Received: 1 June 2020 | Accepted: 17 June 2021
DOI: 10.1111/jvim.16210

STANDARD ARTICLE

Journal of Veterinary Internal Medicine Open Access
ACVIM American College of Veterinary Internal Medicine

Comparison of nonenhanced computed tomography and ultrasonography for detection of ureteral calculi in cats: A prospective study

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Abstract

Background: Radiographs and ultrasound (US) are the primary imaging modalities used to assess ureteral calculi in cats. Reports describing the use of nonenhanced computed tomography (CT) are scarce.

Hypothesis/Objectives: To compare US and nonenhanced CT for detection, number and localization of ureteral calculi in cats.

Animals: Fifty-one cats with at least 1 ureteral calculus, and 101 ureters.

Methods: Prospective case series. All cats underwent an US followed by a non-enhanced CT. Cats were included in the study if at least 1 ureteral calculus was diagnosed on either modality. Number of calculi and their localization (proximal, middle, and distal) were recorded on both modalities. Pelvic dilatation and maximal ureteral diameter were recorded with US.

Results: More calculi were detected by nonenhanced CT (126) compared to US (90), regardless of localization ($P < .001$). More ureters were affected on nonenhanced CT (70) compared to US (57; $P < .001$). The number of calculi detected was significantly different between US and nonenhanced CT in the proximal ($P = .02$) and distal ureteral region ($P < .001$). Bilateral calculi were more frequent with nonenhanced CT (19 cats) compared to US (9 cats; $P < .001$). A pelvic size superior to 5 mm and a maximal ureteral diameter value superior to 3 mm were always associated with ureteral calculi.

Conclusions and Clinical Importance: Computed tomography is an emerging imaging modality in cats with a suspected ureteral obstruction. Combination of CT and US can be beneficial for case management.

KEYWORDS
diagnostic imaging, feline, stone, ureter

1 | INTRODUCTION

Ureterolithiasis is the leading cause of ureteral obstruction in cats. Additional causes include strictures, dried solidified blood calculi,

Abbreviations: US, ultrasound; XR, standard radiographs; CT, computed tomography.

blood clots, fibrinosuppurative exudates, neoplasia, and iatrogenic causes.[1-7] Most upper urinary tract calculi are composed of calcium oxalate which is radiopaque.[1,8-10] Currently, standard radiographs (XR) and abdominal ultrasound (US) are the primary imaging modalities used to diagnose ureterolithiasis in cats.[1,2,4,7,11] When XR and US are used in combination on cats, a 90% sensitivity has been described.[1] The accuracy of US for detection of ureteral obstruction and ureteral calculi has differed in recent studies.[1,7,11] The pelvic diameter of obstructed kidneys shows variation and can be similar to the pelvic diameter of nonobstructed kidneys, requiring additional evaluation.[12,13] Anterograde pyelography is used to confirm the presence of ureteral obstruction, without damaging renal function. Its sensitivity and specificity, regardless of cause, can reach 100%[14] However, this procedure is associated with complications.[14-16] Intravenous urography and contrast-enhanced computed tomography (CT) are rarely used in human and veterinary ureteral obstruction cases because of the potential nephrotoxicity of iodinated contrast media and decreased contrast media filtration.[2,14,17]

In humans, ureterolithiasis is the primary cause of ureteral obstruction.[18] Several studies investigating renal colic in humans have shown superiority of nonenhanced CT compared to US and intravenous urography.[19-23] XR are no longer used in the diagnosis of renal colic, and US is mostly used in emergency management.[23,24] The sensitivity and specificity of nonenhanced CT for the diagnosis of ureteral calculi in humans has been described as 94% and 97%, respectively.[20] This modality is considered the gold standard for diagnosis in humans.[18,20,24] To our knowledge, only 1 study, comprised of 7 cases, has reported the use of nonenhanced CT for detection of ureteral calculi.[1] CT has become more accessible in veterinary practice worldwide and can be used for the diagnosis of ureteral calculi, as in human medicine.[7,9,18,19,21]

The aim of this study was to compare US and nonenhanced CT for detection and localization of ureteral calculi in cats. We hypothesized that CT would be superior to US to assess the number and precise localization of ureteral calculi in cats. The second aim was to evaluate pelvic and ureteral sizes when ureteral calculi were detected. Our second hypothesis was that pelvic and ureteral diameter would be statistically significantly greater in ureters with a positive diagnosis of calculi on both US and CT compared to those with a positive diagnosis on CT alone (US-negative) or a negative diagnosis on both modalities.

