CLINICAL SIGNIFICANCE OF RENAL PELVIC DILATATION ON ULTRASOUND IN DOGS AND CATS

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Renal pelvic dilatation is often recognized sonographically in dogs and cats, but ranges of measurements expected with different urologic conditions remain unknown. Ultrasound images of 81 dogs and 66 cats with renal pelvic dilatation were reviewed, and six groups were formed based on medical records: (I) clinically normal renal function, and (II) clinically normal renal function with diuresis; (III) pyelonephritis; (IV) noninfectious renal insufficiency; (V) outflow obstruction; (VI) miscellaneous nonobstructive anomalies. Medians for maximal pelvic width (range) for group I was 2.0 mm (1.0–3.8) in 11 dogs, and 1.6 mm (0.8–3.2) in 10 cats; for group II, 2.5 mm (1.3–3.6) in 15 dogs, and 2.3 mm (1.1–3.4) in 16 cats; for group III, 3.6 mm (1.9–12.0) in nine dogs, and 4.0 mm (1.7–12.4) in seven cats; for group IV, 3.1 mm (0.5–10.8) in 33 dogs, and 2.8 mm (1.2–7.3) in 13 cats; for group V, 15.1 mm (5.1–76.2) in six dogs, and 6.8 mm (1.2–39.1) in 17 cats; and for group VI, 3.8 mm (1.2–7.6) in seven dogs, and 3.0 mm (1.3–7.5) in three cats. Pelvic width in group I was lower than in groups III–V ($P = 0.0001$), but did not significantly differ from group II. Pelvic width ≥ 13 mm always indicated obstruction. While the proportion of bilateral pelvic dilatation was not different among groups, the difference in pelvic width (maximal–minimal) was greater in group V vs. groups I, II, and IV ($P = 0.0009$). These results confirm that renal pelvic dilatation can be detected sonographically in dogs and cats with clinically normal renal function, and that it increases with renal insufficiency, pyelonephritis, or outflow obstruction. Nevertheless, renal pelvic width varies substantially within groups and should be interpreted with caution. *Veterinary Radiology & Ultrasound, Vol. 52, No. 1, 2011, pp 88–94.*

Key words: cats, dogs, hydronephrosis, pyelectesia, renal pelvis, ultrasonography.

Introduction

HISTORICALLY, THE DETECTION of renal pelvis dilatation on ultrasound has been related to outflow obstruction, neoplasia, ectopic ureter, or pyelonephritis.[1–8] However, others have reported that pyelectasia, a term for mild to moderate, nonobstructive[6] pelvic dilatation, can result from diuresis associated with intravenous (IV) fluid or diuretic administration,[3,9–11] renal insufficiency due to acute leptospirosis,[12] end-stage renal disease,[6] or renal transplantation.[13,14]

The advent of high-resolution ultrasound systems allows a more clear evaluation of the renal pelvis, even with minimal dilatation, and more accurate measurements can be obtained. The size of the renal pelvis, as well as the range of values, that can be encountered in normal dogs and cats and those with different types of urinary tract disorders is largely unknown.

Our objective was to determine the maximal width of the renal pelvis in dogs and cats with clinically normal renal function, with and without increased diuresis, and to compare these values to ones obtained in animals with nonobstructive urinary tract disorders and those with outflow obstruction. Another objective was to determine whether a cut-off value could be used to predict obstruction in this population.

Materials and Methods

Medical records from 2004 to 2006 were reviewed to identify cats and dogs where pelvic dilatation was noted sonographically. Eligible animals had to have high-quality transverse and longitudinal images obtained at the central level of the pelvis. Images were reviewed by a radiologist (M.A.D) to confirm that maximal pelvic width was consistently measured in a transverse plane, and the proximal ureter was excluded. This plane was selected to ensure that the pelvis was not measured obliquely. Eighty-one dogs and 66 cats were identified. Renal pelvic dilatation was recognized unilaterally in 21 dogs and 15 cats, and bilaterally in 60 dogs and 51 cats.

