Urolithiasis: Review and case description of a Wagyu feeder steer with struvite crystalluria and urolithiasis treated with calcium boluses

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Abstract

Bovine urolithiasis, or formation of calculi in the urinary tract of cattle due to struvite crystalluria, is a life-threatening and painful disease. Clinical signs often go unnoticed until the prognosis of the animal is poor and immediate euthanasia is necessary. The author reports a treatment used to disrupt the disease process. The treatment allowed a valuable beef animal to comfortably complete its finishing stage without using medications that require a withdrawal period prior to harvest. A 27-month-old Wagyu steer in the finishing phase presented with inappetence, polyuria, dysuria and depression. Urinalysis showed an abundance of struvite crystals. Serum chemistry revealed a calcium:phosphorus ratio of 1.2:1. To avoid early harvest and progression of the disease, the steer was treated with over-the-counter calcium boluses, which were successful in dissolving the crystals. Daily urinalysis was used to determine the frequency of treatment needed. The author proposes an alternative method for treating struvite crystalluria and preventing subsequent urolithiasis in feeder steers.

Key words: bovine struvite crystalluria, bovine urolithiasis, finisher steers, calcium bolus

Introduction

Struvite crystalluria and impending urolithiasis are common findings in steers being fed large amounts of concentrated feed, especially if the calcium:phosphorus (Ca:P) ratio of the feed is less than the optimal ratio of 2:1 and water intake is decreased.[1] Struvites, a commonly found type of crystal in cattle urine, are known to form in the presence bacterial infections of the urinary tract, negative water balance, alkaline urine, hyperphosphatemia or a combination of the aforementioned.[1] Formation of uroliths from the struvites may result in blockage and rupture of the bladder or urethra. Prior to rupture, surgery may be performed; however, it is not always a practical option, and the cost can be higher than the value of the animal. Urolithiasis is the fifth most prevalent cause of death in feedlots,[2] and can cause significant economic losses to the beef cattle industry. This case study provides a review of urolithiasis, and the diagnosis, treatment and management of a 27-month-old Wagyu steer with struvite crystalluria and partially obstructive urolithiasis.

Review of urolithiasis in cattle

Etiology and pathogenesis

The etiology of urolithiasis is multifactorial: diet, geographic location, water intake and early castration.[1,3,4] Although crystalluria and urolithiasis can occur in both males and females, females are less likely to be affected due to a urethra that is shorter in length and larger in diameter than the male urethra. Thus, any calculi that form may be easily passed.[3] Males are more prone to the disease due to the presence of a sigmoid flexure of the urethra.[1] Bulls that are castrated at an early age lack the testosterone necessary to further develop the size of the penis and the diameter of its urethra and are more prone to blockages.[1] Diet is the greatest factor in urolithiasis.[1,4] The two most commonly found uroliths are struvites and calcium-based.[1] In feeder animals, high concentrate diets with improper mineral balances, particularly high in phosphorus and low in calcium diets, are the root cause of most struvite crystalluria. Struvite crystals are the most common calculi found in urolithiasis.[1] They are made up of magnesium ammonium phosphate and when combined with calcium carbonate apatite in the presence of mucoproteins and uroepithelial cells, they become calculi or stones.[1] Water sources that contain these minerals in excess can contribute to the disease; and decreased water intake, which allows urine to become concentrated and fewer particulates to be excreted, is also a contributing factor.

Geographic location may play a part in the disease process, in that, geographic areas have unique grazing options and hay types.[1,4] Calcium-based uroliths may develop in animals grazing on high-calcium clover or alfalfa or eating those types of hay. These legumes are grown across the United States and Canada, but are predominantly grown in the northern and western U.S. Silicate calculi are seen in animals grazing on sandy soil that contains high levels of silica as typically found in the western U.S. and Canada.[1,4] Cattle raised and fed in areas that grow and feed large quantities of sugar beet, which is high in oxalates, can experience calcite formation.[1,4]