2 | MATERIAL AND METHODS

2.1 | Animal selection

A prospective study over an 18-month period was conducted at the Centre Hospitalier Vétérinaire Atlantia, Nantes, France. Cats with acute renal injury as defined by IRIS, a worsening chronic renal insufficiency or abdominal pain underwent an abdominal US. If a ureteral calculus was seen on US or if a ureteral obstruction was suspected, the US exam was followed by a nonenhanced CT within a 6-hour period.

Cats with ureteral calculi visible on US were included, as well as cats with a suspicion of ureteral obstruction on US (pelvic or ureteral dilatation) and with at least 1 ureteral calculus detected on CT afterwards. The project was approved by a local ethical review board (ONIRIS—CERVO-2017-16-V).

2.2 | Diagnostic imaging

All US exams were performed by an experienced veterinarian in ultrasonography (I.T.) or by a board-certified veterinary radiologist (M.V.). All CT images were reviewed by a board-certified veterinary radiologist (M.V.). All US exams were performed utilizing the same US machine (MyLab ClassC, Esaote, Italy) with linear (6-18 MHz) and microconvex (3-10 MHz) probes. Nonenhanced CT examination of the abdomen was performed on each cat. Contiguous transverse images (0.625 mm thickness) were obtained using a 16-slice multidetector helical scanner (Brivo CT385, GE Medical Systems, France). All scans were acquired using a technique of 60 mA - 120 kV - 512 × 512 matrix and a bone and soft tissue reconstruction algorithm. All US exams were performed without animal sedation. The nonenhanced CT was performed under general anesthesia, if a procedure under anesthesia was planned (pyelocentesis or surgery), or under sedation with fentanyl (2-5 μg/kg IV). The cats were placed in a sternal recumbency position and gently maintained with straps on a table or placed in an aerated plastic box, if necessary. No medical treatment was attempted between the US and the CT procedures, except for IV fluid maintenance (0.9% sodium chloride, 2 mL/kg/h).

A diagnosis of ureteral calculus was made on US when there was a hyperechoic structure within the ureter, with or without distal acoustic shadowing. A diagnosis of ureteral calculus was made on nonenhanced CT when there was a hyperattenuating (mineralized) structure within the ureter.

Ureter locations were defined as proximal (first 1/3rd), middle (second 1/3rd), and distal (third 1/3rd) portions of the ureter. This was assessed subjectively on US considering the renal and the bladder positions and was assessed on nonenhanced CT as described above, using dorsal reconstructions. The following criteria were measured with US: renal pelvis size on a transverse plane, maximal ureteral diameter, and number of calculi visualized in each location. Renal pelvis size and maximal ureteral diameter were measured on US only as the nonenhanced CT was considered less precise, due to spatial resolution and absence of contrast injection. Number of calculi visualized in each location was recorded using nonenhanced CT.

2.3 | Statistical analysis

Statistical analyses were performed using R software (R Core Team, 2019, Vienna, Austria) by 1 author (L.G.). Descriptive statistics (mean ± SD) were calculated from the tabulated measurements of the pelvic dilatation and maximal ureteral diameter on US. A Wilcoxon signed rank test was used to compare the number of calculi observed with US and nonenhanced CT. The percentage of ureters with calculi, as well as the percentage of cases with bilateral calculi, on US or nonenhanced CT, were compared with a Fisher's exact test.

