Ureteral Obstruction in Dogs and Cats

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ABSTRACT

Ureteral obstructions in dogs and cats have been recognized as a common cause of acute uremia. The diagnosis and management of this disorder is challenging, often necessitating special diagnostic and treatment modalities as well as special surgical skills. Recently, with the development of interventional radiology in veterinary medicine, minimal invasive treatment options emerged for dogs and cats with ureteral obstruction. This review provides medical and surgical guidelines for the diagnosis and management of dogs and cats with ureteral obstruction, and introduces new therapeutic options such as interventional radiology and endoscopy.

Key Words: ureterolith, calcium-oxalate, stent, hydroureter, hydronephrosis, chronic kidney disease, "big kidney little kidney" syndrome.

INTRODUCTION

The ureters are fibromuscular ducts carrying urine from the kidney to the urinary bladder by peristaltic activity, which is transmitted from one muscle cell to the next (1). The ureters originate in the renal pelvices and travel retroperitoneally along the aorta and vena cava towards the urinary bladder. Near the pelvis they join the lateral ligament of the bladder and insert into the dorsolateral aspect of the urinary bladder (2).

Ureteral obstructions can be classified as intraluminal, intramural and extramural. Ureteral obstructions can also be classified as acute or chronic, static or dynamic, unilateral or bilateral, and as partial or complete. Correct classification is crucial, because the nature of the obstruction along with the patient's medical condition are the major determinants of the treatment plan.

Although congenital ureteral obstructions have been described in the veterinary literature, these are relatively rare and acquired ureteral obstructions occur more frequently (2-7). Cats are predisposed to ureteral obstruction due to their small ureteral lumen (0.4 mm in diameter) (8).

The incidence of ureteral obstructions in cats has increased dramatically over the past decades all over the world, and became the leading cause of acute uremia in North America (9). The incidence of ureteral obstruction in Israel is unknown but is seems to be increasing as well (personal observation). As any emerging disease, it is possible that the disorder is initially not recognized by clinicians unfamiliar with it, and thus the perceived incidence is lower than the actual incidence.

Intraluminal obstruction is the most common cause for ureteral obstruction in dogs and cats, thus most of the discussion in the review will focus on intraluminal ureteral obstruction. Nevertheless, the guidelines for the management of intramural and extramural obstruction follow the same principles. Intraluminal obstructions are usually caused by ureteral calculi, which in cats are almost exclusively composed of calcium oxalate (6), however, blood clots and inflammatory debris may also obstruct the ureter, particularly in cats (6). Intramural ureteral obstruction can result from a stricture, neoplasia (primary or metastatic), ureterocele, fibroepithelial polyp and proliferative ureteritis. Among those, ureteral strictures seem to be the most common cause of intramural ureteral obstruction. Strictures can be associated with various causes including previous ureteral surgery, calculi embedded in the ureteral mucosa, but some are classified as idiopathic, possibly in association with circumcaval ureter (5). Extramural obstructions result from retroperitoneal space occupying lesions, inadvertent ureteral ligation or from urinary bladder pathology (2).

Ureteral obstruction is a challenging disorder, often necessitating advanced diagnostic and therapeutic measures as well as advanced surgical skills.

Pathophysiology of ureteral obstruction

Ureteral obstruction in most cases is initially unilateral, however animals often present for medical care with a bilateral ureteral obstruction or with a unilateral obstruction and concurrent contralateral kidney dysfunction due to a previous ureteral obstruction (6,10).

