depends largely on the early detection of renal failure, appropriate treatment, and the ability to adequately treat concurrent disease.

g. Prevention includes providing adequate fluid therapy when there is circulatory compromise or exposure to potential nephrotoxins.

2. Renal dysfunction in the neonate is poorly understood.

a. Some newborn foals may have high serum creatinine levels detected shortly after birth. Although this finding may indicate a renal disorder, high serum creatinine levels can also occur because of a placental problem in the mare. In these cases, the serum creatinine should become normal within several days after birth, and the foal requires no specific treatment.

b. Newborn foals also can have hyperuricemic urine (1.06) for a short period after birth, which may only indicate renal immaturity.

3. Chronic renal failure is a progressive renal disease resulting from the continued loss of nephron function or population reduction. This disorder may be a sequela to acute renal failure. There are two broad categories of chronic renal failure in horses: glomerulonephritis and tubulointerstitial disease.

a. Glomerulonephritis is immunologically mediated and is the most common form of chronic renal failure in horses.

(i) Patient profile. This disorder can occur in horses of any breed, age, or sex.

(ii) Clinical findings. The signs noted in horses depend on the stage and severity of the renal damage. Chronic weight loss, anorexia, and polyuria with a consumption of large quantities of water usually are key findings. Also, if there is major glomerular damage, there may be dependant edema due to massive urinary protein loss, which results in hypoproteinemia.

(iii) Etiology
(a) The glomerular lesion is caused by circulating immune complexes to viral [e.g., equine infectious anemia (EIA)], bacterial (streptococcal), or parasitic antigens that deposit on the epithelial side of the glomerular basement membrane.
(b) Although less common in horses, the glomerular damage can also be the result of autoimmunity, characterized by the formation of antibodies against the glomerular basement membrane.
(c) Pathogenesis. The pathogenesis of both types of chronic renal failure involves a decreased glomerular filtration rate in which solutes that are normally filtered and secreted by tubules are retained. This leads to diuresis and an observed polyuria with a compensatory polydipsia.

(f) As a result of the reduced ability of the tubules to handle water and electrolyte, there is increased sodium, chloride, and phosphate in the urine. Decreased reabsorption of bicarbonate with increased hydrogen ion excretion may also result in acidosis.

(iii) Despite the increased filtration by the nephrons, uremia occurs, and long-term effects cause a moderate anemia, focal ulceration of oral and intestinal mucosa, uriniferous odor to the breath, and excessive dental tartar.

(5) Diagnostic plan and laboratory tests

(a) Laboratory findings
(i) Moderate azotemia and isosthenuria may be evident in affected horses with normal hydration.
(ii) Persistent proteinuria without hematuria is specific to glomerulonephritis.
(iii) Specific urine protein testing should be performed because the routine urine dipsticks often give a false-positive result for protein in alkaline or concentrated urine.
(iv) Hypoproteinemia or hypoalbuminemia may also be found in the serum if there have been prolonged losses.
(v) Hypercalcemia may be present, but this finding may indicate a diet high in calcium (e.g., alfalfa).

(b) A renal biopsy can be taken but may not be warranted because of the risk of hemorrhage and the lack of contribution to therapy and prognosis.

(6) Therapeutic plan. There is no effective treatment for glomerulonephritis because it is usually only recognized when permanent renal insufficiency has occurred. Usually, the disease progresses, and ultimately, the horse must be euthanized.
a. Corticosteroids may be administered to reduce the effects of the immune complex disease.

b. Diet. Horses that are stable and not markedly affected by the clinical effects of the disease can be managed with a high-quality carbohydrate diet and reduced protein (less than 10%) in feeds.

c. Plasma transfusions have been advocated to provide temporary relief of edema caused by hypoproteinemia.

(7) Prevention is not possible because the reasons for a specific horse developing the disease are unknown.

b. Tubulointerstitial disease

(1) Patient profile. This disease can occur in horses of any age or breed and may be related to a history of prior acute illness that caused acute tubular necrosis.

(2) Clinical findings

(a) Signs are similar to chronic renal failure of glomerulonephritis (see I A 3 a (2)), with the exception of edema of hypoproteinemia. Affected horses also have polyuria or polydipsia, but in certain management situations where water consumption is not readily observed, this may go unnoticed.

(b) On rectal palpation, the left kidney may be smaller than normal.

(c) Etiology. Tubulointerstitial disease may be a sequela to acute tubular necrosis, with reported causes in horses including vitamin K₃ administration, aminoglycoside or mercury toxicity, pyelonephritis, hydronephrosis, myoglobinuria from acute myositis, or nephritis. Often, however, the cause is not determined.

(b) Renal ultrasound can identify a renal mass or renal pelvis calculi.

c. A renal biopsy can be performed, but this test seldom provides information regarding the cause or directs treatment.