If several examinations were performed, only values from the initial examination were used. In bilateral pyelectasia, both pelvic width values were recorded and dilation was considered symmetric when there was less than 25% difference between the smallest and the greatest pelvic

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width value; otherwise the pelvic dilation was considered asymmetric. In order to compare pelvic symmetry in the entire population of animals, nondilated pelves were attributed a width of 0 mm. In these patients, the difference in pelvic width (maximal–minimal values) corresponded to the maximal value.

The following data were also recorded: age; body weight; prior administration of IV fluids, diuretics or corticosteroids (yes or no); and cause of outflow obstruction based on reports of surgery, imaging and/or necropsy. Dogs and cats were divided into six groups according to medical data:

Group I: Clinically normal renal function based on absence of azotemia, normal creatinemia and phosphorus; and a urine specific gravity (> 1.035).
Group II: Clinically normal renal function except a urine specific gravity below 1.035 and evidence of diuresis, such as due to IV fluids, diuretics, or polyuria associated with hyperadrenocorticism, corticosteroid therapy, or diabetes.
Group III: Pyelonephritis based on a combination of positive urine culture and/or presence of bacteria and increased white blood cell count on cystocentesis or pyelocentesis, an inflammatory leukogram, and relevant clinical signs such as fever, lethargy, and renal pain.
Group IV: Acute or chronic renal insufficiency other than pyelonephritis, based on history, increased creatinine and urea and urine specific gravity (< 1.035).
Group V: Partial to complete outflow obstruction based on clinicopathologic findings, imaging, and follow-up.
Group VI: Miscellaneous nonobstructive conditions including ectopic ureter and nonobstructive renal neoplasia.

Mean pelvic width was analyzed using a linear model with group as a factor and taking into account unequal variances among groups. Contrasts were used to compare means between pairs of groups and *P*-levels were adjusted with the sequential Bonferroni's procedure. Exact χ^2 was used to determine the association between bilaterality and symmetry of pyelectasia and group. The association between the mean difference in pelvic width in animals by bilateral pyelectasia, and the animal group, was tested with a linear model with group as a factor and taking into account unequal variances among groups. Tukey's post hoc tests were used to compare means between all pairs of groups. The relationship between body weight, age, and maximal pelvic width was determined with a linear regression model. The level of statistical significance was set at 0.05 throughout. Statistical analyses were carried out using SAS v. 9.1.*

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Results

Patient signalment and distribution of renal pelvic dilatation (bilaterality and symmetry) in the six groups are reported in Table 1, and the mean, standard deviation (SD), median and range of pelvic width for each group are reported in Table 2 and Fig. 1. Examples of pelvic dilatation in the different groups are presented in Fig. 2. Frequency of prior administration of IV fluids and other specific results for groups II–VI were the following:

Group II: Nine dogs and 13 cats received IV fluids; three dogs and three cats were diagnosed with a disease that resulted in increased urine production (four diabetes, two hyperadrenocorticism); and three dogs had received corticosteroids.
Group III: Three of the nine dogs (33%) and two of the seven cats (29%) of group III were receiving IV fluids when sonography was performed.
Group IV: Thirteen dogs (40%) and six cats (46%) were receiving IV fluids when sonography was performed.
Group V: Animals were diagnosed with ureteral calculi (three dogs and 10 cats), with bladder and/or utereral neoplasia causing ureteral obstruction (three dogs), or with acute urethral obstruction (seven cats). One dog (17%) and eight cats (47%) of group V were receiving IV fluids when sonography was performed.
Group VI: Cats were 1, 3.3, and 14.1 years old and weighed 5.5, 7.4, and 9.3 kg. Diagnoses were ureteral ectopia (four dogs, one cat), renal neoplasia (two dogs and one cat), or glomerulopathy without evidence of azotemia (one dog, one cat). Three dogs (43%) and one cat (33%) were receiving IV fluids when sonography was performed.

When combining data for cats and dogs, there was significant heterogeneity in mean pelvic width ($P = 0.0001$). The mean was smaller in group I than in groups III, IV, and V, and smaller in group II than in group V. While the range of pelvic width overlapped between all groups, a value of pelvic width equal or exceeding 13 mm was associated only with outflow obstruction.

