Prevalence of circumcaval ureters and double caudal vena cava in cats

Régine Bélanger, DVM, MVSc; Cindy L. Shmon, DVM, DVSc; Peter J. Gilbert, BVSc, MvetSc; Kathleen A. Linn, DVM, MS

Objective—To determine the prevalence of circumcaval ureters and other caudal vena cava variations in cats and determine whether circumcaval ureters were associated with macroscopic evidence of ureteral obstruction.

Sample—301 domestic cat cadavers obtained from an animal shelter.

 Procedures—All cat cadavers were examined, and anatomic variations of the ureters and caudal vena cava were recorded. In cadavers with a circumcaval ureter, kidney length, width, and height were measured, and the ureters were examined macroscopically to determine whether there was gross evidence of ureteral obstruction in cats with circumcaval ureters.

 Results—At least 1 circumcaval ureter was present in 106 of the 301 (35.2%) cats, with a right circumcaval ureter identified in 92 (30.6%) cats, a left circumcaval ureter identified in 4 (1.3%), and bilateral circumcaval ureters identified in 10 (3.3%). Twenty-one (7.0%) cats had a double caudal vena cava, including 2 cats in which the double caudal vena cava was the only anatomic abnormality identified. No sex predilection for anatomic abnormalities was found. Mean right kidney length was significantly greater than mean left kidney length in cats with a right circumcaval ureter.

Conclusions and Clinical Relevance—Circumcaval ureter was present in approximately a third of cats in this study. Variation in the development of the caudal vena cava is the proposed cause. The clinical relevance of this variation is unknown. (Am J Vet Res 2014;75:91–95)

The ureter normally originates at the renal pelvis and runs caudoventrally and medially in the retroperitoneal space to terminate at the bladder. The right ureter is closely associated with the vena cava. Circumcaval ureter, also known as retrocaval ureter, is a condition where the ureter passes dorsal to the vena cava. It results from a developmental anomaly of the inferior vena cava (caudal vena cava in nonhuman mammals) in relation to the ureter.1,2 The right caudal cardinal vein from the embryogenic venous system persists after birth instead of degenerating, pushes the ureter during its migration, and entraps it, leading to the development of circumcaval ureter.3

Circumcaval ureter has a reported frequency of 1/1,000 live births4,5 in people. It is almost exclusively right-sided2,4 but left-sided circumcaval ureter has been observed in patients with situs viscerum inversus. A male-to-female ratio of 2:11 has been reported. More than 20% of affected people have concomitant abnormalities of the cardiovascular system and genitourinary tract.2

In human urology, circumcaval ureters have been classified into 2 clinical types according to their radiographic appearance.6 With type I, or low loop, circumcaval ureter, the middle ureteral segment sharply deviates medially, creating a fish-hook deformity.6–8 This type is the most common in people and the most frequently symptomatic.1 Symptomatic patients have right-sided abdominal pain and recurrent urinary tract infection with or without hematuria,1 and 50% of patients have moderate to severe hydronephrosis.6 With type II, or high loop, circumcaval ureter, the ureter passes around the caudal vena cava at the level of the ureteropelvic junction.8 With this type, the proximal portion of the ureter is not kinked. The renal pelvis and proximal portion of the ureter are directed almost horizontally, and the ureter travels in a gentle curve to encircle the caudal vena cava.8 This type is associated with mild or no hydronephrosis and occurs in only 10% of patients.

Treatment in symptomatic human patients with type I circumcaval ureter involves excision or stenting of the narrowed middle segment of the ureter.1,3 In patients in which ureteral resection and anastomosis has been performed, histologic evaluation of the excised ureteral segment has shown sclerosis and muscular hypertrophy.1 In symptomatic patients with type II cir-
Circumcaval ureter, the stenotic ureteropelvic junction is excised, and the proximal portion of the ureter is spatulated and anastomosed to the renal pelvis. In cats, the ureters leave the kidney to course retroperitoneally toward the urinary bladder, where they enter at an acute angle on the bladder’s dorsal surface and tunnel through the muscular wall before opening into the lumen.