Excessive minerals, such as calcium, silica and oxalates in a diet are primarily excreted in the urine. Ingested phosphorus is primarily excreted in the saliva, which becomes available for use in the rumen and can be reabsorbed along the gastrointestinal tract prior to being excreted in manure. When an animal is fed a diet high in concentrate and low in roughage, it produces a lower amount of saliva. Excessive amounts of phosphorus that cannot be excreted in the saliva and gastrointestinal tract are transported via the bloodstream to the urinary system, where they are excreted.[4] Since calcium has an inverse relationship with phosphorus, it is important that a proper ratio of the two minerals be in a diet. The Ca:P ratio in a beef cattle diet should be approximately 2:1.[5] The effective ratio may be affected by the bioavailability of the minerals used and the presence of vitamin D.[5] The formation of crystals from excess minerals in the urine occurs when there is a disruption of urine concentration and pH, and then uroliths form as the crystals accumulate in the presence of mucoproteins and mucopolysaccharides.[1] Mucoproteins originate from shed cells of the urinary tract from the kidney tubules downward.[6] Calculi formed from excess minerals can cause

injury to the urinary tract, which results in inflammation and swelling. The calculi alone or in addition to the resulting edema can cause partial obstruction or complete obstruction of the urinary tract. These calculi may be found in the kidneys, bladder and urethra, but are rarely found in the ureters.[4] Occasionally, urinary tract infections are a concurrent finding, due to partial urethral obstruction or inflammation.[1]

Clinical presentation

An early clinical sign of urolithiasis is the presence of mineralized granules that have the appearance of sand in the hair surrounding the prepuce. Other signs may be polyuria, stranguria, dysuria, hematuria, inappetence and depression.[1] As the disease progresses to partial or complete obstruction, the animal may become restless and kick at its abdomen, twitch its tail during urination or lie down and vocalize. Frequent attempts to urinate result in dribbling urine or the inability to urinate.[4] If a complete obstruction occurs and remains, the bladder or urethra will rupture. A ruptured urethra will present as subcutaneous swelling between the peripreputial area and the sigmoid region, while a ruptured bladder causes urine to accumulate in the ventral abdominal cavity,[3] which is commonly referred to as "water belly."

Diagnosis

Diagnosis is strongly suggested by history and clinical signs. Urolithiasis may be diagnosed by the presence of calculi in the hair surrounding the prepuce and crystals found in urinalysis.[7] A CBC and blood chemistry may reveal nutritional imbalances, infection and evidence of dehydration and azotemia. Urine culture may indicate infection. Partial or complete obstructions may be diagnosed via rectal palpation and ultrasound of the urinary tract.

Treatments

Oral treatment with ammonium chloride (233-333 mg/kg) is used to acidify urine and dissolve struvites that are associated with a high-grain diet.[1] Judicious anti-inflammatory use is warranted and a smooth muscle relaxant may be prescribed.[1] Patients with acute (<24 hours) urethral obstruction without bladder or urethral rupture will generally have mild bloodwork abnormalities and be better candidates for successful surgery.[8] Urethrostomy involves creating a stoma to the urethra in the perineal region dorsal to the sigmoid flexure, where blockages generally occur in steers and bulls. The opening allows access to the bladder to allow for draining and flushing. A urinary catheter should be placed in the bladder using a flexible endoscope to avoid the dorsal diverticulum located at the ischial arch.[8] Urethrostomy is considered a salvage procedure.[8] Surgery to repair urethral and bladder ruptures are largely unsuccessful treatments, but may be attempted knowing they have a poor prognosis.[1] Drug withdrawal times should be considered when selecting a salvage procedure for an animal to be slaughtered for beef.

Prevention and treatment

Understanding the cause and type of crystalluria and urolithiasis is essential to prevention and treatment. Diets that contain high levels of calcium, silicate or oxalates should be avoided. In the case of high-grain diets being fed, ensure a proper Ca:P ratio, use a urine-acidifying agent such as ammonium chloride, and increase water intake to promote excretion and dissolution of the crystals and formed stones. Offering free-choice salt and/or adding salt to the diet may encourage water intake. The chloride ions from the salt may bind with excess magnesium, which is more soluble than magnesium phosphate; and mucoproteins, which decrease phosphate binding resulting in reduction of calculi formation.[7] If urolithiasis is suspected in an animal showing signs of distress and crystals are discovered in the urine, it is crucial to administer pain medications and anti-inflammatories, as the animal is likely suffering from cystitis. Smooth muscle relaxants may also be administered.[1]

