IMAGING ESSENTIALS

Ultrasonography of the Urinary Tract: Kidneys and Ureters

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Welcome to our series of articles on small animal abdominal ultrasonography. The initial articles provided an overview of basic ultrasonography principles and a discussion about how to perform a systematic scan of the abdomen. The rest of the series discusses ultrasound evaluation of specific abdominal organs/systems.

Read the other small animal abdominal ultrasonography articles published in *Today's Veterinary Practice* at **tvpjournal.com**.

NORMAL ULTRASONOGRAPHIC FEATURES

Kidneys

The kidneys are paired structures located in the retroperitoneal space and surrounded by adipose tissue. Normal kidneys are symmetric in size and shape; they can be oval shaped in cats and bean shaped in dogs.

The cranial pole of the left kidney is adjacent to the greater curvature of the stomach and dorsomedial to the craniodorsal extremity of the spleen (seen cranial and lateral). In dogs, the right kidney is located more cranially than the left kidney and lies within the renal fossa of the caudate lobe of the liver. In cats, the right kidney is often separated from the caudate lobe of the liver by retroperitoneal fat.

The widely accepted normal ultrasonographic measurement for kidneys in a cat varies between 3 and 4.3 cm in length. One report proposed that feline kidneys can measure 3.2 to 4.1 cm in length, 2.2 to 2.8 cm in width, and 1.9 to 2.5 cm in height.[1]

Currently, there is no widely accepted method for determining ultrasonographically normal kidney size for dogs. Ultrasonographic size is usually subjective. The following are proposed methods of measuring normal canine kidney size that have been discussed in recent reports:

- The ratio of the left and right kidney to the length of L5 or L6, with normal being 1.3 to 2.7[2]
- The ratio of kidney length to aortic diameter, with normal ranging from 5.5 to 9.1[3]

When viewing the kidneys in sagittal orientation, the renal sinus, medulla, and cortex can be identified. The renal medulla is the least echogenic region, followed by the renal cortex, and then the renal sinus with hyperechoic fat (**Figure 1**).[4] When assessing for changes of the renal parenchyma, the corticomedullary

distinction should be readily identified. At the corticomedullary junction, the interarcuate vessels can be identified normally in some dogs and cats.

The normal renal cortex in dogs can be slightly hyperechoic to the liver.[5] In normal cats, however, it is not unusual for the renal cortices to be isoechoic or hyperechoic to the hepatic parenchyma. The renal medulla is homogeneous but often has a coarser echotexture than the renal cortex.

The renal vessels (artery and vein) can be seen entering the renal hilum. Within the renal hilum, extending into the renal sinus, fat can be deposited (hyperechoic), especially in cats. Normally, the renal pelvis is not dilated, but a small amount of

