Urinary Sonography: A Good Place to Start

William Tod Drost, DVM, DACVR
Ohio State University
Columbus, OH

A 5.0-10 MHz transducer may be used for medium to large dogs while a 7.5 MHz or higher transducer is best suited for smaller dogs and cats. Use of higher frequency transducers allows the best resolution and image detail, the trade-off being depth discrimination. Linear array transducers provide excellent anatomic detail of superficially located kidneys in smaller patients. The hair coat is clipped and acoustic gel is applied to the skin to properly acoustically couple the transducer to the patient.

Kidneys have three distinct anatomic regions; the renal cortex (intermediate echogenicity), the medulla (hypoechoic to nearly anechoic) and the renal pelvis/sinus (hyperechoic). Renal cortical and medullary tissues are routinely evaluated for relative echogenicity and sonographic distinction between them. The cortex is hyperechoic relative to the medulla and a distinct demarcation between them should be present. Often an echogenic rim separates cortical from medullary tissue. This is seen in normal and abnormal kidneys. The medulla is hypoechoic, sometimes to the degree that inexperienced sonographers may mistake its echogenicity as anechoic and make an incorrect diagnosis of hydronephrosis. Normal kidneys have a smooth contour bordered by a thin echogenic capsule. In comparison to other organs, the canine renal cortex is usually less echogenic than the splenic parenchyma, and may be hypoechoic to isoechoic relative to the liver.

Ultrasound determination of canine kidney size and correlation with body weight or surface area is limited primarily due to large variation in kidney length and volume among normal dogs and difficulty in accurate mensuration. The normal cat kidney is approximately 4 cm long. Larger male cats (especially intact males) have the largest kidneys, small spayed females the smallest.

Diffuse renal disease

Diffuse renal disease is much more difficult to diagnose than focal or multifocal disease. Not all diseases cause a change in the sonographic appearance of an organ. There are many instances in which renal failure is present, yet the ultrasound appearance of the kidneys is considered normal. When ultrasound abnormalities are identified, the lesions may not be specific for a particular disease process. In cat kidneys, the degree of cortical echogenicity is positively correlated to the amount of fat vacuoles in the cortical tubular epithelium. Kidneys with a large amount of fat vacuoles have a distinct difference between the hyperechoic cortical tissue and the hypoechoic medulla. The cortical echogenicity becomes similar to the highly echogenic renal sinus.

Diffuse renal disease may cause increased cortical echogenicity with enhanced corticomedullary distinction or result in decreased definition between the cortex and medulla as a result of disease affecting both of these regions. Diseases diffusely affecting the kidney include acute and chronic glomerulonephritis and interstitial nephritis, bacterial infections (e.g., Leptospirosis), acute tubular necrosis from toxins (e.g., ethylene glycol toxicosis), amyloidosis, end-stage kidneys and nephrocalcinosis. In the cat, lymphosarcoma, feline infectious peritonitis (FIP) and metastatic squamous cell carcinoma cause hyperechoic cortices, with maintained corticomedullary definition. Reduced cortical echogenicity, or multifocal hypoechoic nodules or masses may represent lymphosarcoma. The size of the kidneys may be normal, enlarged, or small with diffuse renal disease. Acute nephritis, FIP, lymphosarcoma generally cause renal enlargement. Determination of normal renal size for a particular patient is problematic. Serial examinations may be necessary to detect renal size changes in response to therapy.

Ethylene glycol toxicity

Ethylene glycol toxicity (antifreeze) often produces extremely hyperechoic cortices and medullary tissue. Severe cases may produce complete acoustic shadowing. Some cases of ethylene glycol toxicity have a hyperechoic rim at the corticomedullary junction. Concurrent peritoneal, retroperitoneal and subcapsular renal fluid can be observed in some cases. Subtle to moderate renal enlargement is usually present.

A general increase in renal echogenicity (cortical and medullary), with loss of the corticomedullary junction is noted in cases of acute and chronic inflammatory disease, amyloidosis, some types of toxicity and end-stage kidneys in dogs and cats. End-stage kidneys are small, distorted, and irregular. End-stage renal disease may be seen in older patients, or in young or even juvenile patients, a result of congenital renal dysplasia. The kidneys may be asymmetrical.