(5) Therapeutic plan. Long-term treatment is unlikely to be successful, but, because these horses are not losing protein in large quantities, they can often be maintained humanely by ensuring unlimited access to water, provision of a salt block, and good-quality feed with low calcium content (no alfalfa).

(a) Any prerenal component to the renal failure (e.g., diarrhea, dehydration) or any acute exposure to nephrotoxic drugs or agents should be corrected.

(b) Ancillary treatment may include anabolic steroids and B vitamins. Periodic serum monitoring of blood gases can be done, and if plasma bicarbonate drops below 18 mEq/L as a result of acid retention, the horse can be given sodium bicarbonate (225 g/day orally).

(6) Prevention. Horses with acute renal failure, particularly of hemodynamic or toxic causes, should be treated early in the course of disease and with sufficient amounts of fluid support to prevent this permanent renal tubular damage.

4. Pyelonephritis

a. Patient profile. Pyelonephritis mainly affects female animals. However, in certain circumstances (e.g., bladder paralys), males may also develop pyelonephritis.

b. Clinical findings. In horses, pyelonephritis is often subclinical, with the only detectable signs being frequent urination and pus in the urine.

c. Etiology and pathogenesis

(1) Etiology. Bacteria isolated from affected horses include coagulase-positive Staphylococcus species and Proteus species.

(2) Pathogenesis. In horses, this disorder can follow parturition, be associated with an urinary bladder atony or ectopic ureters (see II D), or may occur without any identifiable risk factor.

(a) Urine stasis, which occurs in ectopic ureter or bladder atony, is a recorded risk factor.

(b) The short urethra in females predisposes them to the development of ascending urinary tract infection, which leads to pyelonephritis.

(d) Diagnostic plan and laboratory tests

(1) Laboratory tests

(a) Pyuria is usually a hallmark of the disease and may be accompanied by proteinuria and hematuria. These urine changes can also be found in cystitis; however, evidence of renal involvement may be observed with systemic changes to blood samples (e.g., leukocytosis with a neutrophilia, hypogammaglobulinemia, high fibrinogen).

(b) Azotemia of renal failure may be noted but is not always present, because the infection may be restricted to the renal pelvis, may affect only one kidney, or may result in damage to less than two-thirds of the body's renal function.

(2) Renal ultrasound may be used to detect purulent debris in the renal pelvis or enlargement of the renal pelvis.

(3) Urine culture confirms the causative organism but does not indicate the extent of invasion in the urinary tract.

e. Therapeutic plan

(1) Any predisposing factor, such as ureteral ectopia or ascending urinary tract infection, should be treated. To assess the response to treatment, a catherized urine sample can be submitted for culture and cytology 1 week following the cessation of therapy to ensure that the urinary tract has returned to its normally sterile condition.

(2) Catheterization. When bladder atony or paralysis is the cause, the bladder should be emptied frequently by catheterization. However, a return to normal bladder function is needed for long-term success in treatment.

f. Prognosis. The long-term survival of affected animals depends on early detection and appropriate treatment. The correction of any predisposing urinary tract abnormality that may result in continued urine stasis also influences long-term recovery.

B. Renal disease in cattle

1. Acute tubular necrosis is reported as the most common cause of renal failure in cattle in selected areas of the United States and may be related to the increased risk of plant toxicities in those regions.

a. Patient profile. Acute tubular necrosis usually affects adult cattle when related to plant toxicity, but this disease can occur in cattle of any age when associated with the administration of nephrotoxic drugs.

b. Clinical findings

(1) Complaints are nonspecific and include mild depression, anorexia, dehydration, and decreased rumen motility or rumen stasis.

(2) Physical examination reveals an elevated temperature, pulse, and respiratory rate.

(a) A primary disorder (e.g., sepsis, diarrhea) may be obvious, predisposing the animal to the development of acute tubular necrosis.

(b) A bleeding diathesis may be seen in uremic cattle, along with recumbency.

(c) On rectal palpation, the kidney is likely a normal size and consistency.

c. Etiology and pathogenesis. Acute tubular necrosis can be caused by decreased renal blood flow, the administration of nephrotoxic drugs, or the ingestion of nephrotoxic plants. The management systems of cattle production may expose cattle to all of these causes.

(1) Decreased renal blood flow

(a) Hypovolemia. Acute severe volume depletion may be caused by diseases such as neonatal calf diarrhea, lactic acidosis ("grain overload"), or abdominal torsion (in older cattle).
2. Amyloidosis

(a) Hemodynamically mediated diseases (e.g., endotoxemia of mastitis or metritis) can also cause decreased renal blood flow.

(b) Severe ruminal distention (e.g., bloat, volvix indigestion) is another cause of decreased renal blood flow.

(c) Nephrotoxic drugs can cause tubular damage.

(i) The most commonly reported nephrotoxic reaction is aminoglycoside toxicity from neomycin.