Circumcaval ureter has been reported previously in 2 dogs and 5 cats. A left circumcaval ureter was reported in a female Bernese Mountain Dog with a right divisional intrahepatic portosystemic shunt. The circumcaval ureter in this dog was associated with hydrourerter and hydrenephrosis. In another female Bernese Mountain Dog, left ureterohydronephrosis secondary to transposition of the caudal vena cava and circumcaval ureter was diagnosed by means of MRI. A right circumcaval ureter was identified as an incidental finding in a cat during routine dissection for teaching purposes. The right ureter deviated medially before crossing the vena cava dorsally at the level of the fifth lumbar vertebra. It continued between the caudal vena cava and the abdominal aorta, coursed back ventrolateral to the caudal vena cava, and entered the trigone normally. Hydrenephrosis, hydrourerter, and signs of urinary tract inflammation were not present. Right circumcaval ureters were also found in 4 other cats, all with ureteral obstruction in the proximal ureteral segment, a few centimeters cranial to the area where the vena cava crossed the ureter.

Circumcaval ureters have been induced experimentally in rabbits. Exposure of fetal rabbits to high doses of diethylene glycol monomethyl ether, a chemical found in industrial solvents, caused circumcaval ureter and renal pelvis dilation as well as forelimb flexion, a few centimeters cranial to the area where the vena cava crossed the ureter.

The current scientific literature suggests that circumcaval ureters are rare in cats, but at our institution, they have been observed relatively commonly during teaching laboratories that use feline cadavers. To our knowledge, no data on the prevalence of circumcaval ureter in domestic cats have been published. The primary objective of the study reported here, therefore, was to determine the prevalence of circumcaval ureters in cats. The secondary objective was to determine whether there was macroscopic evidence of ureteral obstruction in cats in which circumcaval ureters were identified. We hypothesized that circumcaval ureters would be relatively common in cats, but that macroscopic evidence of ureteral obstruction would not be detected.

Materials and Methods

Specimens—Domestic cats that had been euthanized over a 3-year period at a local animal shelter for reasons unrelated to the present study and collected for use in student surgery laboratories were considered for inclusion in the study. Immediately after each cat was euthanized, the colon was removed through a flank celiotomy and the small intestines were flushed with diluted chlorhexidine to minimize autolysis. Cadavers were individually bagged and frozen at −20°C for storage. Cadavers were thawed at room temperature (approx 22°C) for 24 hours before use in student surgery laboratories.

As students were performing various abdominal procedures during surgery laboratories, supervising staff (surgeons and surgical residents) examined each animal. Sex of the animal, anatomic path of the ureter (normal ureteral anatomy or right, left, or bilateral circumcaval ureter), gross evidence of hydroureter, and caudal vena cava status (normal or double caudal vena cava) were recorded. If an anatomic abnormality of the ureter or caudal vena cava was detected, an external examination and full exploratory laparotomy were performed. The urinary tract was examined for evidence of macroscopic hydroureter or hydroureter, and the entire abdomen was examined for additional pathologic changes. Any anatomic abnormalities were noted. The kidneys were collected by transecting the ureter and renal blood supply at the level of the hilus. The length and width of each kidney were measured by means of published anatomic landmarks. The kidney was then incised in a transverse plane at the center of the hilus, and renal height was measured at the highest point. The kidneys, renal pelves, and ureters were visually examined and compared with the contralateral side for macroscopic evidence of dilation or obstruction.

Data analysis—The study was a cross-sectional study to estimate point prevalences of circumcaval ureter and abnormalities of the caudal vena cava in domestic cats. Mean and 95% confidence intervals were calculated for prevalences of circumcaval ureter overall, right circumcaval ureter, and double caudal vena cava. A χ² test was used to determine whether detection of any anatomic variants (normal anatomy vs abnormal [right circumcaval ureter, left circumcaval ureter, double caudal vena cava or combinations of circumcaval ureter and double caudal vena cava]) was significantly associated with sex (male vs female). Similarly, a χ² test was used to determine whether detection of a right circumcaval ureter (present vs absent) was significantly associated with sex (male vs female). Mean, SD, and 95% confidence intervals were calculated for kidney length, width, and height for clinically normal males, males with right circumcaval ureter, clinically normal females, females with right circumcaval ureter, clinically normal males, and males with right circumcaval ureter). For all analyses, values of P ≤ 0.05 were considered significant. Graphing statistical software was used for all analyses.