The following variables were log10 transformed before statistical analysis to normalize distributions: maximal pelvic width, difference in pelvic width (maximal–minimal values), age, and body weight. There was no significant relation between bilateral pelvic dilatation (as opposed to unilateral), or symmetry, and group. On the other hand, when combining data from dogs and cats, there was significant heterogeneity in the mean difference between maximal and minimal pelvic width among groups ($P = 0.0009$). The mean was higher in group V than in groups I, II, and IV. There was no significant association between body weight, or age, with maximal pelvic width, regardless of the species or animal group.

Table 1. Patient Signalment and Distribution of Renal Pelvic Dilatation

Group	Dogs N	Dogs Age* (years)	Dogs Bodyweight* (kg)	Dogs Pelvic Dilatation Bilateral (Frequency)	Dogs Pelvic Dilatation Symmetric (Frequency)	Cats N	Cats Age* (years)	Cats Bodyweight* (kg)	Cats Pelvic Dilatation Bilateral (Frequency)	Cats Pelvic Dilatation Symmetric (Frequency)
I. Normal renal function	11	9.0 ± 3.2	28.8 ± 15.9	7 (64%)	8 (73%)	10	7.9 ± 4.5	5.8 ± 2.4	6 (60%)	5 (50%)
II. Normal renal function with diuresis	15	7.9 ± 3.8	24.7 ± 12.7	12 (80%)	9 (60%)	16	10.4 ± 3.8	4.7 ± 1.2	13 (81%)	4 (25%)
III. Pyelonephritis	9	9.7 ± 4.3	20 ± 17.6	9 (100%)	3 (33%)	7	9 ± 5.2	4.5 ± 0.8	7 (100%)	2 (29%)
IV. Acute or chronic renal insufficiency	33	10.1 ± 4.3	16.2 ± 10.4	24 (73%)	8 (24%)	13	10.3 ± 4.9	5.2 ± 1.9	11 (85%)	6 (46%)
V. Obstructive disorders	6	8.2 ± 3.1	14.4 ± 12.2	5 (83%)	2 (33%)	17	7.8 ± 4.4	4.8 ± 1.4	14 (82%)	8 (47%)
VI. Miscellaneous nonobstructive disorders (ureteral ectopia, renal neoplasia)	7	5.9 ± 3.1	19.6 ± 14.7	3 (43%)	3 (43%)	3	—	—	1 (33%)	0 (0%)

*Results are expressed as means ± standard deviation, except for group VI in cats because of small sample ($N = 3$).

Discussion

Our results confirm that renal pelvic dilatation can be detected unilaterally or bilaterally in several pathologic conditions as well as in normal dogs and cats due to a physiologic response. Dogs can develop unilateral or bilateral pyelectasia when receiving IV saline (0.9% NaCl).[10,15] However, it is generally accepted that the renal pelvis should not be identifiable sonographically in normal dogs and cats not receiving IV fluids, and that if the renal pelvis is seen under these conditions then outflow obstruction, pyelonephritis, or a congenital anomaly such as ectopic ureter should be considered.[11] Conversely, in our population, a pelvic width reaching 3 mm was observed in several dogs and cats with clinically normal renal function that were not receiving IV fluids (group I). Although mean pelvic width was increased in animals with polyuria and/or receiving diuretics or IV fluids (group II) as opposed to group I animals (2.5 vs. 2.0 mm in dogs; 2.3 vs. 1.8 mm in cats), this difference was not significant. Also, neither age nor body weight influenced pelvic width values between groups.

Pyelectasia has also been described in humans with normal renal function, and in those with polyuria.[16,17] Pyelectasia can also be found in humans during pregnancy or with a full urinary bladder.[16] Similarly, it was proposed that pyelectasia may result from bladder distension in dogs,[9] although the impact of bladder size on pelvic dilatation has not been clearly established. Bladder distension was inconsistently recorded or graded in this retrospective study, precluding any conclusion on its potential repercussion on renal pelvis size.