Groups, including ureters with or without calculi, were determined for each imaging modality. The renal pelvic size and the maximal ureteral diameter were compared between these groups using a Student *t*-test. Based on the differences observed between US and nonenhanced CT, 3 groups were created. In the first group, no calculus was detected in any imaging modality. In the second group, ureteral calculi were detected on CT, but not detected on US. In the third group, ureteral calculi were observed in both modalities. US measurements of the renal pelvis and the maximal ureteral diameter were compared between these 3 groups with a Pairwise comparison using Wilcoxon rank sum test (Holm method). The level of statistical significance was set at .05.

3 | RESULTS

3.1 | Animals

Fifty-one cats were included in the study. The majority, 34/51 (67%), were domestic shorthair cats. Other breeds represented in the study population included 4 British Shorthair (8%), 4 Persian (8%), 3 Main Coon (6%), 3 Birman (6%), 2 Chartreux (4%), and 1 Turkish Angora (2%). Twenty (39%) cats were neutered males, 30 (59%) were spayed females, and 1 (2%) was an intact female. The mean age of the cats was 6.7 ± 3.1 years. The mean weight was 3.8 ± 1.1 kg.

3.2 | Number and localization of ureteral calculi

From these 51 cats, 101 kidneys and ureters were evaluated. One cat presented with only 1 right kidney following a previous left nephrectomy due to a perirenal pseudocyst.

In 12 cases, 1 ureter was not seen on US. Therefore, the maximal ureteral diameter could not be measured in those cases and no ureteral calculi were found. Among these 12 ureters, 10 were on the left side and 2 on the right side. No calculus was detected in the 10 left ureters on nonenhanced CT. One calculus was detected in both right ureter cases on nonenhanced CT, and the calculi were both located in the distal part.

A total of 90 calculi were observed on US. Twenty-one (23%) were located in the proximal ureter, 52 (58%) in the mid ureter, and 17 (19%) in the distal ureter. Forty-three (48%) calculi were observed on the left side and 47 (52%) on the right side. Calculi were observed in 57 ureters (56%). The most distal calculus was observed in the proximal ureter in 10 cases (18%), in the middle ureter in 35 cases (61%), and in the distal ureter in 12 cases (21%). On nonenhanced CT, a total of 126 calculi were visualized. Twenty-nine (23%) were in the proximal ureter, 55 (44%) in the middle ureter, and 42 (33%) in the distal ureter (Figure 1). Calculi were observed in 70 ureters (69%). The most distal calculus was observed in the proximal ureter in 7 cases (10%), the middle ureter in 33 cases (47%), and the distal ureter in 30 cases (43%). The percentage of affected ureters was significantly different between US and CT ($P < .001$). The Wilcoxon signed rank test showed a significant difference in the total number of calculi observed between US and CT ($P < .001$). Regarding the different portions of the ureters between US and CT, there was a significant difference in the number of calculi in the proximal ($P = .02$) and distal portions ($P < .001$), but the difference was not significant in the middle portion ($P = .70$). These results have been summarized in Table 1. When considering the number of calculi observed on the left or right side in each location, there was a significant difference between US and CT in the right proximal ($P = .04$), left distal ($P = .01$) and right distal ($P < .001$) portions of the ureters. However, there were no significant differences in the proximal left portion ($P = .42$), the middle left portion ($P = .60$), and the middle right portion of the ureter ($P = 1$).

Multiple localizations of calculi were observed in 6 ureters on the left side and 10 on the right side on nonenhanced CT (Figure 2); and in 4 ureters on the right side only on US. Furthermore, 6 calculi were detected on US, but not detected on nonenhanced CT (3 on the left side and 3 on the right side), in 4 different ureters. In all these 4 ureters, there was 1 calculus observed on CT, but more calculi were found on US. In 13 ureters, calculi were detected on CT but not on US. The difference in number of calculi detected in US and CT is summarized in Table 2. Calculi were observed bilaterally in 8 cats (16%) on US and in 19 cats (37%) on nonenhanced CT. The percentage of bilaterally affected cats was significantly different between US and CT ($P < .001$).