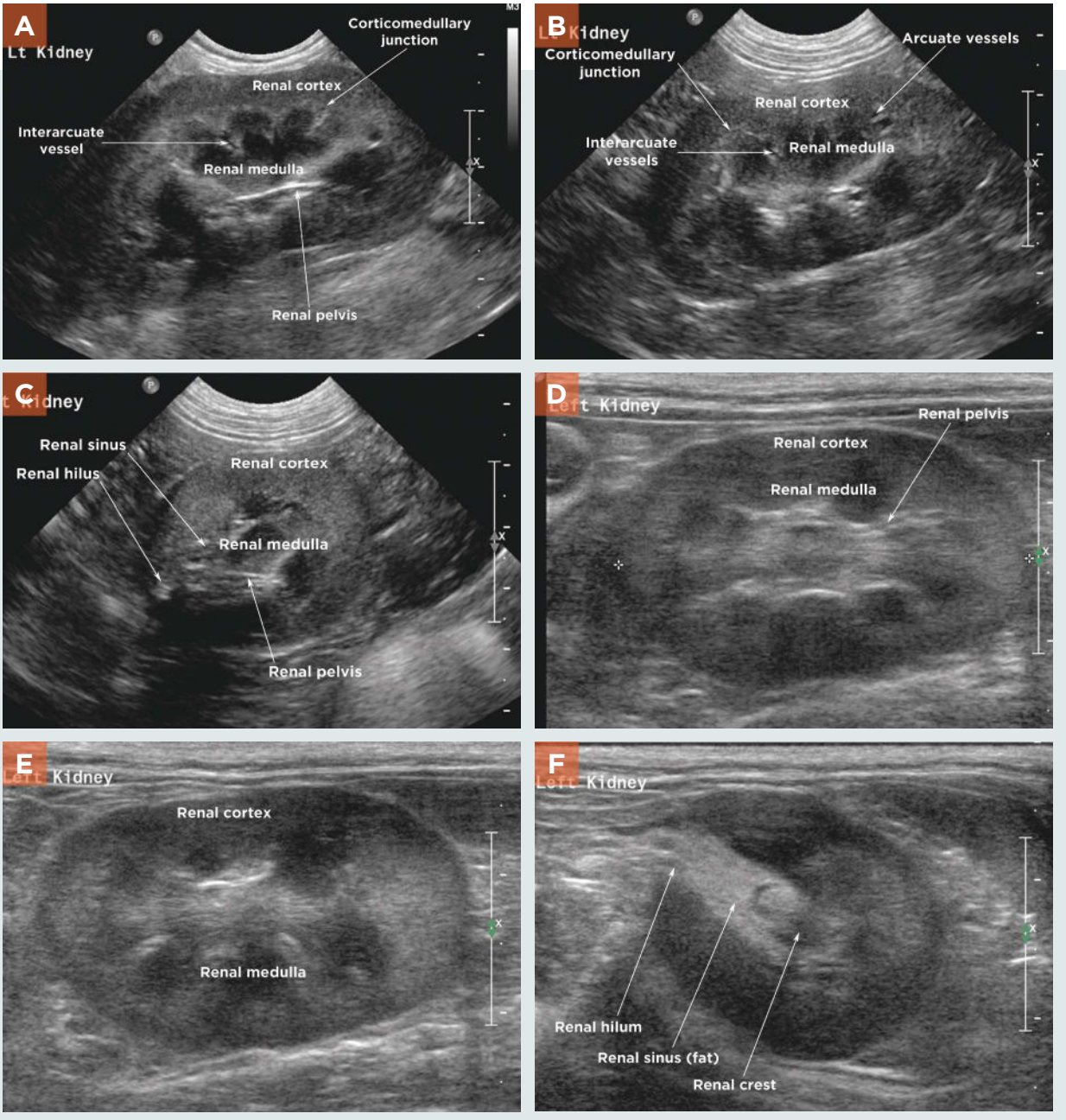

FIGURE 1. Imaging planes of the left kidney in a dog: (**A**) long axis dorsal, (**B**) long axis sagittal, (**C**) short axis transverse. Imaging planes of the left kidney in a cat: (**D**) long axis dorsal, (**E**) long axis sagittal, (**F**) short axis transverse. The different parts of the kidney are labeled in each image. The renal cortex is equal in thickness with the renal medulla and is hyperechoic relative to the renal medulla.

anechoic fluid can occasionally be seen; in the transverse plane, the pelvic width can measure up to 2 mm in dogs and 1.6 mm in cats.[6]

Ureters

The proximal and mid portions of the ureters extend along the retroperitoneal space lateral to the aorta and caudal vena cava. When examining the urinary bladder, the distal ureters, if seen, can be evaluated as they enter the ureteral papillae in the region of the trigone. Ureteral jets into the bladder lumen can often be detected when scanning the area of the papillae, and detection of the jet may be enhanced by use of color Doppler.

SCANNING TECHNIQUE

To optimize images of the urinary tract, the patient's hair must be clipped and ultrasonic gel applied to the skin before examination.

As discussed in "A Tour of the Abdomen: Part 1" (January/February 2016), the urinary tract is examined in a clockwise fashion, beginning with the left kidney, urinary bladder, proximal urethra, and then right kidney. Each kidney is evaluated in its long and short axis; these often correspond to the long and short axis of the patient, although, in some cases, the kidneys are oriented obliquely relative to the patient's sagittal and transverse planes, requiring some adjustment of the ultrasound imaging plane to obtain true renal sagittal and transverse images.

There are 3 renal imaging planes: 2 long axis (dorsal and sagittal) and 1 short axis (transverse).