Case study

History

A 630 kg, 27-month-old Wagyu feeder steer, presented with tail switching, pollakiuria, oliguria, dysuria and inappetence during winter in northeastern United States. The steer had 24-hour access to a county water source, which he accessed through a Miraco E-Fount™ 3465-E with a thermostat-controlled heating element. The waterer was drained and cleaned at least once per month. Salt was available in the form of a 50 lb. (22.7 kg) mineral salt block, a 4lb. (1.8 kg) white salt block placed in the feed trough, a hanging Himalayan salt block and loose salt in a feed pan. He was one of a group of four finisher steers that were each fed approximately 20 lbs. (9 kg) of a corn and wheat middling-based feed per day along with free-choice first-cutting mixed-grass hay. The feed mix formula showed the Ca:P ratio to be 1.6:1, and a feed analysis found the actual ratio to be 1.7:1. The steers had 24-hour access to a pasture, dry asphalt area and shelter that was cleaned and bedded daily. The steer's surroundings revealed easy and free access to clean water, hay and salt.

Clinical findings

Physical examination revealed a bright, alert and responsive steer with a body condition score of 7 out of 9 and weight of 1,390 lbs. (632 kg). All vital signs were within normal limits. Small, mineral calculi were found on the hairs around his prepuce. A urinalysis was performed using a free-catch urine sample to look for suspected crystalluria. The observed urine flow did not indicate urinary tract obstruction; however, the steer twitched his tail while urinating, which indicated that he was experiencing discomfort. Moist oral mucous membranes and medium-yellow colored urine findings deemed the hydration status normal.

Therapeutic management

A presumptive diagnosis of partially obstructive urolithiasis was made and medical therapy was started. Meloxicam 15 mg tablets[a] (1 mg/kg PO) were administered daily as needed for pain and were chosen for ease of use. The oral pain medication was dissolved in molasses water and mixed with salt to entice increased water consumption. Urinalysis[b] using a mid-stream, free-catch sample collected in a sterile plastic vial revealed numerous struvite crystals (Figure 1A). Blood samples processed at Cornell University Diagnostic Laboratory on March 3, 2022, showed slightly increased lymphocytes 8.6 thou/uL (1.7 to 7.5 thou/uL), normal calcium 9.4 mg/dL (8.9 to 10.9 mg/dL) and high phosphate 7.8 mg/dL (4.1 to 7.3 mg/dL) concentrations[d]. A repeat urinalysis on March 10, 2022, showed no change in struvite numbers, and red blood cells

as well as cocci bacteria were seen. It is likely that the bacteria seen were the result of a contaminated urine sample, however, a long-acting ceftiofur[e] antibiotic (3.0 mg ceftiofur equivalents (CE)/lb or 6.6 mg CE/kg SQ) was administered at the base of each ear since a urine culture was not performed to confirm a urinary tract infection.

To dissolve the struvites and minimize the risk of recurrent urolith formation, a feed supplement was chosen that would both acidify the urine and address the Ca:P imbalance indicated by the bloodwork results. The steer was given a BoviKalc™ calcium bolus[f] comprised of 43 grams of calcium, including calcium chloride dehydrate, calcium sulfate and calcium sulfate hemihydrates. The combination of compounds provides quick and sustained calcium availability. To determine if the bolus was acidic enough to lower the pH of the urine, a 30% solution of the bolus in water was prepared and revealed a pH of 6.0. The following day, a urinalysis revealed that it was acidic enough to dissolve the struvites. Daily urinalysis showed that the bolus prevented new struvites from forming for 3 days. A second bolus was administered, and again, the struvites dissolved and only trace amounts were detected after 3 days. The large size, high cost and concern about administering too much calcium prompted the search for an alternative product. The BoviKalc™ boluses[f] were replaced with Quadrical™ mini boluses[g], which each contain 10 to 12 grams of calcium chloride, calcium sulfate, calcium propionate, calcium lactate, niacin and vitamin D, which allowed more control over the amount of calcium to administer. The varied calcium compounds provide rapid, intermediate and sustained absorption of calcium, and vitamin D aids absorption.[5] The recommended daily requirement of calcium for growing and finishing cattle on an as fed basis is 0.31% of the total diet, which should consist of 1.5 to 2% of the animal's body weight.[5] The steer's diet was calculated at 1.5% of his body weight, so that percentage was used to calculate his recommended daily requirement of calcium.

632 kg × 1.5% = 9.48 kg feed × 0.31% = 0.0294 kg calcium or 30 g of calcium.