When intraluminal ureteral obstruction occurs, local inflammation, swelling and spasm of the ureteral muscle may aggravate the mechanical obstruction. Damage to the ureter, such as rupture and urine leakage, may occur but is not common (2,6). The obstruction results in increasing hydraulic pressure along the obstructed ureter and renal pelvis and is transmitted to the renal tubuli and Bowman's space. When the pressure is high enough, glomerular filtration may stop altogether. If the contralateral kidney has normal function, the patient is not expected to become azotemic and thus clinical signs are mostly pain related due to stretching of the renal capsule. Due to the non-specific clinical signs, these episodes of unilateral ureteral obstruction often go unnoticed by owners (6). The fate of the obstructed kidney will be determined by the nature of the obstruction. If the obstruction is complete and static, the kidney will undergo cystic atrophy or, more commonly fibrosis. If the obstruction is partial or dynamic, subsequent kidney damage will be determined by the time and severity of the obstruction. Therefore, the affected kidney may have normal to minimal residual function after the obstruction has been relieved. Recurrent obstructions may lead to progressive renal damage and further decrease in renal function based on the above criteria (6).

When partial or complete loss of one kidney function occurs, the contralateral kidney will undergo compensatory hypertrophy, which results in kidney enlargement. Since the affected kidney is small due to chronic changes, the end result is one big kidney (due to compensatory hypertrophy) and one small kidney (due to fibrosis) and thus the syndrome is often referred to as "big kidney little kidney syndrome" (2,11). This new steady state may last for a long period of time, but is often interrupted when a new obstruction of the hypertrophied kidney occurs. This scenario is very common in cats with predisposition to stone formation (6,10). In these instances the severity of azotemia reflects the nature of the current obstruction and the residual function of the previously obstructed contralateral kidney. If the new obstruction is complete, the degree of azotemia is a relatively accurate reflection of the residual function of the previously obstructed kidney, once steady state has been reached. If the latter has no function and the current obstruction is complete, azotemia may become severe and is often accompanied by life-threatening hyperkalemia. Oliguria and anuria may be present, however their absence does not rule out complete unilateral obstruction, as urine may be produced by the contralateral kidney, even if the latter does not contribute substantially to overall glomerular filtration rate (GFR).

Clinical signs and clinicopathologic abnormalities

The presentation of animals with ureteral obstruction varies substantially from one patient to the other. Many of these patients present with classical clinical signs of acute uremia, whereas others present only pain or clinical signs mimicking the presentation of animals with chronic kidney disease due to other causes (6). The type of clinical signs at presentation depends on the aforementioned criteria. The diversity in the clinical presentation is one of the factors that contribute to the challenges facing the clinician and the difficulty to provide strict therapeutic guidelines to this heterogeneous population of patients. Thus each animal needs to be assessed and managed individually (6). Interestingly, many azotemic cats with ureteral obstruction present a considerably better clinical demeanor compared to cats with similar levels of azotemia of other causes.

Physical examination is a key factor in the diagnosis of ureteral obstruction in cats. Most of kidney diseases in dogs and cats (acute and chronic) are symmetrical whereas ureteral obstruction is one of the few exceptions in which one kidney is small, due to previous obstruction, and one kidney is firm and enlarged. Therefore asymmetrical kidneys upon abdominal palpation are suggestive of an obstructive disease. Nonetheless, ureteral obstruction is not the only rule out for asymmetric kidneys in cats. The consistency of the kidney upon abdominal palpation can increase the level of suspicion to the presence of an obstruction. Obstructed kidneys tend not only to be enlarged, but also to be firm, similar to the difference between an enlarged and an obstructed urinary bladder.

Common laboratory abnormalities of cats with ureteroliths include normocytic normochromic anemia (~50%), azotemia (80%) and hyperkalemia (35%) (6), whereas in dogs, leukocytosis (50%) and azotemia (56%) are common (6,12). The presence of anemia in cats is likely a combination of anemia of inflammation (as some of the cats may have concurrent pyelonephritis), over hydration, and underlying chronic kidney disease.

Urinalysis often does not provide specific information in cases of ureteral obstruction but may reveal hematuria, pyuria, cylinduria and crystalluria. Urine culture is positive in only 8% of the cats, but is positive in 50% of the dogs (6,12). Crystalluria is not a sensitive marker of ureteral calculi because only 6.5% of cats with calcium oxalate ureteroliths present calcium oxalate crystalluria (6).