Within the dorsal plane (**Figure 1**), the renal pelvis is located in the far field of the image, and within the sagittal plane, the long axis of the kidney is seen but the renal pelvis is not. Typically, imaging the kidney from the lateral abdominal wall creates the dorsal plane, and imaging the kidney from the ventral aspect of the abdomen creates the sagittal plane.

The transverse plane can be created by rotating the transducer 90°. Mild renal pelvic dilation is usually best seen in the transverse plane when centered on the renal hilum.

Be sure to evaluate each kidney from medial to lateral or dorsal to ventral in one of the long axis imaging planes and from cranial to caudal in the transverse imaging plane. Any abnormalities should be documented with static images or short video clips.

Left Kidney

The left kidney is easier to localize than the right kidney because of its lateral location along the mid abdomen. Occasionally, it is seen deep to the spleen (located in the near field). The transducer is initially placed in the left cranial abdomen and is moved medially and caudally until the left kidney is visible in a long axis.

Right Kidney

The right kidney is typically more difficult to image due to its craniodorsal location in the abdomen in dogs; it is especially difficult in deep-chested dogs. The transducer is placed in the right dorsolateral subcostal region to visualize the right kidney. However, a lateral approach through the 11th or 12th intercostal space might be needed, especially in deep-chested dogs.

The presence of gas and gastrointestinal contents within the stomach, descending duodenum, and/or the ascending colon can affect the image of the right kidney.[7]

URINARY TRACT ABNORMALITIES

Congenital Abnormalities of the Kidneys

Renal Agenesis or Hypoplasia

Unilateral renal agenesis is rare, but has been reported in dogs and cats.[8] If only one kidney exists, compensatory hypertrophy of that kidney may occur. In this instance, the kidney is enlarged but retains normal internal architecture.

Congenital Renal Dysplasia

This defect can be hereditary or result from neonatal infection, such as feline panleukopenia virus or canine herpesvirus. Renal dysplasia is defined as the disorganized development of renal parenchyma leading to misshapen and fibrosed kidneys.[9] These kidneys can be normal in size or small, irregular, and hyperechoic with reduced corticomedullary distinction.

Renal Ectopia

Congenital malposition of one or both kidneys may occur. The etiology is unknown. Classification is based on the ectopic kidney's anatomic position:

pelvic, iliac, or abdominal.[10] Ectopic kidneys are structurally and functionally normal, but they can be abnormally small, and a short ureter may be kinked, predisposing to obstruction, secondary hydronephrosis, or pyelonephritis.[11]

Ectopic Ureters

This congenital condition results in an abnormal vesicoureteral orifice at the urinary papilla and can be bilateral or unilateral. Ectopic ureters is the most common congenital condition causing dilated ureter and renal pelvis.[12] It is more common in female dogs. Ectopic ureters may be dilated due to ileus, concurrent infection, or partial obstruction at the point of entry to the urethra or vagina/vestibule.

Autosomal Dominant Polycystic Kidney Disease

This is an inherited disease reported mostly in Persian or Persian-cross cats, cairn terriers, and bull terriers.[13,14] Persian cats and bull terriers inherit this disorder as an autosomal dominant trait. In Persian cats, this disease can be detected as early as 6 to 8 weeks of age, but absence of cysts does not preclude development of cysts later on in life.

Ultrasonographically, these cysts are rounded, centrally anechoic, and have smooth, sharply demarcated thin walls with distal acoustic enhancement (**Figure 2**). The cysts are located in the renal medulla and cortex, but most are within the cortex or at the corticomedullary junction. Occasionally, these cysts may be found in the liver as well as the pancreas.

Focal Abnormalities of the Renal Parenchyma

Renal Cysts

Renal cysts may be solitary or multiple, involving both kidneys.[15–17] This condition may be congenital, as explained previously, or acquired. Renal cysts are round to oval in contour and anechoic, and they have smooth, sharply demarcated thin walls with a distinct far wall border and distal acoustic enhancement.