Ten cats had a circumcaval ureter, all unilateral (20%). Nine were on the right side and 1 was on the left side. Five circumcaval ureters did not present any calculi (50%). Two cats had bilateral ureteral calculi, and 3 had unilateral calculi on the side of the circumcaval ureter. There were no calculi in the left circumcaval ureter. The localization and number of calculi in the circumcaval ureters are reported in Table 3.

3.3 | Renal pelvis and maximal ureteral diameter

There was a significant difference between the renal pelvic size with or without associated ureteral calculi based only on US results ($P < .001$). A similar significant difference was observed for the US maximal ureteral diameter ($P < .001$).

Due to the higher number of calculi detected on nonenhanced CT compared to US when the 101 ureters are considered, the US measurements were divided into 3 groups: no calculi detected on both modalities, calculi only detected on nonenhanced CT, and calculi detected on both modalities. The mean ± SD of pelvic dilatation and maximal ureteral diameter observed in these groups are provided in Figure 3. A graphic evaluation of the data is available in Figure 3. A

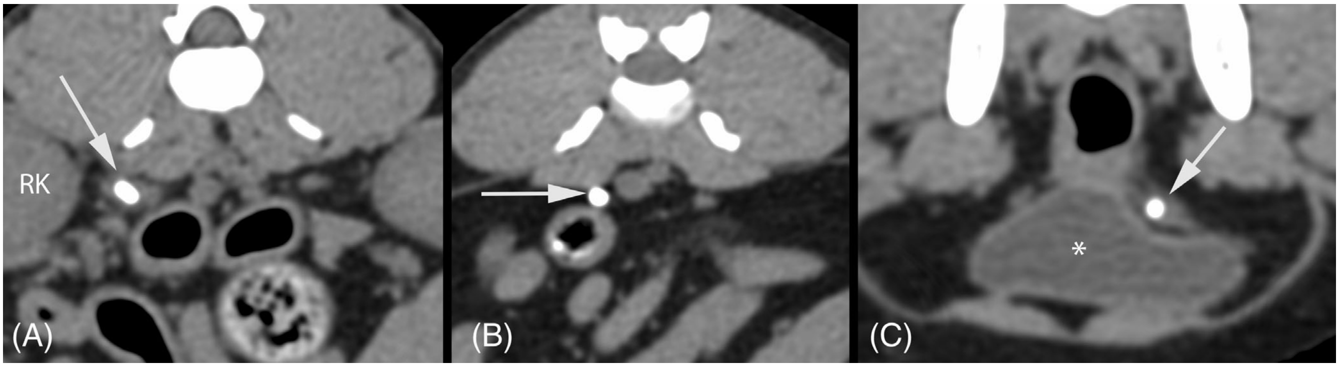

FIGURE 1 Nonenhanced CT (transverse images) of 3 ureteral calculi (arrows) in 3 different cats. A, One is located in the proximal ureter; B, 1 in the middle ureter; and C, 1 in the distal ureter. CT, computed tomography; RK, right kidney; *, urinary bladder

TABLE 1 Number of calculi found in each ureteral location and the *P*-value associated when US and CT is compared using a Wilcoxon signed rank test

	Proximal	Middle	Distal	Total
US	21	52	17	90
CT	29	55	42	126
P-value	$P = .02$	$P = .7$	$P < .001$	$P < .001$

Abbreviations: CT, computed tomography; US, ultrasound.