The 9.48 kg diet consisted of a finisher feed (85% or 8 kg) and mature, first-cutting hay (15% or 1.4 kg). The finisher diet contained 0.61% of calcium as fed and a hay analysis was not available to determine calcium content.

The steer was already getting macronutrients from his grain, so to avoid hypercalcemia, one Quadrical™ bolus[g] was administered. Urinalysis showed the beginnings of struvite dissolution. Two boluses were administered the next day and there was a remarkable dissolution of struvites (Figure 1B). The struvites continued to dissolve and only trace amounts were observed for 5 days before they began to return (see Figures 1C and 1D). Urinalysis also revealed red blood cells, which possibly indicated moving calculi or irritation to the ureter or urethra lining due to crystals. Daily urinalyses were performed to monitor the formation of struvites. Treatment with 2 Quadrical™ boluses[g], administered every 3 days or when struvites reappeared, was successful at keeping the struvites under control until he was harvested on April 25, 2022. The steer appeared to be comfortable the last 10 days prior to harvest, so treatment was discontinued.

Antibiotic administration did not have an effect on the number of bacteria seen in the urine sample, so a urine culture was performed using Accumast™ tri-plate[h] to rule out infection. The sample was incubated[i] and the results showed coagulase-negative staphylococcus growth. This finding was likely a result of normal skin flora in the prepuce, since blood work did not indicate the presence of infection, and white blood cells were not seen in the urinalysis. Other testing included a feed analysis. Feed samples were submitted to Dairy One Co-op, Inc. for mineral analysis to assist with reformulation of the feed. The results showed a Ca:P ratio of 1.7:1. A second blood chemistry on April 12, 2022 showed increased potassium 8.9mEq/L (4.0 to 5.9mEq/L), increased chloride 101mEq/L (92 to 99mEq/L), increased creatinine 1.0 mg/dL (0.1 to 0.9 mg/dL), increased phosphates 8.6 mg/dL (4.1 to 7.3 mg/dL), decreased GGT 7 U/L (17 to 54 U/L) and increased creatine kinase 428 U/L (88 to 292 U/L)[j].

Treatment using calcium boluses controlled the steer's disease process and eliminated the subsequent need to use pain medication and antibiotics, and the animal could be harvested for beef. The abattoir granted a request for kidneys and urinary tract. The author performed a post-mortem on the organs. The kidneys appeared normal except for a few discreet, ill-defined, 0.04 to 0.24 inch (1 to 6 mm), pale spots on the exterior surface of the renal lobes (see Figure 2A). Upon examination of the urinary tract, the apex of the bladder mucosa revealed red spots indicative of inflammation (Figure 2B). The urine contained small calculi that resembled sand particles (Figure 2C). Microscopic examination of the calculi revealed that they were composed of struvites.

Discussion

The objective for this case was to find an alternative for current, standard treatment of struvite crystalluria and urolithiasis, which includes early harvest of the affected animal, or treatment with ammonium chloride fed at a rate of 233-333 mg/kg to acidify the urine and dissolve the crystals.[1] A urinalysis was performed on the other steers that were being fed with the affected steer. Two of the samples collected had no struvites and one showed only a few crystals, so they did not require treatment. Treating an individual animal with ammonium chloride can be challenging when animals are fed in a group, and it is difficult to determine if the affected animal's intake is adequate. Even if the animal is separated for feeding, the addition of ammonium chloride to the feed can make it unpalatable. Ammonium chloride boluses, which can have a pH as low as 4.5, can be prepared and administered; however, too much acid in the rumen may destroy beneficial bacteria and cause rumen acidosis. This may result in weight loss and inappetence, and does nothing to address a possible primary cause, which may be an incorrect Ca:P ratio. The ideal ratio for feeder steers is approximately 2:1.[5] Even if a diet is formulated to yield that ratio, animals metabolize nutrients differently, and nutritional values of ingredients vary and have different absorption rates. For example, some forms of calcium are more absorbable than others and the presence of vitamin D increases the efficiency of calcium absorption.

This case report describes the early diagnosis and treatment of struvite crystalluria and urolithiasis using over-the-counter calcium boluses, which allowed an animal to comfortably complete the finishing phase prior to harvest. The calcium boluses dissolved the struvite crystals and provided comfort for the steer. During experimentation with the number and frequency of boluses needed to dissolve struvites, the steer exhibited some signs of discomfort when struvites were present and Meloxicam[a] was administered. Once a pattern of

Table 1: Data collected during testing and treatment of 27-month-old steer with urolithiasis and crystalluria.