Cysts may deform the renal capsule if they become large enough or if autosomal dominant polycystic kidney disease is present. Also, they can contain internal echoes in association with hemorrhage or necrotic debris. Diagnostic differentials for solitary cysts include hematoma, abscess, and solid or cavitary mass. The presence of cystic lesions of the kidneys in some breeds, such as German shepherds, should raise concern for some neoplasms, such as renal cystadenocarcinoma, which can be associated with cutaneous paraneoplastic fibrotic nodular lesions (nodular dermatofibrosis).[18]

Renal Hematoma

Renal hematomas typically occur in a young animal with a clotting disorder or recent trauma. They may contain a mixture of anechoic, hypoechoic, and hyperechoic components within the renal cortex or medulla. Differentiation from some neoplastic lesions, such as renal hemangiosarcoma, can be ultrasonographically challenging.

FIGURE 2. Long axis sagittal image of the left kidney in a ragdoll cat. Multiple smoothly marginated, rounded, anechoic foci with distal acoustic enhancement are seen throughout the entire renal parenchyma (**white arrows**). These cystic structures are distorting the entire internal architecture of the kidney. The caudal pole of the kidney is indicated by the **white arrowhead**.

FIGURE 3. Short axis transverse image of the left kidney in an Alaskan malamute. This renal abscess is located within a portion of the kidney and is irregularly shaped with a thick wall containing anechoic and echogenic fluid (**black arrowheads**); the hyperechoic component is forming a sediment in the dependent portion of the abscess, causing a fluid-fluid line. More normal renal architecture is still present (**white arrow**).

Renal Abscess

A renal abscess can occur in conjunction with fever and leukocytosis. Abscesses appear as poorly demarcated cavitary lesions that are irregular in contour with internal echoes and sedimentation, and they have variable degrees of distal acoustic enhancement (**Figure 3**). Typically, the renal pelvis is enlarged.

Renal Infarctions

Ultrasonographically, organized infarcts are well-defined, wedge-shaped, cortical lesions located perpendicular to the capsule and extending centrally to the renal pelvis (**Figure 4**). The base of the wedge-shaped lesion is directed toward the renal capsule while the apex points towards the hilus. They vary in appearance and, at the chronic phase, are typically hyperechoic and cause focal cortical depressions secondary to contracture and fibrosis.

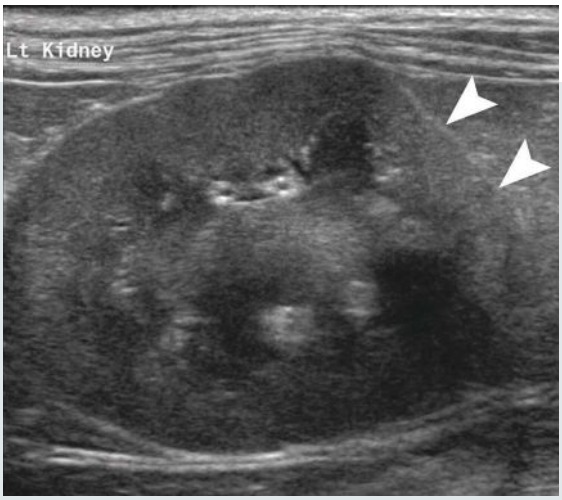

FIGURE 4. Long axis sagittal image of the left kidney in a domestic shorthaired cat. A focal, hyperechoic, wedge-shaped, focally concave, renal cortical infarction is seen extending from the cortex to the corticomedullary junction (**white arrowheads**) along the caudal pole of the kidney.

FIGURE 5. Long axis sagittal image of the left kidney in a Siamese cat. Overall, the kidney is irregularly shaped, lobulated, and small. There is a large, hyperechoic, smoothly marginated nephrolith with distal acoustic shadowing located within a renal diverticulum (**white arrow**). Note the renal pelvis distended with anechoic fluid (**white arrowhead**).

Renal Mineralization (Nephrocalcinosis)

Renal mineralization can be seen in older dogs and cats. It is classified based on its location. Renal diverticular mineralization is caused by dystrophic mineralization. Renal parenchymal mineralization, however, is caused by mineralization of the renal cortex from deposition of calcium salts or other minerals (eg, ethylene glycol toxicosis).

Mineralization is identified as hyperattenuating foci with distal acoustic shadowing within the renal diverticuli, pelvis, and/or cortex (**Figure 5**); however, if there are punctate foci of hyperechogenicity, distal acoustic shadowing may not be evident.