(ii) Selected sulfonamides and the administration of outdated or excess doses of tetracyclines can also result in nephrotoxicity.

(iii) Acute intravascular hemolysis in cattle (or sheep) from copper toxicity results in tubular necrosis from endogenous pigment damage.

(ii) Plant toxins that result in tubular necrosis include oak (Quercus species), which is particularly common in the southeastern United States, and oxalate-containing plants, such as redroot pigweed (Amaranthus retroflexus). The effect of any nephrotoxic agent is enhanced by decreased blood volume or electrolyte (sodium, potassium) depletion.

(d) Diagnostic plan and laboratory tests. Failure of renal function is usually diagnosed by laboratory examination because clinical signs are seldom diagnostic.

(i) Serum creatinine and urea are increased, with urine specific gravity less than 1.022.

(ii) Proteinuria may be present. If the sample is analyzed rapidly before the destruction by alkaline urine, granular casts (an early finding in acute renal tubular necrosis) may be present.

(iii) Dehydration is suggested by the increased hematocrit and total plasma protein.

(e) Therapeutic plan

(i) Fluid therapy. The main goal of treatment is providing intravenous fluid and electrolytes to restore and maintain circulating blood volume, which ensures renal perfusion. Fluids should be isotonic, containing sodium, potassium, chloride, and calcium. Normal saline with small quantities of added potassium and calcium can be used.

(ii) Other treatments include administering appropriate antimicrobial therapy (if there is ongoing sepsis), discontinuing any aminoglycoside, sulfonamide, or tetracycline therapy, and relieving any abdominal distention.

(iii) Prognosis. Acute tubular necrosis is a highly reversible condition if detected early and treated appropriately, particularly if the condition is related to decreased renal blood flow. The prognosis is less favorable if there is sepsis associated with the tubular necrosis.

(iv) Prevention of acute tubular necrosis in cattle includes avoiding the use of potentially nephrotoxic drugs and restricting access to pastures that may contain plant nephrotoxins (e.g., oak).

3. Pyelonephritis

(a) Patient profile and history. Pyelonephritis usually occurs in adult dairy cows from November to May (i.e., during the time the cows are more likely to be stabled indoors). Recent urinary catheterization or artificial insemination may be found in the history.

(b) Clinical findings

(i) Complaints. Affected cattle may have an acute decrease in appetite and milk production, show reluctance to walk, and may have abdominal pain that could be confused with an intestinal obstruction. Although these signs are very similar to traumatic reticuloperitonitis (TRP), affected animals resist a withers pinch (in contrast to those with TRP) and are not sensitive to pressure at the xiphoid region.

(ii) Physical examination findings

(a) Urine. The urine initially has blood clots associated with short episodes of acute colic. As the disease progresses, frank pyuria may be present. Polka-kuiuria and hematuria are also seen.

(b) On rectal examination, the kidneys may be enlarged with a loss of normal lobulation. More chronic cases also have ureteral enlargement that can be palpated rectally.

(c) Etiology and pathogenesis

(i) Etiology. In cattle, Corynebacterium renale can cause pyelonephritis, sometimes in outbreaks. C. renale is found in clinically normal cattle, and the organism does not survive in the environment for a long period of time.

(ii) Pathogenesis

(a) Transmission occurs via mechanical means, such as tail switching, urine splashing, and the use of contaminated equipment (e.g., catheters, specula).

(b) Route of infection. When the organism gains entry, it ascends the urethra (not always bilaterally), invades the renal pelvis and medulla, and later invades the renal cortex, causing fibrosis.

(c) Manifestations of disease include:

(i) Toxemia and fever

(2) Amyloid infiltration into the small intestine, resulting in gastrointestinal lymphangiectasia and edema, intestinal malabsorption, and gastrointestinal motility dysfunction, is responsible for the intractable diarrhea and weight loss.
Cystitis

1. Patient profile. In large animals, cystitis is sporadic and uncommon. This disorder occurs mainly in adult females and is associated with recent parturition or breeding.

2. Clinical findings. The disease is observed in sows or gilts post breeding. Initially, some sows may have a vaginal discharge. Affected animals become ill suddenly, show profound depression and fever, and can die within 12 hours of the onset of clinical signs. Most affected sows die without premonitory signs.

3. Etiology and pathogenesis. The causative organism is commonly *Eubacterium suis*. Infection may be introduced at mating or may be residual from the previous farrowing. The relationship between mating and pyelonephritis is well established in sows.

4. Diagnostic plan and laboratory tests are the same as for horses (see I.A 4.d).

5. Therapeutic plan. Sows that show signs of urinary bleeding or dysuria after breeding should be treated prophylactically with antibiotics. To assess the response to treatment, a catheterized urine sample can be submitted for culture and cytology 1 week following the cessation of therapy to ensure that the urinary tract has returned to its normally sterile condition.