DIAGNOSTIC APPROACH

The diagnosis of ureteral obstruction is based on the history, physical examination, clinicopathologic abnormalities and is confirmed by various imaging modalities (6,10). The aim is to identify the disease as early as possible, establish its severity, and to classify the obstruction as partial or complete and as static or dynamic. The potential of the kidney to return to normal function once the obstruction has been relieved should also be assessed as part of the diagnostic evaluation (2). Recent kidney function prior to the obstruction, when known, is extremely useful information when assessing the potential of the obstructed kidney to return to normal function and the likelihood for a successful outcome, once ureteral patency has been restored. If the kidney function was normal prior to the obstruction and the obstruction is acute, and irreversible kidney damage has not occurred, short and long term prognosis are expected to be good once the obstruction has been relieved (13,14). This information can be used to encourage owners to pursue diagnosis and therapy, which may be cost prohibitive. Conversely, if azotemia was present before the acute exacerbation, long term prognosis is considered less favorable. Unfortunately, this information is not always available and the assessment should be based on other criteria. The overall GFR and the relative contribution of each kidney to the GFR are also vital information that can guide therapy, however these are difficult to assess as long as the obstruction is present (2,15).

Imaging modalities are often used to diagnose ureteral obstruction, but may have moderate sensitivity. The latter results from lesions that cannot be identified using routine imaging techniques (e.g., strictures) or when ureteroliths are small (common in cats). The sensitivity of survey radiographs and ultrasonography to ureteral obstruction in cats is estimated to be ~80%, namely 20% of the cats with ureteral obstruction due to ureteroliths will not be identified as such using these tests (12). In dogs, due to the nature of ureteroliths, sensitivity is higher. In one study 88% and 100% of ureteral calculi were identified using survey radiographs and ultrasonography, respectively (12). The above sensitivities are reported from referral centers that have advanced equipment and in which the evaluation is made by board certified radiologists. Therefore these are expected to decline even further in other clinical settings. Each one of the imaging modalities has its advantages and disadvantages, thus they are often used in conjunction.

The combination of ultrasonography and radiography has been shown to increase the sensitivity for detection of ureteroliths in cats to 90% (6). Radiographs are extremely useful to follow ureteroliths' location and to determine whether the obstruction is static or dynamic. Ultrasonography is another useful tool to detect the obstruction and to assess renal geometry and architecture, but it is highly operator dependent (2, 6, 10). Typically, on ultrasonography, a shadowing hyperechoic structure consistent with an ureterolith is identified with a proximally torturous and dilated ureter and hydronephrosis (6). Hydronephrosis and dilatation of the collecting system may take days to develop, thus, their absence should not rule out an obstruction (6). The dilatation of the collecting system occurs from proximal to distal and may not reach the obstruction site. Ultrasonographic examination can also aid in the overall assessment of the kidneys' potential to return to normal function, once the obstruction has been removed; however, this should be done cautiously. If advanced chronic changes or marked hydronephrosis accompanied by massive parenchymal loss are documented in the obstructed kidney, the prognosis for renal recovery is poor (10).

When the suspicion for ureteral obstruction is high but the obstruction cannot be documented using radiography or ultrasonography, contrast studies or computerized tomography should be considered. Intravenous urography is not used often since GFR reduction, subsequent to the obstruction, decreases contrast elimination through the kidneys, and thus enhancement along the collecting system of the obstructed kidney may not be sufficient for a diagnostic study (16). Alternatively, antegrade pyelography can be utilized. This procedure is performed under ultrasonographic or fluoroscopic guidance (16,17). The dilated renal pelvis is punctured and urine is collected for urinalysis and culture. A contrast material is then injected into the renal pelvis and follow-up radiographs are obtained. Normally the contrast material should move down the ureter and reach the urinary bladder immediately. This procedure assures sufficient amount of contrast material within the collecting system and it eliminates the risk for nephrotoxicity. Contrast computerized tomography is less invasive than antegrade pyelography and its high sensitivity allows the use of a small amount of contrast material (18), however, it is cost prohibitive in some patients.