Renal Cystadenocarcinomas

These tumors are commonly found in German shepherds and are associated with paraneoplastic nodular dermatofibrosis (neurofibromas). Ultrasonographically, one to several fluid-filled cavities (cysts) can be detected, and a solid tissue component can infiltrate the kidney and protrude into the cyst.[19]

Other Renal Neoplasia

Solid soft tissue masses may appear in a variety of ways:

- Homogeneous or heterogeneous
- Hypoechoic, isoechoic, or hyperechoic
- Regular or irregular with variable margins (**Figure 6**)
- Altered renal internal architecture
- Hypoechoic halo at the periphery of the cortex
- Hyperechoic foci or striations throughout the medulla
- Pyelectasia
- Hypoechoic medullary or cortical nodules or masses[20]

The differential diagnosis of hypoechoic nodules or masses includes lymphoma and malignant histiocytosis.[21] Other neoplasms that can affect kidneys include adenocarcinomas, hemangiomas, nephroblastomas, hemangiosarcomas, and metastases.[22]

The most common renal tumor in the dog is renal cell carcinoma (**Figures 6 and 7**). The most common renal tumor in the cat is renal lymphoma

(**Figure 8**), where diffuse changes can be seen. The kidneys are usually enlarged, irregular, hyperechoic, with hypoechoic subcapsular thickening.[23]

Diffuse Abnormalities of the Renal Parenchyma

Ethylene Glycol Toxicosis

Ethylene glycol toxicosis causes a severe increase in cortical and, to a lesser extent, medullary hyperechogenicity (**Table 1**). In addition, there can be a **medullary rim sign**, which is denoted as a circumferential hyperechoic band located in the medulla, parallel to the corticomedullary junction (**Figure 9**); this appearance is consistent with mineralization, necrosis, congestion, and/or hemorrhage.[20]

FIGURE 6. Long axis sagittal image of the right kidney in a Rhodesian ridgeback. There is a large, lobulated, heterogeneous mass located in the cranial pole of the kidney. The margins of this mass are well demarcated (**white arrowheads**). More normal renal parenchyma can still be identified in the caudal pole of the kidney (**white arrow**). This mass was diagnosed as a renal cell carcinoma.

FIGURE 7. Long axis sagittal image of the left kidney in a Labrador retriever. There is an expansile, well demarcated, lobulated, heterogeneously hyperechoic mass in the caudal pole of the kidney, causing distortion of the renal architecture and shape. This dog was diagnosed with renal cell carcinoma.

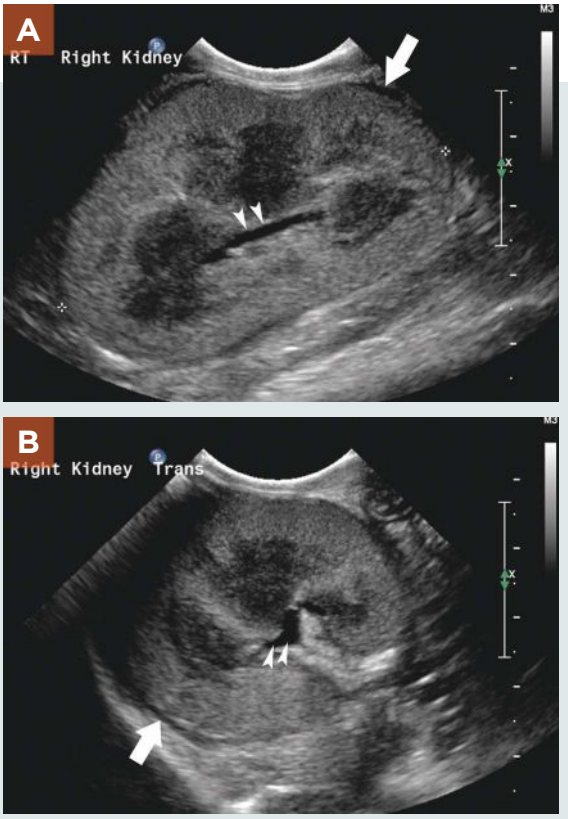

FIGURE 8. (**A**) Long axis sagittal and (**B**) short axis transverse images of the right kidney in a domestic shorthaired cat. The cortex is thickened and hyperechoic, and its margin is irregular. Anechoic fluid is detected within the mildly to moderately distended renal pelvis (**white arrowheads**). A very small amount of anechoic to hypoechoic fluid surrounds the kidney (**white arrow**). This cat was diagnosed with renal lymphoma.