6. Prognosis is the same as for horses (see I.A 4.f).

II. LOWER URINARY TRACT DISORDERS

A. Cystitis

1. Patient profile. In large animals, cystitis is sporadic and uncommon. This disorder occurs mainly in adult females and is associated with recent parturition or breeding.

2. Clinical findings. The disease is observed in sows or gilts post breeding. Initially, some sows may have a vaginal discharge. Affected animals become ill suddenly, show profound depression and fever, and can die within 12 hours of the onset of clinical signs. Most affected sows die without premonitory signs.

3. Etiology and pathogenesis. The causative organism is commonly *Eubacterium suis*. Infection may be introduced at mating or may be residual from the previous farrowing. The relationship between mating and pyelonephritis is well established in sows.

4. Diagnostic plan and laboratory tests are the same as for horses (see I.A 4.d).

5. Therapeutic plan. Sows that show signs of urinary bleeding or dysuria after breeding should be treated prophylactically with antibiotics. To assess the response to treatment, a catheterized urine sample can be submitted for culture and cytology 1 week following the cessation of therapy to ensure that the urinary tract has returned to its normally sterile condition.

6. Prognosis is the same as for horses (see I.A 4.f).

B. Urinary incontinence is an uncommon problem in large animals and is associated with neurologic diseases (e.g., sacral fractures) in all species. In horses, urinary incontinence is associated with equine protozoal myelitis (EPM), equine herpes virus type 1 (EHV-1) infection, cauda equina neuritis syndrome, and sorghum or Sudan grass intoxication (see Chapter 11). Other causes of urinary incontinence are rare and sporadic, including bladder tumors, estrogen-responsive incontinence in mares, and anatomic defects (e.g., ectopic ureters; see I.I.D).

C. Patent urachus is discussed in Chapter 18 VI B. The urachus serves as a connection between the fetal bladder and the allantoic cavity, which should spontaneously close at birth.

D. Ectopic ureters

1. Patient profile. This congenital problem has been reported only sporadically in horses. However, it may simply be overlooked in other large animal species that are under less intensive observation. Although ectopic ureters have been reported in both sexes, they may be more readily detected in females because of more obvious urinary dribbling.

2. Clinical findings. Affected horses show urinary incontinence from birth but may appear able to void urine normally. Urine scald is evident around the perineum, but the horse may otherwise be clinically normal. In prolonged cases, ascending urinary tract infection may ensue, resulting in pyelonephritis and signs of systemic illness.

3. Diagnostic plan.
   a. The clinical sign of urine dribbling from birth is usually sufficient for a diagnosis.
   b. Cystoscopic observation of the aberrant entry of ureters to the bladder neck, urethra, or even vagina can confirm the diagnosis.
   c. Retrograde urography and intravenous excretory urography have been used effectively to determine the location of the ureters' entry into the lower urinary tract.

4. Therapeutic plan. When identified, the ectopic ureters should be surgically relocated to enter the bladder. If the ectopia is unilateral and the ipsilateral kidney is hydronephrotic, it can be removed surgically.

E. Bladder rupture in horses

1. Patient profile. Bladder rupture occurs most frequently in male foals, but it has been found in mares after dystocia and in other adult horses in isolated cases. In foals, the rupture is presumed to occur before or at parturition. This disorder is also increasingly recognized in recumbent newborn foals that require intensive care and may be a complication of iatrogenic increases in abdominal pressure while lifting or moving the foal.

2. Clinical findings.
   a. Foals appear normal at birth, with signs of depression beginning approximately 24–48 hours after birth.
   b. Mild but progressive abdominal enlargement develops, with fluid accumulation and a reduced interest in suckling.
   c. Foals may make frequent attempts to urinate but often pass only small amount of urine. These signs of straining may be mistaken for meconium impaction, but...
within several days, respiratory distress from the abdominal enlargement and severe depression from azotemia and fluid and electrolyte disturbances are evident. d. Patent urachus may be an accompanying abnormality.

3. Etiology and pathogenesis
a. With bladder rupture in male foals, the small diameter and increased length of the urethra allows pressure to build up within a distended bladder during foaling, causing the rupture of the dorsal body of the bladder (which is the weakest point). b. Some foals may also have a congenital bladder wall defect that predisposes to rupture during parturition, but there is little hemorrhage associated with the site of rupture.

4. Diagnostic plan and laboratory tests
a. The history and clinical findings are highly suggestive of bladder rupture. b. Abdominal ultrasound to confirm the presence of urine in the abdomen can also be performed. (1) Methylene blue can be instilled into the bladder. Its presence in a peritoneal fluid sample confirms the presence of urine in the abdomen. (2) Creatine level. Demonstration of an abdominal fluid creatine level that is at least two times higher than the serum creatine level also confirms the presence of urine in the abdomen. (3) Calcium carbonate crystals. In adult horses, calcium carbonate crystals (normally found in urine) can be detected in the affected animal's abdominal fluid. c. Laboratory studies. Characteristic changes on a serum electrolyte panel (e.g., severe hyponatremia, hypochloremia, and hyperkalemia) indicate uroperitoneum. The hyperkalemia can be severe enough to cause cardiotoxicity. Azotemia is a predictable finding in foals.