Pyelonephritis is another cause of pyelectasia that has been documented sonographically in experimentally,[1] and clinically infected dogs.[18] Similarly, the pelvic width was increased in nine dogs and seven cats in our patients with pyelonephritis (group III), with mean values of 5.6 and 4.6 mm, respectively, and with values reaching 12 mm in

Table 2. Pelvic Width (PW) Values by Group and Species

Group	Dogs N	Dogs Maximal PW Mean ± SD (mm)	Dogs Maximal PW Median (mm)	Dogs Maximal PW Range (mm)	Dogs Minimal PW Mean ± SD (mm)	Dogs Max–Min PW Mean ± SD (mm)	Cats N	Cats Maximal PW Mean ± SD (mm)	Cats Maximal PW Median (mm)	Cats Maximal PW Range (mm)	Cats Minimal PW Mean ± SD (mm)	Cats Max–Min PW Mean ± SD (mm)
I. Normal renal function	11	2.0 ± 0.9	2.0	1.0–3.8	1.1 ± 1.0	1.0 ± 1.0	10	1.8 ± 0.8	1.6	0.8–3.2	0.7 ± 0.7	1.0 ± 0.9
II. Normal renal function with diuresis	15	2.5 ± 0.7	2.5	1.3–3.6	1.4 ± 1.0	1.1 ± 1.0	16	2.3 ± 0.9	2.3	1.1–3.4	1.2 ± 0.9	1.1 ± 0.7
III. Pyelonephritis	9	5.6 ± 3.7	3.6	1.9–12.0	2.8 ± 1.4	2.7 ± 2.9	7	4.6 ± 3.6	4.0	1.7–12.4	2.7 ± 1.7	1.9 ± 2.2
IV. Acute or chronic renal insufficiency	33	3.4 ± 1.8	3.1	0.5–10.8	1.7 ± 1.5	1.7 ± 1.3	13	3.0 ± 1.6	2.8	1.2–7.3	1.7 ± 1.2	1.3 ± 1.1
V. Obstructive disorders	6	24.9 ± 26.6	15.1	5.1–76.2	7.1 ± 6.6	17.8 ± 28.9	17	10.9 ± 10.8	6.8	1.2–39.1	4.0 ± 4.6	6.9 ± 10.0
VI. Miscellaneous nonobstructive disorders (ureteral ectopia, renal neoplasia)	7	4.5 ± 2.2	3.8	1.2–7.6	0.9 ± 1.1	3.4 ± 2.4	3	3.9 ± 3.2	3.0	1.3–7.5	0.4 ± 0.6	3.6 ± 3.4

Significant heterogeneity in maximal PW ($P = 0.0001$) and in the difference between maximal and minimal pelvic width (Max–Min) ($P = 0.0009$) was revealed when combining canine and feline groups. Post hoc tests revealed the following statistically significant differences after the sequential Bonferroni's correction: the maximal mean was lower in group I vs. groups III, IV, or V; and lower in group II vs. group V. The mean difference in pelvic width (Max–Min) was lower in animals of groups I, II and IV, vs. group V.

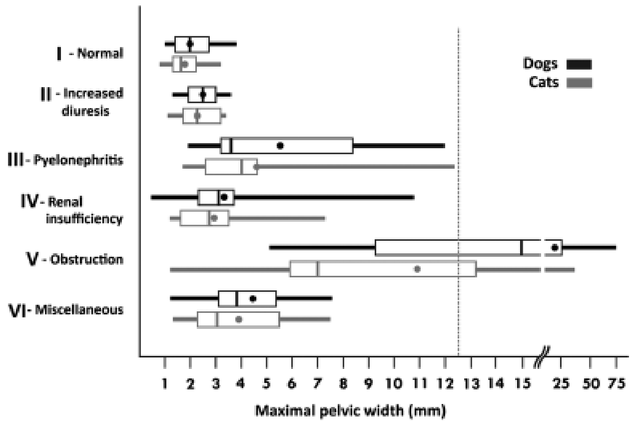

FIG. 1. Box-plot of maximal pelvic width (mm) in dogs and cats, by group. The left and right extremities of each box represent the 25th and 75th percentile values, respectively. The transverse line and dot in each box represent the median and mean, respectively. The horizontal lines indicate the extent of maximal pelvic width values in each group. A maximal pelvic width value of $\geq$12.5 mm (dotted line) was always associated with obstruction (group V).