Medical management of ureteral obstruction

Management of ureteral obstruction can be either medical or surgical (10). The type of therapeutic intervention is determined by the nature of obstruction (i.e., static vs. dynamic), its location, presence and severity of clinicopathologic abnormalities (e.g., hyperkalemia), presence of renal infection and the risks associated with each one of the available procedures (10). These parameters will also determine the urgency of intervention. When intraluminal ureteral obstruction is diagnosed, medical management may be the only therapy needed for a subset of patients, however, in other types of obstruction (e.g., stricture) or when the obstruction cannot be relieved with medical management, surgical management should be considered (10).

In non-azotemic patients with unilateral obstruction, pain management and a close monitoring to assure antegrade movement of the ureterolith may be the only therapeutic means needed. The type of stone and its location makes dissolution not possible and even contraindicated. There are no guidelines in veterinary medicine to assess the likelihood of antegrade movement of ureteroliths based on their size and location, therefore follow up imaging studies are required (10). Unfortunately, there is also no solid evidence to guide medical management of ureteral obstruction, thus treatment is often empirical. In theory, administration of fluids and diuretics may increase the hydraulic pressure on the ureterolith and promote antegrade movement. Other therapies used in human patients to facilitate antegrade stone movement and to decrease local edema and inflammation, such as glucagon, ureteral muscle dilators, and anti-inflammatory drugs, have not been evaluated extensively in dogs and cats.

When medical management is attempted the risk for irreversible renal damage during the monitoring period should be considered. The degree of renal damage depends on the degree and duration of the obstruction (19-21). In dogs, complete ligation of the ureter for 4 days results in complete recovery to normal kidney function (19-21). Ligation of the ureters for 14 days results in 46% recovery of the original kidney function (19-21). However ureteral ligation for 40 days or longer is associated with minimal recovery (19-21). Partial ureteral ligation for 14, 28 and 60 days resulted in 100%, 31% and 8% return to baseline kidney function, respectively (19-21). It is therefore clear that there is only a very short period of time (i.e. days) in which medical management can be applied before irreversible damage occurs. The aforementioned period for "safe" medical management may even be shorter when considering that the obstruction often is present before presentation for medical care. In some cases, ureteral obstructions may be an incidental finding. When neither azotemia nor any evidence of pelvic dilation is present, there is a dilemma whether surgical intervention is warranted, especially in facilities where these surgeries are not being performed routinely. On one hand, the short term consequences of surgical intervention may be detrimental, but on the other hand there is no practical way of knowing whether the obstruction is associated with any gradual decrease in kidney function. Due to the high recurrence of these stones, especially in cats, one may argue that renal function should be preserved at any cost.

In patients with azotemia the first therapeutic effort is directed towards patient stabilization. The presence of azotemia after excluding its pre-renal component, attests for decreased contralateral kidney function. In fact, when the obstruction is complete, the presence of azotemia is a good reflection of the residual function of the contralateral kidney, once steady state has been reached. Management of hyperkalemia and acidemia are crucial before pursuing diagnostic procedures such as imaging, as some require sedation or general anesthesia. In severely azotemic and hyperkalemic patients hemodialysis or peritoneal dialysis will allow patient stabilization prior to other interventions (22). Renal replacement therapies also enables a longer period of time for dynamic intraluminal obstructions to resolve spontaneously; however despite the reduction of uremia toxins, progressive kidney damage continues to occur as long as the kidney is obstructed.

When renal replacement therapies are not available, urine diversion can be performed using nephrostomy tubes (23). These can be placed either surgically or under fluoroscopic or ultrasonographic guidance. Placement of nephrostomy tubes not only facilitates patient stabilization, but also can be used to assess the kidney's potential to return to normal function, and to predict prognosis once the obstruction is removed. This information can guide future treatment and can assist owners, before making cost prohibitive decisions. Nephrostomy tubes also prolong the window of opportunity for medical management and provide additional time in which intraluminal obstructions can move antegrade and reach the urinary bladder. Complications include urine leakage, poor drainage and tube dislodgment (10).