5. Therapeutic plan
a. Surgery. The tear or defect in the bladder requires surgical correction. However, because of the often profound fluid and electrolyte disturbances, initial correction of these metabolic abnormalities is essential before placing the animal under general anesthesia. b. Fluid drainage. The extravasated fluid in the abdomen, if causing severe abdominal distention, should be drained by a large-bore needle puncture to relieve the pressure on the diaphragm. c. Fluid therapy should be given in the form of normal saline to increase sodium and chloride levels. Dextrose (5%) should be added to help reduce the serum potassium. Additionally, foals may be acidotic and require sodium bicarbonate, which also helps reduce the serum potassium to less cardiotoxic levels.

F. Obstructive urolithiasis

1. Obstructive urolithiasis in ruminants is likely the most common and clinically important urinary tract disease of ruminants. Clinical disease occurs when calculi lodge in the urethra and cause urinary tract obstruction. The highest incidence of clinical signs of urolithiasis in cattle and sheep is noted during the early concentrate feeding period (i.e., fall, winter) and during cold weather when water consumption decreases.

a. Patient profile. Clinical disease is mainly seen in castrated males and is particularly common in feedlot and range-fed steers or wethers. Although bulls, cows, heifers, ewes, and rams also form urinary calculi, these cases less often develop into a clinical problem. (1) The female urethra is shorter and more able to pass urethral calculi than the male urethra. (2) In bulls, the urethra is up to 40% larger in diameter than in a similarly aged steer; therefore, bulls are less likely to become obstructed by uroliths.

b. Clinical findings vary with the site and completeness of urinary tract obstruction. (1) Partial or incomplete obstruction. Urine dribbling from the preputial (prepuce) or penis appendage. (2) Bloody urine. If the blood-tinted urine surrounding the prepuce may be evident, with white, powdery crystals precipitating around the preputial orifice. (3) Dehydration, feet slipping, and precocious sexual behavior may develop.

(2) Complete urethral obstruction. Bladder rupture occurs after 48–72 hours if the obstruction is not relieved.

a. Inappetence, depression, and colic signs (with kicking at the abdomen) may be evident. b. Treading. Steers shift their weight to opposing hind limbs (i.e., treading) and appear restless, getting up and down frequently. c. Teneleus may also be present, with palpable pulsations of the urethra and straining sufficient to prolapse the rectum. d. The preputial orifice hairs are dry. e. Sheep may also exhibit tail wriggling.

(3) Signs include grunting and grinding of the teeth (i.e., odontoprisis, bruxism).

(4) Rectal palpation may reveal a large and tightly distended urinary bladder.

c. Etiology and pathogenesis. The precipitation of urinary solutes around a nidus leads to the formation of calculi. This metabolic disorder is a combination of dietary, endocrine, and climatic factors. (1) Nidus formation. Factors involved in nidus formation include the administration of estrogen implants or the consumption of estrogenic feeds, vitamin A deficiency, or other factors that result in excessive urinary tract epithelial desquamation. (2) Urinary solute precipitation occurs for several reasons, including:

a. Increased concentration of urine solutes as a result of water deprivation in cold weather.

b. Heavy fluid loss, which may occur in hot weather.

c. Excessive mineral intake (which often occurs in feedlots), particularly with respect to a high phosphate intake.

(3) Mucoproteins in the urine act as cementing agents to solidify the solutes that have formed around the nidus. Therefore, increased mucoprotein favors calculus formation. Heavy-concentrate and low-roughage feeding and the pelleting of rations (common practice in most feedlot feeding regimens) greatly increase the quantity of mucoproteins in the urine.

(4) Calculi. Cattle usually have single, hard, discrete calculi, but there can be up to 200 calculi present in an individual animal's urinary tract.

a. Location

(i) Cattle. Stones most often cause obstruction at the distal portion of the sigmoid flexure of the penis. There is a natural stricture at this site, which is where the retractor penis muscles attach. (ii) Sheep and goats tend to have fine, sand-like calculi, which are located throughout the urinary tract but most often block the veriform appendix. (iii) With massive urolithiasis, obstruction may occur anywhere along the urethra in both cattle and sheep.

b. Types of calculi. Although several crystal types have been found in ruminant uroliths, the two main types are magnesium ammonium phosphate and silicate uroliths.