both species. However, as found previously in experimentally induced pyelonephritis in dogs, one minimal pyelectasia (below 2 mm) was also encountered, which may have been related to the short duration of the infection. Moreover, because the sonographic detection of pelvic dilatation was the primary selection criterion, it is possible that patients with pyelonephritis that were not included in this study did not have pyelectasia during sonography, as seen experimentally.[1]

Pyelectasia was also noted in patients with acute and chronic renal insufficiency (group IV), bilaterally in 76% of dogs and cats, and symmetrically in 31% of these. The maximal pelvic width (mean of 3.4 and 3.0 mm in dogs and cats, respectively) were slightly above those found in groups I and II. Interestingly, pelvic width values of up to 10.8 mm in dogs and 7.3 mm in cats were found. Renal pelvic dilatation has been noted qualitatively in dogs and cats with acute or chronic renal failure,[12,19] end-stage renal disease,[6] and following kidney transplant.[13,14] However, the magnitude of pelvic dilatation that can result from increased urine production and renal architecture remodelling has not been clearly established. Our findings confirm that the presence of moderate to marked pyelectasia, in association with parenchymal changes and sometimes renal mineralization is not necessarily indicative of obstruction.

As expected, mean maximal pelvic width was significantly increased in dogs (24.9 mm) and cats (10.9 mm) with urinary outflow obstruction secondary to ureteral calculi, ureteral, or urinary bladder neoplasia, or urethral obstruction (group V). In both species, a cut-off value of 13 mm was 100% predictive of obstruction. Cats were particularly present in that group (17, 26%), and most often affected with ureterolithiasis, as described previously.[7] However, several cats with ureteral calculi had only minimal renal pelvic dilatation (1–2 mm). The absence of renal pelvic dilation was also reported in 5–6% of cats[7,20] and in 32% of humans[21] with confirmed ureteral calculi. In another study in humans in which complete or nearly complete ureteral obstruction was confirmed by IV urography, there was no evidence of renal pelvis dilatation on ultrasound in 30% of patients.[22] Although the presence of dilatation of the renal pelvis and calices is the primary sign of obstruction in humans,[23] it may fail to occur, or occur later with obstruction. The duration and degree of outflow obstruction and the changes in urine production and pressure are likely linked to the presence of hydronephrosis in these patients.

In our population, animals were categorized as obstructed if there was evidence with imaging, surgery, and/or necropsy of an obstructive lesion involving the urinary outflow tract such as ureterolithiasis or bladder neck neoplasia. Excretory urography[24] was only performed if obstruction was equivocal, as ultrasound was generally preferred for the detection, localization and follow up of animals with sonographically detected ureteroliths. With recent high-resolution systems, ultrasound is highly sensitive and specific for detection of ureteral stones in humans, with a detection rate of 98%.[21] The accuracy of ultrasound for the detection of ureteroliths in small animals has not been investigated extensively. However, hyperechoic foci with shadowing were recognized in only five of 10 cats with confirmed ureterolithiasis.[20] In that study, ultrasound-guided antegrade pyelography was presented as a valuable alternative to excretory urography for confirmation and localization of ureteral obstruction, particularly as it does not require systemic administration of iodinated contrast medium in azotemic or anuric patients.[20]

Several diagnostic avenues have been explored in humans to increase the accuracy of detection of ureteral obstruction using ultrasound. Doppler-derived measurement of renal resistive index is a sensitive test to identify complete obstruction in humans, but is less sensitive in partial obstruction,[16,25] and is generally associated with relatively high false-negative and false-positive rates in dogs (26–27% and 23%, respectively).[4,26] Diuretic sonography can also help in confirming outflow obstruction in humans.[27] While the use of diuretics has been described with scintigraphy,[28] it has not been described with ultrasonography in small animals.