Surgical management of ureteral obstruction

Surgical intervention is indicated when the obstruction is static, when there is damage to the obstructed ureter (e.g., urine leakage), and when the obstructed kidney is infected. Surgical options include ureterotomy, ureteral resection and anastomosis (mostly in dogs), ureteroneocystostomy (i.e. re-implantation of the ureter to the urinary bladder) and renal transplantation when available (10). In cats, due to the relatively narrow ureteral lumen, resection and anastomosis are rarely applied, as these are likely to result in narrowing and re-obstruction at the anastomosis site (10). Ureteroneocystostomy is more commonly applied, but the ureteral orifice, at the re-implantation site is also prone to narrowing. This procedure is usually utilized when the obstruction is located in the middle of the ureter or distally, but it can also be applied in proximal obstructions along with caudal and cranial displacement of the kidney and the bladder, respectively (renal desensus and psoas cystopexy) (10). A few methods for re-implantation have been evaluated previously and among those the extra-vesical simple interrupted technique was considered to have the best outcome (8, 24).

Ureteronephrectomy is considered as a last resort when the obstruction cannot be eliminated or bypassed (e.g., proximal stricture, neoplasia) and when severe and irreversible renal infection or damage (e.g. renal abscess) are present. Renal function (even partial) should be preserved in patients with ureteral obstruction whenever possible. This procedure should only be considered when there is no alternative, because further reduction in kidney function can be detrimental for the patient, either at the current episode or in the future. One should also be extremely cautious in determining that there is no remaining kidney function based on the ultrasonographic appearance. Presence of azotemia is an indication of substantial decrease in function of the contralateral kidney and any additional reduction in the overall GFR following nephrectomy may turn a patient to unmanageable with medical therapy. Even when azotemia is not present, nephrectomy should be performed as a last resort since patients with ureteral obstructions often develop obstructions in the contralateral collecting system.

When both kidneys are chronically affected by repeated obstructions and surgical management is not likely to increase the kidney function, renal transplantation is considered (10). It has been shown that cats with ureteral obstruction may form calculi in the graft as well; however, survival of these cats is not different from cats undergoing renal transplantation due to other reasons (19).

Minimally invasive procedures and interventional radiology

Extracorporeal shock can be used for the management of ureteroliths. Extracorporeal shock wave lithotripsy delivers external shockwaves directed under fluoroscopic guidance in 2 planes (25). The stone is shocked thousands of times in different energy levels. Ureteral stent placement prior to lithotripsy is recommended to aid in stone passage to the urinary bladder and decreases the risk for obstruction. Extracorporeal shock wave lithotripsy has been used successfully in dogs and cats to fragment ureteroliths, however, feline kidneys are more sensitive to shock wave induced injury and therefore this modality is not being applied commonly in cats with ureteral obstruction.

Interventional radiology and endoscopy can be used also to facilitate management of ureteral obstruction in dogs and cats and provide additional therapeutic measures (14). The most common method to divert urine from the renal pelvis into the urinary bladder is placement of ureteral stents (14). Stents do not only divert the urine from the renal pelvis to the bladder but also encourage passive dilation of the obstructed ureter (14, 26). There is a controversy whether ureteral stents should be recommended as the treatment of choice in ureteral obstructions. Ureteral stents however bear many advantages including minimal invasiveness, shorter recovery period, and prevention of future obstructions (13,14).

The double pigtail stent is the stent of choice in cats with ureteral obstruction (13,14). It has also been used successfully in dogs with malignant ureteral obstructions (26). One loop of the pigtail is curled in the renal pelvis and the other is curled in the urinary bladder. Stent placement can be performed under fluoroscopic guidance and with cystoscopic assistance in dogs and in female cats, but in male cats (and often in female cats as well) open surgery is required to facilitate stent placement. A description of placement techniques is beyond the scope of this review and can be found elsewhere (14). All minimally invasive procedures require special equipment, training and experience.