(i) Magnesium ammonium phosphate calculi are found most commonly in feedlot cattle and sheep fed high-concentrate and low-roughage rations. These calculi are highly insoluble in alkaline urine (pH of 8.5–9.5); thus, they precipitate readily in the normally alkaline urine of herbivores. These calculi are usually small, smooth, and soft, with a high recurrence because there are many present. (ii) Silicate calculi occur in range-fed animals in the Great Plains regions, with grazing on mature prairie grasses or wheat or oat stubble (which can contain up to 2% silica). Water in these areas can also be high in silicates. Silicate calculi are rough and hard, usually forming only a single calculus. Given the high level of silica in both diet and water,
there can be outbreaks of urinary tract obstruction resulting from this calcui at any time of the year in any age and gender animals.

(c) Sequelae of hrolithiasis include the rupture of the urethra, rupture of the urinary bladder, or both.

(i) Urethral rupture. The clinical lodged in the penis urethra, usually at the sigmoid flexure, and causes pressure necrosis of the urethral wall. Urine leaks into the subcutaneous tissue around the penis and accumulates in the subcutaneous connective tissue along the propuse, resulting in extensive edema along the abdominal floor (extending from the sigmoid flexure to the umbilicus). Usually, the leakage of fluid relieves the acute pain of urinary bladder distention, but over time, this fluid can cause toxemia and tissue necrosis with sloughing of the skin of the ventral abdomen.

(ii) Bladder rupture. Abdominal pain is no longer present, and there is bilateral fluid-filled distention of the abdomen (a "pear-shaped" abdomen). In contrast to urethral rupture, there is little or no detectable ventral edema in the preputial or umbilical region. On rectal examination, the bladder is not palpable.

d. Diagnostic plan and laboratory tests

(1) The clinical examination often is sufficient to make a diagnosis of either urethral or bladder rupture.

(a) Urethral rupture

(i) The ventral abdominal edematous swelling that is associated with the prepuce caudally to the level of the scrotum, accompanied by pain at the sigmoid flexure, is usually sufficient to make the working diagnosis.

(ii) In sheep and goats, the vermiform appendage is usually blocked with sabulous material. Examination of the penis tip often reveals a turgid cyanotic vermiform appendage. Blockage further proximal in the penis urethra is usually present.

(b) Bladder rupture

(i) In the patient with abdominal swelling, the five "Fs" of abdominal distention should be considered: fat, fluid, feces, fetus, and flatus. A fluid wave can usually be balled across the abdomen, and centesis of the abdomen with a large-bore needle readily yields a large amount of clear, acellular fluid.

(ii) Palpation of the penis at the sigmoid flexure may identify the site of obstruction, with pain induced on manipulation of the region.

(iii) On rectal palpation, the urinary bladder is usually nonpalpable. Although the abdomen is filled with fluid, this cannot be determined by per rectum palpation.

(2) Laboratory tests

(a) Serum biochemistry reveals an azotemic animal with a marked reduction in serum sodium and chloride. Potassium, however, does not increase markedly in ruminants with bladder rupture.

(b) An abdominocentesis fluid sample can be used to confirm ureperitoneum (see II E 4 b).

e. Therapeutic plan. The goals of treatment are to reestablish patent urethra and correct fluid, acid-base, and electrolyte imbalances.

(1) Cattle

(a) Medical therapy

(i) For early cases of urethral obstruction in which urethral or bladder rupture have not occurred, it is possible to attempt medical therapy by using tranquillizers (acepromazine at 20–40 mg/kg intramuscularly), smooth muscle relaxants, or antispasmodics (e.g., dipyrone). These agents can induce relaxation of the retractor penis muscle which allows the sigmoid flexure to straighten, producing a wider, stronger urethra. Some reports suggest a 70% effectiveness in early cases.

(ii) If there is no urine passage within 6 hours, these medications can be repeated, but surgery may be required. Rectal examination to assess bladder size and tumour can be used to assess the need for surgery.

(b) Surgery. In the case of urethral or bladder rupture, surgical intervention (under epidural anaesthesia) is required.

(i) A low urethrostomy at the distal part of the sigmoid flexure can be performed to expose and remove the calculus, suturing the incision site if the stone has not caused extensive necrosis.

(ii) A high perineal urethrostomy should be performed if local cellulitis or necrosis is present. The penis is transected proximal to the site of blockage and anchored to the skin. The more proximal urethra can be probed for evidence of additional calculus, but a urethral diverticulum at the level of the ischial arch usually prevents catheterization into the bladder. Tears in the bladder wall in bladder rupture usually heal spontaneously without requiring abdominal surgery.

(iii) In both urethral and bladder rupture, systemic antibiotics post surgery are advised. The correction of fluid and electrolyte losses with isotonic sodium chloride is indicated but is seldom performed in field situations. Animals with urethral or bladder rupture should be sent to slaughter as soon as they are no longer uremic.

(2) Sheep and goats

(a) Massaging the vermiform appendage free of the sandy debris should be attempted, but usually, the vermiform appendage needs to be amputated.