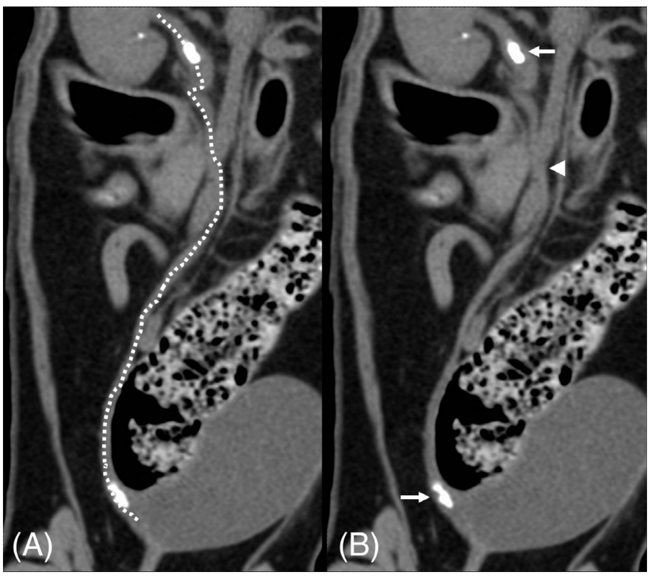

FIGURE 2 Dorsal oblique image from curved multiplanar reconstruction in a cat. A, The right ureter is represented by the dotted line. B, Two calculi are seen within the right ureter, proximal and distal (arrows). The right ureter has a circumcaval position (arrowhead)

significant difference occurred between these groups for the mean of the pelvic dilatation ($P < .001$) and the maximal ureteral diameter ($P < .001$). A pelvic size superior to 5 mm and a maximal ureteral diameter value superior to 3 mm were always associated with ureteral calculi. The difference between left and right pelvic dilatation was greater than 3 mm in half of the cases with bilateral calculi.

TABLE 2 Comparison between number of calculi observed with US and CT in all ureters

	Number of ureters affected
US detects more calculi than CT	
1 calculus	2
2 calculi	2
CT detected more calculi than US	
1 calculus	9
2 calculi	2
3 calculi	3
5 calculi	1
US and CT detect the same number of calculi	38
US detects calculi and CT does not detect any	0
CT detects calculi and US does not detect any	13

Abbreviations: CT, computed tomography; US, ultrasound.

4 | DISCUSSION

The number of calculi detected with nonenhanced CT was higher compared to that detected with US. Nonenhanced CT detected significantly more calculi in the distal part of the ureter bilaterally and in the right proximal ureter. The means of the pelvic dilatation and maximal ureter diameter were significantly different between the 3 groups (no calculi detected on both modalities, calculi only detected on nonenhanced CT, and calculi detected on both modalities), even if overlapping values were observed. However, calculi were easier to detect with US when the size of the pelvis or ureter was increased. Therefore, nonenhanced CT is a feasible imaging modality in cats to detect ureteral calculi and provide their exact localization. This study is the first to assess the usefulness of nonenhanced CT to detect ureteral calculi and to compare it to US.

TABLE 3 Number of calculi observed in cats with circumcaval ureters

Localization	Proximal	Middle	Distal
US	0	4	0
Nonenhanced CT	1	4	2

Notes: All were observed in the right ureter.
Abbreviations: CT, computed tomography; US, ultrasound.

More calculi were detected on nonenhanced CT compared to US. This is similar to data available in the literature from human studies and from 1 veterinary study.[20,23,25] In 1 study,[1] 7 cats underwent both CT and US. The number of calculi detected on CT was higher than on US in 3 of the 7 cats. To date, the ability of US to detect calculi has been compared to radiography, anterograde pyelography, surgery, and autopsy.[1,3,7,14] The number of ureteral calculi detected with US is underestimated when compared with surgery or autopsy results.[26]

In our study, nonenhanced CT detected a larger number of cases of bilateral calculi compared to US. In some US cases, failure to lateralize the calculi was reported.[1] CT, being a cross-section imaging modality, allows the correct lateralization of the calculi. The difference found in our study can also be explained by the asymmetric pelvic dilatation observed in some cases and the difficulty evaluating the entire length of the ureter when not dilated.[1] Another explanation could be a satisfaction of search error. This type of error is well known in human radiology[27,28] and can be explained by a failure to complete the search after the detection of a single calculus. There is no search for additional calculi, especially if there is no further ureteral dilatation. In our study, however, considering its prospective design, this type of error should be nonexistent but cannot be completely ruled out.