Results

A total of 347 cats were examined, but 46 were excluded because of incomplete data. The remaining 301 cats (141 males and 160 females) were included in the study. In 193 (mean and 95% confidence interval, 64.1 ± 1.4%) cats, both ureters and the caudal vena cava were anatomically normal (Figure 1). Anatomic variations of the ureters (n = 86), vena cava (2), vena cava...
and 1 or both ureters (19), or right ureter and right renal vein (1) were detected in the remaining 108 (35.9 ± 2.5%) cats (Table 1). Abnormalities were detected in 57 of the 141 (40.4 ± 7.1%) males and 51 of the 160 (31.9 ± 7.1%) females. There was no significant association between sex (male vs female) and detection of any anatomic abnormality (present vs absent).

A right circumcaval ureter was the only anatomic abnormality in 83 cats and was identified in conjunction with a double caudal vena cava or double right renal vena in an additional 19 cats. In all cats in which a right circumcaval ureter was detected, the right ureter left the hilus perpendicular to the long axis of the kidney. It coursed dorsally and to the left of the caudal vena cava before curving markedly back to the right of midline ventral to the caudal vena cava to enter the trigone in a normal anatomic position (Figure 2). There was no significant association between sex (male vs female) and detection of a right circumcaval ureter (present vs absent).

Overall, 21 cats (7.0 ± 6.7%) had a double caudal vena cava, including 2 cats in which the double caudal vena cava was the only anatomic abnormality identified. The division was located between the phrenicoabdominal and renal veins (Figure 3). Each branch of the double caudal vena cava received drainage from the ipsilateral deep circumflex iliac, ovarian or testicular, and renal veins.

In all 106 cats with a circumcaval ureter, there was no gross evidence of hydronephrosis, dilation of the renal pelvis, or dilation of the ureter proximal to where it partially encircled the vena cava.

Kidney measurements (length, width, and height) were obtained in 34 of the 83 cats in which a right circumcaval ureter was the only anatomic abnormality (Table 2). In these cats, the right kidney was signifi-
cantly ($P < 0.001$) longer than the left, but kidney width and height were not significantly different between the right and left sides.

**Discussion**

Results of the present study suggested that circumcaval ureter was a relatively common abnormality in cats, with 106 of the 301 (35.2 ± 2.6%) cats in the present study having at least 1 circumcaval ureter. This was much higher than the prevalence reported for people (1/1,000 live births).1,5 No sex predilection for circumcaval ureter was identified, and the clinical relevance of this anatomic abnormality could not be determined because none of the affected cats in the present study had gross evidence of hydronephrosis, dilation of the renal pelvis, or dilation of the ureter proximal to where it partially encircled the vena cava. Nevertheless, given the high prevalence of circumcaval ureter in cats, surgeons should be aware of this anatomic variation when performing procedures such as nephrectomy, ureterotomy, ureteral stenting, and renal transplantation.

Circumcaval ureters reportedly result from anomalous development of the caudal vena cava.3,11 In early development, the embryonic venous system is transformed into the caudal vena cava by fusion, anastomosis, and asymmetric vascular degeneration.3,5 Five theories have been proposed to explain the origins of the postrenal segment of the caudal vena cava in mammals, but the supracardinal theory is thought to best explain caudal vena cava development in cats.11 According to this theory, the embryonic kidney, or metanephros, is surrounded by 3 pairs of embryonic vessels that eventually form the caudal vena cava. These are, from lateral to medial, the caudal cardinal, supracardinal, and subcardinal veins. The caudal cardinal veins are the first venous system. Their initial anatomic position is lateral and ventral to the metanephros.3 A substantial portion of the right caudal cardinal vein develops into the common iliac veins and the caval fork. The left caudal cardinal vein completely disappears, except for those parts of it that connect to adult structures.5,18 The right subcardinal vein, located medial to the metanephros, develops into the right hepatic vein and prerenal segment of the caudal vena cava.3 The caudal portions of the supracardinal veins, located dorsomedial to the metanephros, form the postrenal segment of the caudal vena cava, and the cranial portions separate to form the azygos vein on the right and hemiazygos vein on the left.3 The renal segment of the caudal vena cava is formed by anastomosis of the right subcardinal and supracardinal veins, which are both medial to the metanephros. When the right caudal cardinal vein, rather than the supracardinal vein, persists to form the postrenal segment of the caudal vena cava, it pushes the right ureter toward midline during its migration and entraps it, creating a circumcaval ureter.3