Recently, subcutaneous ureteral bypass device placement has been described for the management of ureteral obstruction. In this procedure a nephrostomy and cystostomy tubes are placed and connected subcutaneously using male to male adaptors, typically under the skin or, less typically, inside the abdomen (13). This procedure is performed most commonly for proximal ureteral strictures, in which stent placement is less effective as passive ureteral dilation is less likely to occur and re-implantation is more challenging due to the proximal location (5). Although the number of procedures performed to date is relatively small, the procedure seems to be successful and associated with a favorable outcome (13).

PROGNOSIS

The prognosis of ureteral obstruction is highly dependent on the available therapeutic tools and surgical skills. Outcome in referral centers with extensive expertise with ureteral surgery is favorable, with a one month survival rate of 75% (10,12). Nonetheless, complication rate is ~30% (10). Surviving cats have relatively long term survival of ~90% with surgical management and ~70% with medical management (10). The expected morbidity and mortality is likely substantially higher when special operating equipment such as operating microscopes and microsurgical experience are not available. Close to 50% of the cats are expected to sustain chronic kidney disease and 40% have ureteral stone recurrence (10). Therefore, patients with ureteral obstruction should be closely monitored periodically for recurrence. Preventative treatments should be initiated in cats with ureteral calculi due to the high recurrence rate.

REFERENCES

1. Osborne, C. A. and Fletcher, T. F.: Applied anatomy of the urinary system with clincopathologic correlation. In: Osborne, C.A. and Finco, D.R.: eds. Canine and Feline Nephrology and Urology. Williams & Wilkins, New York: 3-28, 1995.
2. Segev, G.: Diseases of the ureter. In: Bartges, J. and Polzin, D.J. eds. Nephrology and Urology of Small Animals Wiley-Blackwell, Iowa: 583-590, 2011.
3. Berzon, J. L.: Primary leiomyosarcoma of the ureter in a dog. J. Am. Vet. Med. Assoc., 175:374-376, 1979.
4. Ragni, R. A. and Fews, D.: Ureteral obstruction and hydronephrosis in a cat associated with retroperitoneal infarction. J. Feline Med. Surg. 10:259-263, 2008.
5. Zaid, M. S., Berent, A. C., Weisse, C. and Caceres, A.: Feline ureteral strictures: 10 cases (2007-2009). J. Vet. Intern. Med. 25:222-229, 2011.
6. Kyles, A. E., Hardie, E. M., Wooden, B. G., Adin, C. A., Stone, E. A., Gregory, C. R., Mathews, K. G., Cowgill, L. D., Vaden, S., Nyland, T. G. and Ling, G. V.: Clinical, clinicopathologic, radiographic, and ultrasonographic abnormalities in cats with ureteral calculi: 163 cases (1984-2002). J. Am. Vet. Med. Assoc. 226:932-936, 2005.
7. Lam, N. K., Berent, A. C., Weisse, C. W., Bryan, C., Mackin, A. J. and Bagley, D. H.: Endoscopic placement of ureteral stents for treatment of congenital bilateral ureteral stenosis in a dog. J. Am. Vet. Med. Assoc. 240:983-990, 2012.
8. Kochin, E. J., Gregory, C. R., Wisner, E., Cain, G. and Gourley, I. M.: Evaluation of a method of ureteroneocystostomy in cats. J. Am. Vet. Med. Assoc. 202:257-260, 1993.
9. Cannon, A. B., Westropp, J. L., Ruby, A. L. and Kass, P. H.: Evaluation of trends in urolith composition in cats: 5,230 cases (1985-2004). J. Am. Vet. Med. Assoc. 231:570-576, 2007.
10. Kyles, A. E., Hardie, E. M., Wooden, B. G., Adin, C. A., Stone, E. A., Gregory, C. R., Mathews, K. G., Cowgill, L. D., Vaden, S., Nyland, T. G. and Ling, G. V.: Management and outcome of cats with ureteral calculi: 153 cases (1984-2002). J. Am. Vet. Med. Assoc. 226:937-944, 2005.
11. Langston, C. E.: Acute renal failure caused by lily ingestion in six cats. J. Am. Vet. Med. Assoc. 220:49-52, 36, 2002.
12. Snyder, D. M., Steffey, M. A., Mehler, S. J., Drobatz, K. J. and Aronson, L. R.: Diagnosis and surgical management of ureteral calculi in dogs: 16 cases (1990-2003). NZ. Vet. J. 53:19-25, 2005.
13. Berent, A.: Management of feline ureteral obstructions: an interventionalist's approach. In: The American College of Veterinary Surgery symposium Chicago, IL, USA: 2011.
14. Berent, A. C.: Ureteral obstructions in dogs and cats: a review of traditional and new interventional diagnostic and therapeutic options. J. Vet. Emerg. Crit. Care. (San Antonio). 21:86-103, 2011.
15. Langston, C. E.: Acute uremia. In: Ettinger, S.J and Feldman, E.C. eds. Textbook of Veterinary Internal Medicine. Saunders WB, Philadelphia: 1955-2115, 2010.
16. Adin, C. A., Herrgesell, E. J., Nyland, T. G., Hughes, J. M., Gregory, C. R., Kyles, A. E., Cowgill, L. D. and Ling, G. V.: Antegrade pyelography for suspected ureteral obstruction in cats: 11 cases (1995-2001). J. Am. Vet. Med. Assoc. 222:1576-1581, 2003.