More than 7 calculi have been observed in a single ureter.[9] The percentage of reported cases presenting multiple calculi in 1 ureter varies between 6% and 13%.[3,7,26] Due to the variable ability to evaluate the entire length of the ureter on US, the number of calculi can be underestimated with this modality.

Differences were observed when the localizations of the calculi were compared between US and nonenhanced CT in our study. This can be explained by the difficulty during the US exam to evaluate the exact localization of a calculus in the ureter, as the entire length of the ureter cannot always be examined; especially considering that a large number of calculi were detected in the distal ureter with nonenhanced CT. Some of them were not detected with US. Some studies state that ureteral dilatation does not always reach the level of the calculus,[1,14] which is also the authors' experience. A nondistended ureter is more difficult to evaluate entirely with US, and consecutively some calculi can be missed. In addition, the narrowing of the caudal abdomen, the artifacts caused by the descending colon, or the degree of dilatation of the urinary bladder, complicate the US evaluation of the distal part of the ureter.[1]

Most of the calculi detected with nonenhanced CT in our study were observed in the middle ureter, followed by distal and proximal localizations. The proportion differed from previous studies based on XR and US where proximal and middle localizations were more frequent.[3,9,26] This could be explained by individual variation in the cats and by underestimation of small calculi on XR[1,14] When considering both left and right ureters, more calculi were detected in the proximal ureter on nonenhanced CT compared with US. This could be

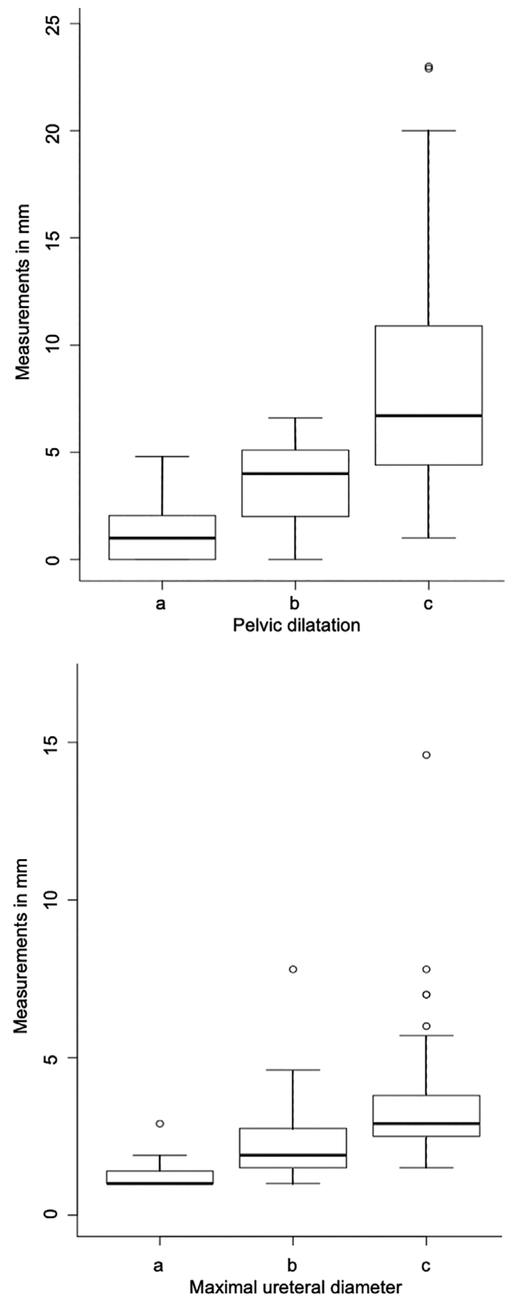

FIGURE 3 Boxplots of the ultrasound measurements of the pelvic dilatation and maximal ureteral diameter in 3 different groups: a, no ureteral calculi detected; b, ureteral calculi detected with nonenhanced CT only; and c, ureteral calculi detected with both modalities. The short lower and upper lines represent the minimum and the maximum. The thick black line represents the median, the central box contains 50% of the values, between the 25% and 75% quartiles. CT, computed tomography