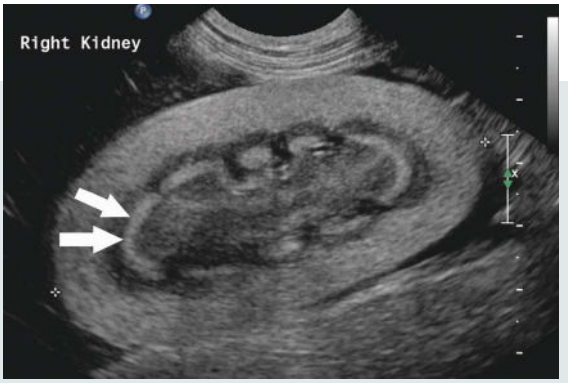

FIGURE 9. Long axis sagittal image of the right kidney in a mixed-breed dog. The renal cortex is severely hyperechoic. There is also a hyperechoic band within the medulla traversing parallel to the corticomedullary junction (**white arrows**). This dog was diagnosed with ethylene glycol toxicosis.

from the urinary bladder. Ultrasonographic changes associated with pyelonephritis include:

- Mild renal enlargement and mild to moderate pelvic and ureteral dilation[34]
- Hyperechoic mucosal margin parallel to the wall of the renal pelvis and proximal ureter[24]
- Echogenic medullary band at the corticomedullary junction
- Focal hyperechoic areas in the renal medulla and patchy, focal hypoechoic or hyperechoic areas in the renal cortex[24]

Urine echogenicity may increase and even contain sedimentation due to pyuria. In chronic cases, renal pelvic and diverticula distortion and a hyperechoic rim can be seen.

Hydronephrosis

Hydronephrosis occurs when the renal pelvis and diverticuli become dilated, distorting and compressing the renal parenchyma.[33] The renal diverticuli become rounded and appear as anechoic finger-like projections extending from the anechoic renal pelvis (**Figure 12**).

Possible causes of hydronephrosis include congenital malformation, lower urinary tract obstruction, and ureteral or renal pelvic obstruction from a calculus, stricture, or trigonal or retroperitoneal mass.

In chronic cases, the renal pelvis is distended, and the renal parenchyma can atrophy. Hydroureter is often seen in combination with hydronephrosis. Hydronephrosis may progress to pyonephrosis, caused by urinary stasis and subsequent infection.[35]

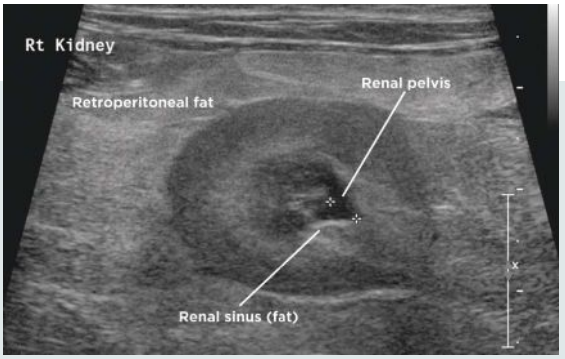

FIGURE 11. Short axis transverse image of the right kidney in a domestic shorthaired cat. The retroperitoneal fat is hyperechoic. There is poor corticomedullary distinction. The renal pelvis is mildly distended with slightly echogenic fluid. This cat was diagnosed with presumptive pyelonephritis.

Hydroureter

If ureters are filled with fluid, they are easily identified beginning at the renal hilus. Ureters can be abnormally distended secondary to ectopia, ureteritis, obstruction, or congenital conditions.[36]

In chronic obstructions, the distended ureters can become severely enlarged and tortuous, making it possible to follow them caudally to the level of the obstruction. If **ureteroliths (ureteral calculi)** are suspected to be the inciting cause, smoothly to irregularly marginated, hyperechoic foci with distal acoustic shadowing can be identified within the abnormally distended ureteral lumen.