17. Rivers, B. J., Walter, P. A. and Polzin, D. J.: Ultrasonographic-guided, percutaneous antegrade pyelography: technique and clinical application in the dog and cat. J. Am. Anim. Hosp. Assoc. 33:61-68, 1997.
18. Rozear, L. and Tidwell, A. S.: Evaluation of the ureter and ureterovesicular junction using helical computed tomographic excretory urography in healthy dogs. Vet. Radiol. Ultrasound, 44:155-164, 2003.
19. Fink, R. L., Caridis, D. T., Chmiel, R. and Ryan, G.: Renal impairment and its reversibility following variable periods of complete ureteric obstruction. Aust. NZ. J. Surg. 50:77-83, 1980.
20. Leahy, A. L., Ryan, P. C., McEntee, G. M., Nelson, A. C. and Fitzpatrick, J. M.: Renal injury and recovery in partial ureteric obstruction. J. Urol. 142:199-203, 1989.
21. Vaughan, E. D., Jr. and Gillenwater, J. Y.: Recovery following complete chronic unilateral ureteral occlusion: functional, radiographic and pathologic alterations. J. Urol. 106:27-35, 1971.
22. Pantaleo, V., Francey, T., Fischer, J. R. and Cowgill, L. D.: Application of hemodialysis for the management of acute uremia in cats: 119 cases (1993-2003). J. Vet. Intern. Med. 18:418, 2004.
23. Berent, A. C., Weisse, C. W., Todd, K. L. and Bagley, D. H.: Use of locking-loop pigtail nephrostomy catheters in dogs and cats: 20 cases (2004-2009). J. Am. Vet. Med. Assoc. 241:348-357, 2012.
24. Mehl, M. L., Kyles, A. E., Pollard, R., Jackson, J., Kass, P. H., Griffey, S. M. and Gregory, C. R.: Comparison of 3 techniques for ureteroneocystostomy in cats. Vet. Surg. 34:114-119, 2005.
25. Adams, L. G. and Senior, D. F.: Electrohydraulic and extracorporeal shock-wave lithotripsy. Vet. Clin. North Am. Small Anim. Pract. 29:293-302, 1999.
26. Berent, A. C., Weisse, C., Beal, M. W., Brown, D. C., Todd, K. and Bagley, D.: Use of indwelling, double-pigtail stents for treatment of malignant ureteral obstruction in dogs: 12 cases (2006-2009). J. Am. Vet. Med. Assoc. 238:1017-1025, 2011.