Other nonvascular anomalies have been reported in people with circumcaval ureter, including hypospadias, supernumerary lumbar vertebrae, syndactyly, and intestinal malrotation.3,5 None of these abnormalities was found in any of the cats in the present study. However, radiographs were not obtained, so detection of supernumerary lumbar vertebrae was not possible.

In human urology, type I circumcaval ureter is the most common and most frequently symptomatic form of circumcaval ureter. What we observed in these cats was more consistent with a type I circumcaval ureter, in that the ureteral medial deviation was marked and localized, distal to the ureteropelvic junction. These observations seem to agree with the findings of Zaid et al,14 who observed that 4 of 10 cats with ureteral strictures had a right circumcaval ureter with ureteral obstruction in the segment proximal to where the vena cava crossed the ureter but still distal to the ureteropelvic junction.

The clinical relevance of circumcaval ureter in cats is unknown. It is possible that the path of the ureter in cats with circumcaval ureter may predispose affected cats to ureteral obstruction by calculi proximal to the point at which the ureter curves around the caudal vena cava. A study19 of 163 cats with ureteral calculi found that in 42%, calculi involved the left ureter; in 34%, calculi involved the right ureter; and in 25%, calculi were bilateral. This distribution does not reflect the right-side predominance of circumcaval ureter found in the present study. The presence of circumcaval ureter in 4 of 10 cats with ureteral strictures in the report by Zaid et al14 may simply be reflective of the prevalence of circumcaval ureter in the feline population in general. However, their finding that the dilated portion of the ureter was always proximal to the point at which the circumcaval ureter passed around the caudal vena cava suggests that circumcaval ureter may have played a role in stricture formation in these cats. Additional studies are needed to determine whether the presence of circumcaval ureter predisposes cats to development of obstructive ureterolithiasis, pyelonephritis, chronic renal failure, or urinary stasis.

In our study population, the medical history was unknown. There was no gross evidence of hydronephrosis or narrowing of the circumcaval segment of the ureter, but subtle abnormalities may not have been detected. Measurements of the kidneys were obtained in an attempt to detect more subtle changes that could have been missed on visual examination. However, freezing and thawing the cadavers before use could have introduced some experimental error in the measurements. Nevertheless, mean right kidney length was significantly greater than mean left kidney length in cats with a right circumcaval ureter. Because histologic examination of the kidneys from affected cats was not performed, we cannot conclude that this size difference was related to ureteral obstruction.

Enlargement of the right kidney in sexually intact cats, compared with cats neutered at < 7 weeks of age, has been reported.16 Unfortunately, the reproductive status of cats in the present study was not recorded. A prospective study in live cats in which precise measurements of the renal pelvis and ureters are performed could help in identifying mild hydronephrosis and hydrourter. Also, histologic evaluation of fresh samples could help in identifying subtle pathologic changes. If confirmed, the greater length of the right kidney in cats with a right circumcaval ureter may represent a concurrent anomaly or early renal changes, despite the absence of gross changes. In affected people, renal deterioration may not be de-
ected until the third or fourth decade of age, so it is possible that these cats were euthanized before developing clinical signs. Further research is needed to more carefully characterize the potential effects of circumcaval ureter on renal function in cats.

All the cadavers included in the present study were collected from a single local animal shelter. A multi-institutional cross-sectional study would decrease the potential for regional bias. Renal pelvis dilation, circumcaval ureter, and convoluted ureter have been reported in rabbit fetuses after maternal exposure to diethylene glycol monomethyl ether. This molecule is found in deicing additives in aviation fuel, which represents 98% of its use in the United States. The other 2% is found in solvents, inks, paints, and agricultural pesticides. Exposure of our study population to these solvents (or other toxins with a similar teratogenic effect) was possible but unlikely.

References