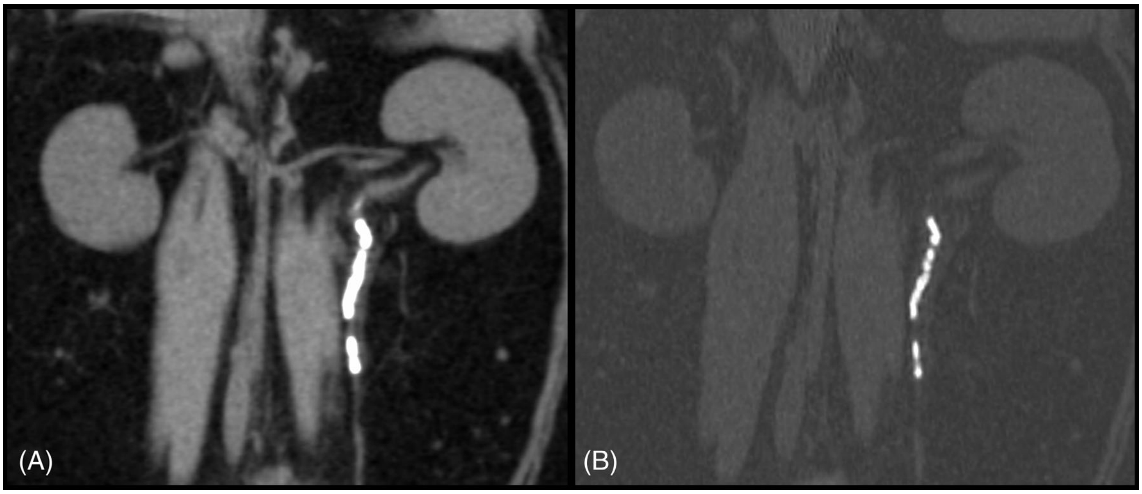

FIGURE 4 Dorsal images from multiplanar reconstruction in a cat with multiple ureteral calculi, in (A) soft tissue and (B) bone reconstruction algorithm. It is difficult to determinate the exact number of ureteral calculi when they are in a row

explained by the anatomy of the proximal ureter.[29] The proximal ureter is also described as tortuous when dilated[26,30,31] and could be more difficult to evaluate with US. When the ureteral side was evaluated, nonenhanced CT detected more calculi in the right proximal ureter. This could be explained by the more cranial localization of the right kidney.[15,29] For both proximal and distal localizations, the absence of standardized sedation or anesthesia might have complicated the US procedure. A difference in the localization of the ureteral calculi between both imaging modalities could also be related to the maximal 6-hour period of time between US and CT. It is possible that a calculus might have moved slightly between both procedures.

A total of 6 stones were observed on US but not detected on CT. In all of these cases, some calculi were detected in the ureters with both modalities. CT is known to have a lower spatial resolution than XR and adjacent calculi might be indistinguishable in CT, even with bone algorithm reconstruction,[32] as illustrated in Figure 4. Therefore, 2 calculi could have been counted as 1 on nonenhanced CT. Also, the nature of the calculi might have affected their detection on nonenhanced CT. Dry solidified blood calculi have been described,[5] but their CT attenuation is unknown. They might have been missed in this study.

The number of circumcaval ureters that were observed in the study population is representative of previous descriptions.[3,26,33,34] Right circumcaval ureters were more frequent, as already described.[3,26,33,34] Half of the circumcaval ureters in our population did not contain any calculi. In the other half, all calculi, except 1, were located caudal to the aberrant portion of the ureter. Because of the low number of cats with circumcaval ureters, no statistical analyses were performed, but the observations did not indicate a direct relationship between circumcaval ureters and ureteral calculi in our study.