							Boluses**		Microscope			Dipstick			
	Date	Meloxicam	Blood draw	Ultra-sound	Urine culture	Excede™ 21 ml	Bovikalc™	Quadricalc™	Sruvites	Cocci bacteria	RBCs	Blood Hemo/Non	pH	Protein	Leukocytes
M	2/28/2022								+++	–	–	–	>9	Tr	–
T	3/1/2022	40	X	X											
W	3/2/2022	40													
R	3/3/2022	40							+++	–	–	H+10	>9	Tr	–
F	3/4/2022	40													
Sa	3/5/2022	40													
Su	3/6/2022	40													
M	3/7/2022	40													
T	3/8/2022	40													
W	3/9/2022	40													
R	3/10/2022	40							+++	+++	+++	H+++250	>9	+30	–
F	3/11/2022	40				X	1								
Sa	3/12/2022	40							–	++	–				
Su	3/13/2022														
M	3/14/2022					X			+	++	+	NH+10	>9	++100	–
T	3/15/2022						1		++*	+	–	–	>9	Tr	–
W	3/16/2022								–	+	+	H&NH+10	6.5	Tr	–
R	3/17/2022	42				X		1	++	+	+	H&NH+10	8.5	+30	–
F	3/18/2022	42						2	++*	+	+	NH+10	7.5	+30	–
Sa	3/19/2022				Neg				–	+	+	H&NH++50	8	–	–
Su	3/20/2022	42							Tr	+	+	–	8.5	Tr	–
M	3/21/2022								Tr	+	–	–	8.5	–	–
T	3/22/2022								Tr	+	–	–	9	–	–
W	3/23/2022							2	Tr	+	++	H&NH+10	8.5	+30	–
R	3/24/2022								–	+	+	NH+10	9	+30	–
F	3/25/2022							2	Tr	+	++	H&NH+10	9	+30	–
Sa	3/26/2022	40							–	+	++	H&NH+10	8.5	–	–

Table 1 Continued:

Su	3/27/2022														
M	3/28/2022								–	+	+	H+5	8.5	–	–
T	3/29/2022								–	+	–	–	9	–	–
W	3/30/2022							2	+++	+	–	–	9	–	–
R	3/31/2022								–	+	–	–	9	–	–
F	4/1/2022							2	+	+	–	–	8.5	–	–
Sa	4/2/2022														
Su	4/3/2022														
M	4/4/2022							3	*++	+	–	–	8.5	–	–
T	4/5/2022								–	+	–	–	7	–	–
W	4/6/2022							1	+	+	–	–	9	–	–
R	4/7/2022							2	+	+	–	–	8.5	–	–
F	4/8/2022		X						Tr	+	–	–	7.5	–	–
Sa	4/9/2022							2	+	+	–	–	8.5	–	–
Su	4/10/2022														
M	4/11/2022							2	*++	+	–	–	8.5	–	–
T	4/12/2022								-	+	–	–	8.0	–	–
W	4/13/2022								Tr	+	–	–	9.0	–	–
R	4/14/2022								Tr	+	–	–	9.0	–	–
F	4/15/2022							2	+	+	–	–	9.0	–	–
Sa	4/16/2022								–	+	–	–	9.0	–	–

* Struvite fragments
** Boluses were administered after the urinalysis was completed
\+ Few present
++ Some present
+++ Many present
Blood – Ery/µL
H - hemolyzed
Meloxicam tablets - 15 mg/tablet (1 mg/kg). As the steer gained weight, the dose increased.
Neg – negative
NH – non-hemolyzed
Protein – value is mg/dL
RBCs – red blood cells
Tr - trace

successful treatment was established and the crystals were dissolved, no anti-inflammatories or pain medications were required and the animal continued to eat and gain weight. An added benefit is that there are no drug withdrawal time requirements using the calcium boluses prior to harvest. The ability to harvest an animal with short notice isn't always an option. Some areas of the country have few slaughterhouse locations and appointments are booked a year in advance. Even if an appointment for an animal was procured, an animal may not be ready for harvest, and the producer would experience an economic loss due to small carcass size or, in the case of Wagyu, incomplete intramuscular marbling.