(b) Catheterization. Sabulous debris in the more proximal penile urethra can be flushed out by passing a catheter up the penile urethra and instilling small amounts of saline periodically.

(c) Surgery

(i) Urethrostomy (as performed in steers) may be indicated if other treatments fail. Even after establishing urethral patency, the bladder may not spontaneously empty immediately because of chronic distention and atony.

(ii) In the cases of urethral rupture with urine leakage in the subcutaneous tissues, small linear incisions in the overlying skin can be made to drain the urine that has collected and reduce the risk of extensive skin slough.

f. Prognosis. The survival rate for urethral rupture is approximately 90%, but for bladder rupture, the survival rate is 50%.

g. Prevention. Many dietary and management factors can affect the formation of urinary calculi and subsequent obstruction.

(1) Diet

(a) For animals with phosphate or magnesium ammonium phosphate calculi, the diet can be assessed to ensure a calcium to phosphorus ratio of 1:2. Adding ground limestone to the diet can help avoid precipitation of excess phosphate in urine. Urine pH can be acidified (using ammonium chloride in the feed), increasing the solubility of the calculi.

(b) For range-fed animals with silicate calculi, a common method of reducing problems with urinary blockage is to pasture only females or bulls on the high-risk pastures. Calculi still form but seldom result in urinary obstructive problems.

(2) Adequate water should be provided, particularly in cold weather when water sources may freeze.

(3) Increasing salt intake in the diet by up to 4% can also reduce calculi-related problems. Increased dietary salt forces diuresis (which prevents the crystallization of urinary solutes). Furthermore, in the case of phosphate or magnesium ammonium phosphate crystals, sodium causes chloride to displace the magnesium and phosphate, preventing these minerals from being deposited around nidus of the calculus.

(4) Delaying castration of steers until after 6 months of age can allow the development of a larger urethral diameter, but this delay may not be practical in range or feedlot animals.
Adequate vitamin A intake reduces nidus formation, and estrogenic implants can be avoided to reduce the mucoprotein content in the urine.

2. Obstructive urolithiasis in horses
   a. Patient profile. Cystic calculi (stones in the bladder) are not common in horses and seldom cause acute clinical signs of obstruction. Some males may develop stones that lodge in the urethra.
   b. Clinical findings. Persistent hematuria (or post-exercise hematuria) is often the only clinical sign. Otherwise, horses with cystic calculi can have mild recurrent colic, urine scalding of the perineum, stranguria, dribbling urine, or pollakuria. Weight loss and a stilted gait have also been reported. These bladder stones are usually readily palpable on rectal examination.
   c. Pathogenesis. Less is known about the formation of these calculi in horses than in ruminants, but the factors are likely similar because horses also have alkaline urine, which favors the deposition of carbonate and phosphate crystals. Calculi are usually solitary, large, and composed of calcium carbonate or phosphates. They tend to develop near the neck of the bladder.
   d. Diagnostic plan and laboratory tests
      (1) In addition to clinical findings, cystoscopy or ultrasound can be used to demonstrate or suggest the presence of a stone. Occasionally, calculi can be felt with a urinary catheter.
      (2) Urinalysis reveals crystals, as well as free RBCs and WBCs. Concurrent cystitis is also a common finding.
   e. Therapeutic plan. The stones can be removed surgically by either an abdominal approach or via urethrotomy in male horses. In mares, some stones can be removed manually through the urethra. Electrohydraulic lithotripsy has been used successfully in shattering the stones in situ for ease of removal.
   f. Prognosis. Horses that have had cystic calculi may have problems with chronic cystitis even after stone removal, and the calculi may recur.
   g. Prevention. In selected cases, diet supplementation with urinary acidifiers has helped prevent calculus formation.

2. Which one of the following statements regarding horses with chronic renal failure is correct?
   (1) Hypercalcemia may be present, but it appears to be dependent on diet because calcium levels can return to normal levels in low-calcium diets.
   (2) In glomerulonephritis, the glomerular lesion is caused by autoimmunity to the glomerular basement membrane, or less commonly, circulating immune complexes to viral or bacterial (e.g., streptococcal) antigens.
   (3) Chronic renal failure in horses is most commonly tubulointerstitial, rather than glomerular.
   (4) When recognized, glomerulonephritis in horses is best treated with corticosteroids to reverse the immunologic damage to the glomerular basement membrane.
   (5) Acute renal failure in ruminants can be associated with which of the following?
      (1) Neonatal calf diarrhea, abomasal displacement, and lactic acidosis ("grain overload") can be causes of acute renal tubular necrosis in cattle with their associated profound volume depletion.
      (2) Although aminoglycosides induce nephrotoxicity in all species, ruminants are usually spared from this risk because they rarely receive such drugs.
      (3) Administration of outdated or excess doses of tetracyclines has resulted in renal failure in cattle.
      (4) Copper toxicity in cattle and sheep causes acute renal tubular necrosis due to the cupric ion damage to tubular epithelium.
      (5) Plant toxins that result in renal tubular necrosis in ruminants include oak (Quercus species) and Russian knapweed (Centaurea repens).