As in our population (group VI) and according to previous reports,[5] several other nonobstructive conditions can be associated with variable degrees of pelvic dilatation in dogs and cats. Among these, renal neoplasia was identified in three animals while ureteral ectopia was present in four dogs and one cat. It remains unclear whether a partial outflow obstruction plays a role in the development of ureteral and pelvic dilatation in animals with ureteral

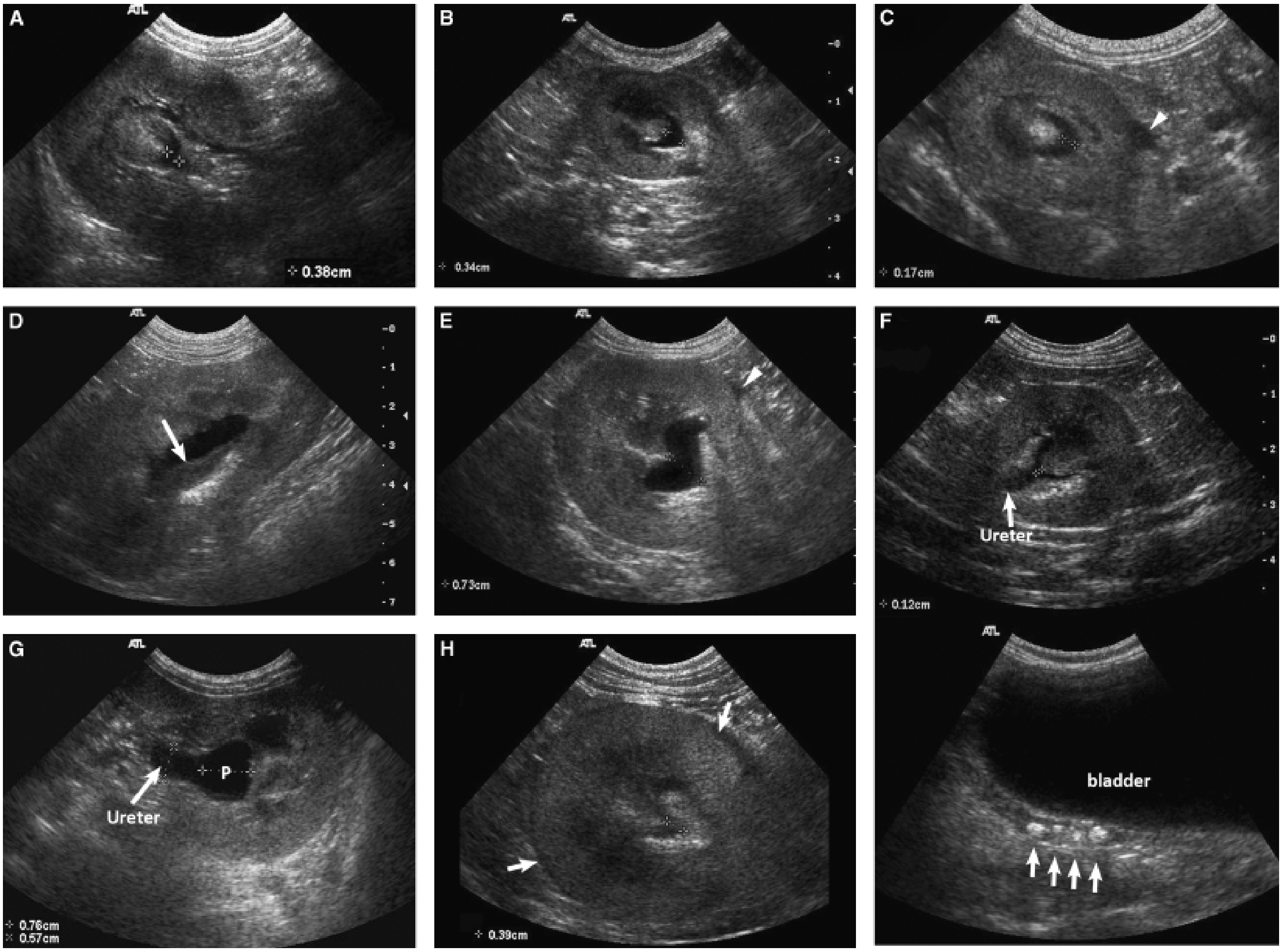

Fig. 2. Collection of sonographic images in different categories of dogs and cats with variable renal pelvic dilatation. (A) Three-year-old, castrated male, Labrador dog with clinically normal renal function. (B) Eight-year-old, domestic short hair, spayed female cat receiving intravenous fluids. (C) Six-year-old, spayed female, domestic short hair cat with acute pyelonephritis. Note the small collection of perinephric fluid (arrowhead). (D) Five-year-old, large mixed breed, castrated male dog with chronic pyelonephritis and echogenic material in the renal pelvis (arrow). Note also the irregular contour of the renal pelvis. (E) Three-year-old, castrated male, domestic short hair cat with acute nephritis. Note the small collection of perinephric fluid (arrowhead). (F) Partial outflow obstruction in a 12-year-old, spayed female, domestic short hair cat with several uroliths in the distal ureter (arrows, dorsal to the bladder). The proximal ureter is mildly dilated. Both the renal pelvis and ureter progressively dilated in this cat over the course of a few days. (G) Six-month-old, large, mixed breed intact male dog with ectopic ureter. Note the dilation of the pelvis (P) and the ureter. (H) Renal lymphoma in a 4-year-old, castrated domestic male cat. Note the peripheral hypoechoic halo sign (arrows).

ectopia, or if congenital wall malformations account for these changes. In a previous study, the renal pelvis was dilated in seven of 14 dogs with ectopic ureter.[5]

Interestingly, there was no significant difference in the proportion of bilateral involvement or in the symmetry of pelvic dilatation between groups, in individual species or when regrouping both species. However, the mean difference in pelvic width (i.e. maximal–minimal) significantly differed between groups. This may be explained by the fact that symmetry, which was arbitrarily set at a threshold of $\pm 25\%$ of variation in pelvic width, was compared only in animals with bilateral pelvic dilation, whereas the difference in width represented an absolute value obtained in all animals. This difference in pelvic width was greater in animals with obstruction (group V), as opposed to animals with normal renal function (group I), with active diuresis (group II) or renal insufficiency (group IV). This was expected if the fact that outflow obstruction is most often unilateral is considered. The lack of difference in regard to groups III (pyelonephritis) or VI (miscellaneous conditions) may be explained partly by the low number of animals in these groups and the fact that some of the diseases in these groups can be unilateral.