The use of calcium boluses appears to be an effective, short-term method of dissolving struvite crystals and calculi. Their effectiveness may be due to their ability to lower urine pH and dissolve calculi, the binding effect that calcium has on phosphorus in the gut to correct a low Ca:P ratio, or a synergistic effect of both. It is unknown why this steer was the only one in his contemporary group to experience the problem. Only 1 urine sample from the other 3 animals fed alongside the affected animal revealed a few struvites.

Figure 1: 400X Microscope views of urine collected from a 27-month-old steer with urolithiasis and crystalluria. **A)** Struvites on March 10, 2022 before treatment. **B)** Struvite fragments on March 18, 2022 after the steer was treated with 3 Quadrical™ boluses. **C)** Only a trace of struvites remained on March 22, 2022. **D)** March 23, 2022 struvites returning 5 days after the last calcium bolus treatment.

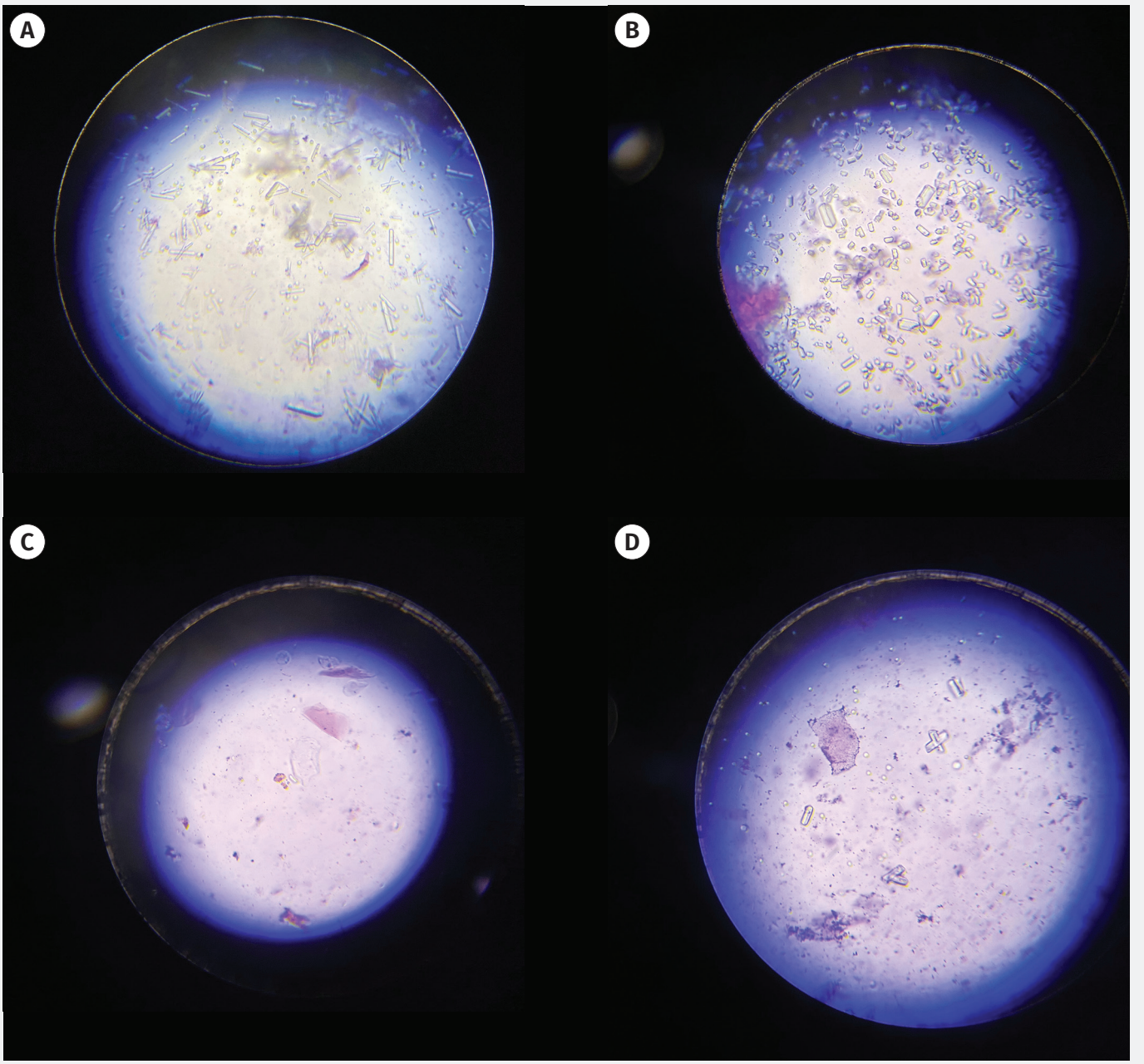
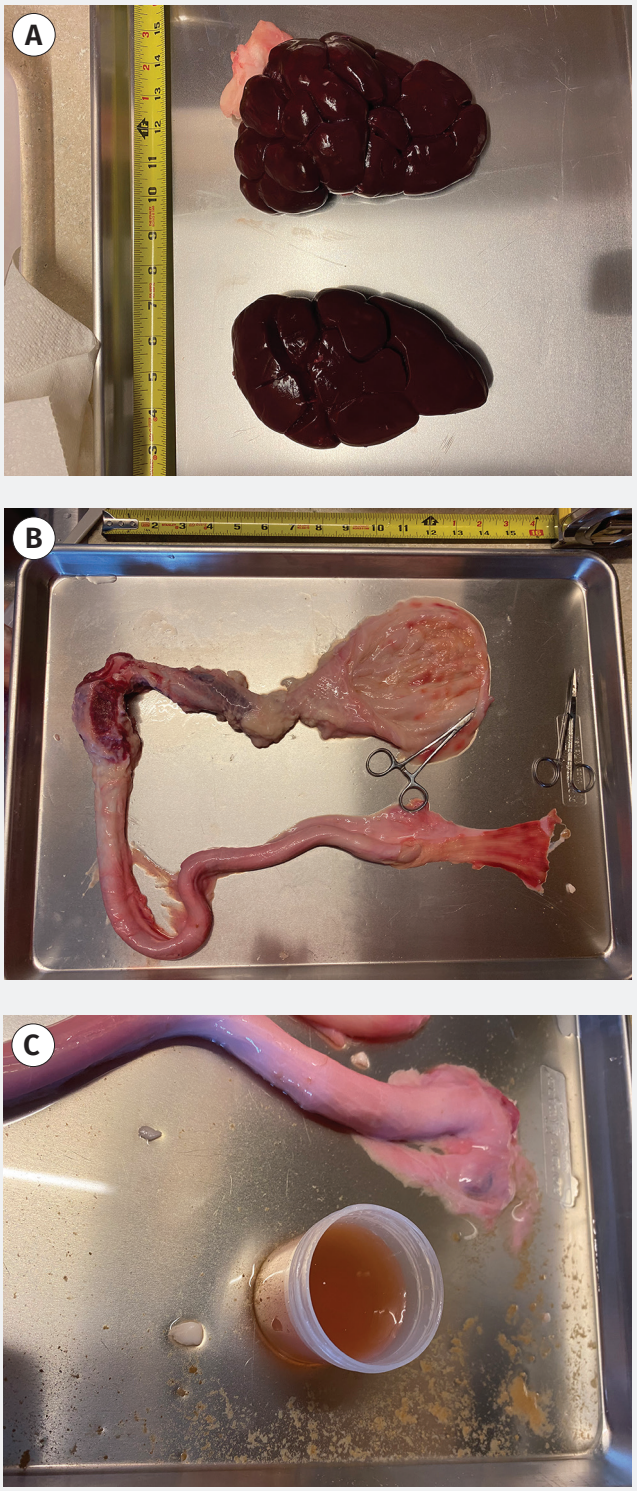