Other tubular structures are also located in the renal hilus, such as the renal vein and artery. To differentiate

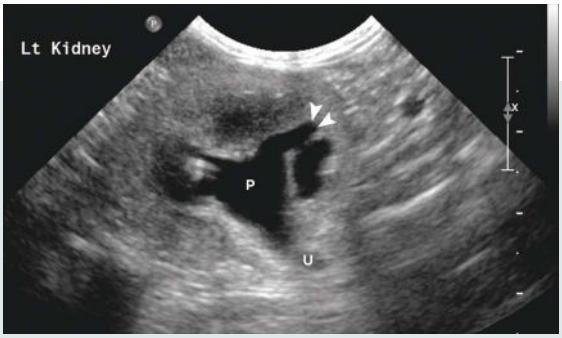

FIGURE 12. Long axis sagittal image of the left kidney in a domestic shorthaired cat. The renal pelvis (**P**) and proximal ureter (**U**) are moderately distended with anechoic fluid. Note the rounded renal diverticuli (**white arrowheads**). This cat was diagnosed with obstructive hydronephrosis and hydroureter secondary to ureteral calculi.

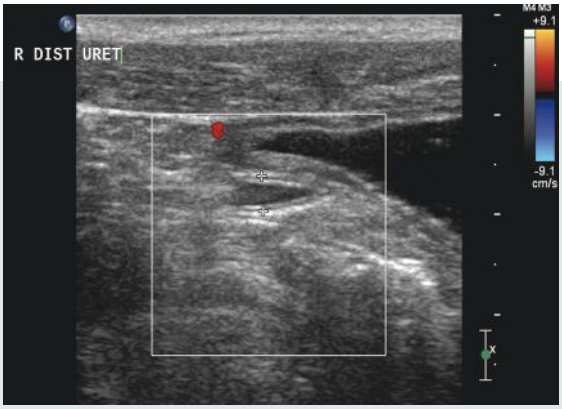

FIGURE 13. Long axis sagittal image of the right ureter at the level of the apex of the urinary bladder in a domestic shorthaired cat. The ureter is distended with anechoic fluid. Note the lack of color Doppler flow within the ureter and the subjectively thickened ureteral wall.

PEER REVIEWED

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hydroureter from a normal renal vessel, color Doppler or power Doppler can be used, focusing on the renal hilum (**Figure 13**); the anechoic tubular structures with flow within their lumen are vascular and should not be mistaken for the abnormally distended ureter.

Abnormalities of the Retroperitoneum

Retroperitoneal transudate appears as linear, triangular, or oval anechoic to hypoechoic foci adjacent to the kidneys. These changes can be seen with accumulation of urine or blood, following trauma to the kidneys and/or ureters.

FIGURE 14. Long axis sagittal image of the right retroperitoneal space in an Australian shepherd. There is an irregularly shaped, heterogeneous mass with anechoic foci (**white arrowhead**) within the retroperitoneal space. The crosshairs demarcate the peripheral extremities of this mass in this view. A malignant neoplasm, such as hemangiosarcoma, was highly suspected; however, no cytology or histopathology was performed to confirm this suspicion.

Retroperitoneal exudate and acute hemorrhage are usually more echogenic because of their higher cell count. Inflammatory processes, such as acute pyelonephritis and ureteritis, can cause the retroperitoneal fat to become hyperechoic and hyperattenuating.

Retroperitoneal abscesses can be caused by migrating plant awns in some regions of the country. They have thickened, irregular walls and often present as anechoic to hypoechoic masses, with or without septae and internal echogenic debris.[37]

Retroperitoneal masses may occur secondary to granulomas, neoplasia, or enlarged sublumbar lymph nodes. They can be variable in size, shape, and echogenicity. Hemangiosarcoma is a common neoplasm of the canine retroperitoneal space (**Figure 14**).[38]

SUMMARY

Abnormalities of the kidneys and ureters are commonly seen when urinary bladder abnormalities are present. A systematic examination of the urinary system is a routine part of the complete abdominal evaluation. TVP

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