This study presents limitations that include the small number of animals in some categories, which may have precluded finding significant differences between some categories. In some groups, the nonuniformity of data distribution resulted in a median markedly different from the mean and a SD that exceeded the lower end of data interval, indicating skewing of the data toward the right. While these data were normalized before statistical analysis, it must be recognized that the means of pelvic width in these groups did not truly represent the central tendency of data distribution. Also, the classification of animals was not always straightforward. Animals were classified according to the most relevant diagnosis in regard to the presence and magnitude of pelvic dilatation. For instance, a patient with acute pyelonephritis but with clinical evidence of chronic renal insufficiency was classified in the pyelonephritis group only, while another patient with outflow obstruction and secondary infection was only considered in the obstruction group. Another limitation is that the rate of IV fluid administration was not known and therefore could not be linked to the degree of pyelectasia in group II at the time of sonography. These data would have been relevant as fluid administration rate can influence the degree of pelvic dilation.[9] Additionally, the administration of IV fluids in several animals in groups III–VI (~30–45%) had a probable impact on the presence and degree of pyelectasia in these animals, in addition to underlying disease. However, this limitation reflects the reality in clinical practice. Finally, other findings that can influence interpretation of pelvic dilatation were not taken into consideration. The retrospective nature of this study, which primarily focused on pelvic width, did not allow the collection of all pertinent findings that could affect renal pelvis width, or that could help to better discriminate between groups. Prospective studies using standardized criteria to be scored during real-time examinations are justified to determine the impact of other sonographic parameters such as: appearance of perirenal fat; presence of retroperitoneal effusion; renal size, shape, contour and parenchymal appearance; shape, uniformity, and content of the renal pelvis and diverticuli; presence of renal mineralization; size of the ureter; size of the bladder; sonographic identification of a cause of outflow obstruction; etc. For example, perirenal effusion may suggest acute renal failure,[19] while the detection of nonshadowing echoes in the renal pelvis typically indicates pyelonephritis or pyonephrosis due to the presence of purulent exudate, hemorrhage, or necrotic debris.[6,8,18,29]

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