Figure 2: Organs harvested from a 27-month-old steer that suffered from urolithiasis and crystalluria. **A)** The kidneys appeared normal except for a few discreet, ill-defined, 0.04 to 0.24 inch (1 to 6 mm), pale spots on the exterior surface of the renal lobes. **B)** Upon examination of the dissected urinary tract, the apex of the bladder mucosa revealed red spots indicative of inflammation. **C)** Urine obtained from the bladder contained small calculi that resembled sand particles. Microscopic examination of the calculi revealed they were composed of struvites.



Conclusion

Over-the-counter, inexpensive, easy to administer, calcium boluses dissolved struvites in the bovine urinary tract. Long-term treatment requires an analysis and rebalancing of the feed ingredients. Fresh, unfrozen, and clean water should be available to the animal at all times. Loose salt as well as salt blocks should be placed near the feed and water areas to encourage water consumption, especially in colder weather. Urolithiasis in this Wagyu steer was successfully managed, and allowed the completion of his finishing phase. The resulting carcass was exceptional and resulted in high levels of intramuscular marbling at harvest.

Endnotes

[a]Meloxicam 15 mg Tablets. Zydus Pharmaceuticals, Pennington, NJ.

[b]Urinalysis: Mid-stream, free-catch urine sample collected in sterile plastic vial. Sample placed into glass conical test tube and centrifuged at medium-high speed for 10 minutes. Supernatant poured off and 1 drop of Sedi Stain™ added. One droplet of sample applied to a glass microscope slide and a cover slip added. A minimum sample of 20 fields was viewed.

[c]One Step Vet-10™ urine dipsticks. Exp. 09/2023. DFI Co., Ltd., Korea.

[d]Cornell University Diagnostic Laboratory Bloodwork, March 3, 2022: Lymphocytes 8.6 thou/uL (1.7 to7.5 thou/uL), Calcium 9.4 mg/dL (8.9 to 10.9 mg/dL), Potassium 6.3 mEq/L (4.0 to 5.9mEq/L), Phosphate 7.8 mg/dL (4.1 to 7.3 mg/dL).

[e]Excede. Zoetis Animal Health, Parsippany, NJ.

[f]Bovikalc™ bolus: 43 grams of calcium per bolus. Calcium chloride dihydrate, calcium sulfate, calcium sulfate hemihydrates. Boehringer Ingelheim Animal Health USA, Inc., Duluth, GA.

[g]Quadrical™ mini bolus: 10-12 grams of calcium per bolus. Calcium chloride, calcium sulfate, calcium propionate, calcium lactate, niacin, D3. Bio-Vet, Inc., Barneveld, WI.

[h]Accumast Tri-plate™. Exp. 09/2022. Fera Diagnostics and Biologicals, College Station, TX.

[i]Vevor™ Incubator operated at 37°C. Vevor, Cucamonga, CA.

[j]Cornell University Diagnostic Laboratory Bloodwork, April 12, 2022: Calcium 9.2 mg/dL(8.9 to 10.9 mg/dL), Potassium 8.9mEq/L (4.0 to 5.9mEq/L), Chloride 101 mEq/L (92 to 99mEq/L), Creatinine 1.0 mg/dL (0.1 to 0.9 mg/dL), Phosphate 8.6 mg/dL(4.1 to 7.3 mg/dL), GGT 7 U/L (17 to 54 U/L) and Creatine Kinase 428 U/L (88 to 292 U/L).

Author contributions

The author is responsible for the following: study conception and design, data collection, urine testing, analysis and interpretation of results and manuscript preparation.

Conflict of interest statement

There are no conflicts of interest. The case study animal was treated in an ethical manner and was treated using conventional, best-practice methods.

Funding

The costs associated with this case study were paid by the author.

References

1. Divers TJ. Urolithiasis in Ruminants. In: Winter AL, Moses MA, Roman NJ, Textor J, Hiebert S, Prouty L eds. *The Merck Veterinary Manual* 11th ed. Merck & Co., Inc.; 2022:890-893.

2. Makhdoomi DM and Gazi MA (2013) Obstructive urolithiasis in ruminants – A review, *Vet World* 6(4):233-238.

3. Urogenital disorders. In: Blowey RW, Weaver AD ed. *Color Atlas of Diseases and Disorders of Cattle* 3rd ed. Mosby Elsevier; 2011: 173-176.

4. Urolithiasis. In: Chase C, Lutz K, McKenzie E, Tibary A eds. *Blackwell's Five-Minute Veterinary Consult Ruminant* 2nd ed. Wiley Blackwell; 2019: 828-830.

5. *Nutrient Requirements of Beef Cattle: Eighth Revised Edition* The National Academies Press; 2016.

6. Grant HG. The proteins of normal urine from the urinary tract. *J Clin Path* 1959;12:510-517.

7. Divers TJ. Urinary tract disorders in cattle. *Bov Pract* 1989;24:150–153. **https://doi.org/10.21423 bovine-vol0no24p150-153**.

8. Van Metre DC,Ortved K. Urolithiasis. In: Fubini SL, Ducharme NG eds. *Farm Animal Surgery* 2nd ed. Elsevier; 2017: 584-591.