The pelvic dilatation and the maximal ureteral diameter were measured in US. There was a significant difference between the mean values in 3 different groups: no ureteral calculi detected, ureteral calculi detected with nonenhanced CT only, and ureteral calculi detected with both modalities, respectively. However, there was a large overlap in values between these groups. This finding has already been observed in several studies on pelvic dilatation[1,3,11,12,26,35,36] or ureteral diameter.[3] In humans, ureteral dilatation in the acute phase of renal colic does not occur in 30% of patients.[18,37] Some veterinary studies have suspected possible variation in the stretching ability of the pelvic tissue due to subobstruction of some calculi, fibrosis of the tissues, or concomitant chronic kidney disease.[1,2,12,14] Additional conditions might be also responsible for pelvic or ureteral dilatation.[12] Calculi could be present with minimal dilatation of the renal pelvis and the ureter, however, in this study, the cut-off values of 5 and 3 mm, respectively for the US pelvic dilatation and ureteral diameter, were always associated with ureteral calculi. These values were lower than that proposed in the study of D'Anjou et al.[12] However, the inclusion criteria of the cases were different as that study focused on the obstruction; whereas, our study only focused on the presence of calculi, regardless of the obstructive aspect. Furthermore, other diseases like pyelonephritis or strictures, that were not evaluated here, could be responsible for pelvic dilatation or ureteral diameter above the cut-off values provided in our study. Pelvic and ureteral dilatation are helpful when searching for calculi on US. In cases where urolithiasis is suspected but there is no renal pelvic or ureteral dilatation on US, nonenhanced CT could be utilized to improve identification of ureteroliths.

Several limitations to this study can be discussed. First, the US examinations were performed without sedation. Due to the dorsal localization of the kidney and the ureter, the pressure applied to the abdomen was considerable and could have been uncomfortable for the cat. Furthermore, the presence of the calculi might have been associated with pain that could have limited the ability to fully assess the area of interest. However, in the hospital where the study was performed, all USs are performed without sedation in cooperative cats. In the previously published study, the conditions regarding anesthesia or analgesia during the US exam was not always mentioned.[1,3,11,26,38] Therefore, the effects of pain management, sedation, or anesthesia on the detection of ureteral calculi remain unknown.

CT is a more expensive technique compared to US. However, considering that anesthesia is not mandatory and postcontrast injection is not performed, the cost of CT could be more affordable. However, both imaging modalities present advantages, and a combination of US and CT can be recommended to obtain different information.

The ionizing characteristics of the CT exam should be taken into account, even if the received dose is low for a single abdominal acquisition. But because nonenhanced CT can provide the exact localization of calculi, it can influence the medical or surgical option proposed to the owner in the best interest of the cat, which is essential. However, it can be sometimes challenging to follow the entire ureter on nonenhanced CT, especially when there is retroperitoneal effusion or inflammation. This did not impact our study as we were searching for mineralized structures, which can be easily detected.

Finally, this study design focused only on the imaging detection of calculi. Neither the clinical aspect, nor the obstructive condition, were evaluated. Also, inclusion was based on US results and clinician suspicion of the presence of calculi on US. Therefore, it is possible that some cases might not have been included because of a pelvic dilatation that was too small on US. We might have therefore overestimated the pelvic and ureteral diameter mean values in this study, considering that some of the cases that were not included might have had a ureteral calculus that could have been diagnosed on CT. Further exams, such as surgery or necropsy, were also not considered in this study. Therefore, we do not have any comparison findings, especially for nonenhanced CT with a confirmed diagnosis.

In conclusion, nonenhanced CT can detect ureteral calculi in cats and detects a greater percentage of ureteral calculi compared to US. The results of this study are a first step in considering nonenhanced CT as the optimal imaging modality for detecting ureteral calculi in cats.

ACKNOWLEDGMENT

No funding was received for this study. The authors thank Sophie Demangeot, Hélène Kolb and Sophie Segond as they provided and cared for study patients.

CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Approved by a local ethical review board (ONIRIS; CERVO-2017-16-V).

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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How to cite this article: Testault I, Gatel L, Vanel M. Comparison of nonenhanced computed tomography and ultrasonography for detection of ureteral calculi in cats: A prospective study. *J Vet Intern Med*. 2021;35(5):2241-2248. https://doi.org/10.1111/jvim.16210