3. Acute renal failure in ruminants can be associated with which of the following?
   (1) Renal amyloidosis occurs with approximately equal frequency in both horses and cattle, with signs of ventral edema, chronic intractable diarrhea, and weight loss, with the kidneys often uniformly enlarged on rectal palpation.
   (2) Cows affected by renal amyloidosis seldom have any other concurrent disease.
   (3) Ectopic ureters in large animals is a congenital problem with signs of urine dribbling from birth. Although this disorder has been reported mainly in horses and in both sexes, it may be more readily detected in females with more obvious urinary dribbling.
   (4) Ectopic ureters in large animals is usually only corrected for aesthetic reasons because, apart from urine scald, the animals seldom have any other associated complications.
5. Which one of the following statements regarding foals with bladder rupture is correct?

1. Bladder rupture occurs most frequently in female foals after dystocia or is otherwise most common in either sex; foal that is stepped on by the dam.

2. Foals appear normal at birth and within 6–12 hours become severely depressed because of azotemia and peritonitis.

3. Foals develop progressive abdominal distention and show signs of straining, which may be mistaken for meconium impaction.

4. If untreated, a main cause for mortality is hypocalcemic peritonitis.

5. Diastolic rupture occurs in female foals after dystocia or is otherwise similar to those in ruminants, with progressive azotemia and peritonitis.

6. Which one of the following statements regarding the prevention of urolithiasis in ruminants is correct?

1. For phosphate or magnesium ammonium phosphate calculi, the diet should have a calcium to phosphate ratio of 2:1, possibly by adding ground limestone to the feed.

2. For silicate calculi, the urine pH can be acidified using ammonium chloride in the diet, which can help avoid the precipitation of excess phosphate in the urine.

3. For silicate calculi that occur in range-fed animals, pasturing only females on the high-risk pastures is advised because the hormonal differences in the cows result in a lower risk of calculi formation.

4. For urolithiasis of most types of calculi, the dietary salt intake should be reduced until after 6 months of age can reduce the problem of urinary obstruction by stones because the testosterone influence prevents nidi formation.

7. Which one of the following statements regarding cystic calculi of horses is true?

1. Clinical signs of bladder stones in horses are similar to those in ruminants, with blockage of the urethra as the primary clinical sign.

2. The main type of stone in horses is silicate calcui, which results from high silica acid on certain pastures and oat feeds.

3. Cystic or bladder stones are usually best diagnosed by urine crystal analysis.

4. Finding high numbers of calcium carbonate crystals in the urine of horses without signs of urinary tract disease does not necessarily suggest the presence of a bladder stone.

6. Answers and Explanations

1. The answer is 4. Sows may die without premonitory signs. The causative organisms are coliforms and *Corynebacterium renale*. The high-risk factors associated with pyelonephritis are commonly bladder paralysis, urine stasis, or ureteral ectopia. Signs in pigs are usually peracute with death.

2. The answer is 1. A 3 a (5). Hypercalcemia may be present, but it appears to be dependent on diet because calcium levels can return to normal levels in low-calcium diets. In glomerulonephritis, the glomerular lesion is caused by autoimmunity to the glomerular basement membrane or, more commonly, by circulating immune complexes to viral or bacterial (e.g., streptococcal) antigens. Chronic renal failure in horses is most commonly glomerulonephritis, rather than tubulointerstitial. Although corticosteroids have been advocated, they do not reverse the damages to glomeruli.

3. The answer is 3. B 1 c. The administration of outdated or excessive doses of tetracyclines has resulted in renal failure in cattle. Diarrhea and grain overload can induce volume depletion, but it usually requires a torsion of the bursa for similarly severe vascular compromise. One of the most commonly drug-associated nephrotoxicities in the United States is from neomycin. Hopefully, this will soon be only a historical note with increased vigilance and care in medicating food-producing animals. Acute intravascular hemolysis that results in tubular necrosis from endogenous pigment damage. Although oak is toxic, ruminants can safely graze on pastures with Russian knapweed (see Chapter 11).

4. The answer is 3. D 1 2. Although ectopic ureter has been reported mainly in horses and in both sexes, it may be more readily detected in females with more obvious urinary dribbling. The clinical signs are appropriate, but horses rarely develop renal amyloidosis. Cows affected by renal amyloidosis often have a chronic bacterial infection (e.g., bovine, pulmonary abscission, peritonitis, metritis), leading to reactive systemic amyloidosis. Associated complications usually include urine reflux, the formation of hydroureter, and the predisposition of the animal to ascending urinary tract infection.