The renal medullary rim sign is present in a number of disease processes, including hypercalcemic nephropathy (lymphosarcoma), ethylene glycol toxicity, pyogranulomatous vasculitis (feline infectious peritonitis), acute tubular necrosis of undetermined etiologies and chronic interstitial nephritis. It is often seen in dogs with portosystemic shunts. It is recognized as a hyperechoic rim parallel to the corticomedullary junction and usually results from mineral deposits within the outer medullary tubular lumens or tubular basement membranes. In FIP, mineralization is not seen histologically. The medullary rim sign was found in normal cats caused by a band of mineral within the lumens of the renal tubules. The medullary rim sign thus provides an ultrasonographic finding indicating primary renal disease in some, but not all patients. This rim sign is frequently seen in dogs and cats without clinical or biochemical signs of renal disease. Thus, interpretation of this sonographic finding must be correlated with other pertinent data.

Aspiration or biopsy of the kidneys using direct ultrasound guidance is useful for determination of diffuse renal disease. While ultrasound guided FNA or biopsies are relatively safe procedures, they are not without risk. Care must be taken to avoid the renal hilus so that laceration of the renal artery and vein does not occur. Sampling the cortical tissue and directing the needle away from the mid-portion of the kidney will reduce risk. Chronically diseased kidneys are at higher risk for hemorrhage. The risk vs. benefit of renal biopsies or FNA should always be considered.

Renal cysts

Renal cysts may be inherited or acquired in dogs and cats. Inherited polycystic disease occurs in Persian cats and Cairn Terriers. Renal cysts may be single or multiple, large or small and unilateral or bilateral. In many instances, renal cortical cysts are an incidental finding. Cysts are usually round, anechoic, have smooth thin walls and show distal acoustic enhancement. They may be so extensive that deformation of the kidney results. Distortion of the collecting system may occur. Differential diagnoses include homogeneous blood clots, unclotted blood, hematomas, abscesses, lymphoma and necrosis. These conditions can mimic the sonographic appearance of cysts, although they usually lack one or more of the criteria for cysts listed above. Lymphoma nodules may appear anechoic (usually they are hypoechoic), but will not show far wall echo enhancement, and show less, if any acoustic enhancement. Increasing the gain setting, may cause a solid, parenchymal lesion to increase in echo intensity. Cysts will not show internal echoes when this is done. Low-level echoes can be seen in the periphery of some cysts, due to slice thickness artifact.

Solid renal masses

Solid renal masses are usually malignant. They may be hypoechoic, hyperechoic, mixed echogenicity or even isoechoic. Although these patterns are not specific for tumor type, uniformly hypoechoic masses or nodules often indicate lymphoma. Hyperechoic masses are less common, but have been reported with chondrosarcoma, hemangiosarcoma and metastatic thyroid adenocarcinoma. Granulomas are an example of non-neoplastic solid renal masses. Viscous debris within an abscess or hematoma may incorrectly be diagnosed as a solid mass.

Focal hyperechoic areas in the renal cortex

Focal Hyperechoic Areas in the Renal Cortex include mineralization, fibrosis, gas and infarcts. Parenchymal mineralization may simulate pelvic calculi. Chronic infarcts are wedge-shaped, and the broad-based periphery of the lesion may be depressed. Acute renal infarcts may be hyperechoic and then become hypoechoic days later. Radiography may help differentiate gas from calculi. IAn excretory urogram can provide complimentary information to the renal sonogram.

Complex renal lesions

Complex Renal Lesions containing anechoic, hypoechoic and hyperechoic regions. Large masses that destroy renal architecture may be difficult to recognize as renal in origin. Etiologies include hematomas, primary or metastatic neoplasia, granulomas, abscesses, and occasionally acute infarcts. The most common primary malignant renal neoplasm in dogs is adenocarcinoma; hemangioma is the most common benign renal tumor. Lymphosarcoma is the most common neoplasm of the cat kidney.

Hydronephrosis

Hydronephrosis (dilation of the renal pelvis) is recognized as an anechoic separation of the central hyperechoic renal sinus. Mild pelvic dilation is observed with diuresis and may be seen in one kidney from increased urine production when the opposite kidney is diseased or absent. Pelvic dilation and increased size and distortion of the renal diverticula can occur in cases of pyelonephritis. The mucosa of the renal pelvis may become hyperechoic and irregular. In addition, hyperechoic focal or multifocal areas may be seen within the renal medullary tissue, and hypo or hyperechoic areas in the cortex. Mild dilatation of the renal diverticula may be difficult to detect and differentiate from renal vessels. In this instance, Doppler evaluation is informative, especially color Doppler. Excretory urography is still the most sensitive imaging modality in detection of mild, subtle dilatation or distortion of the renal collecting system (mild hydronephrosis or pyelonephritis).

Moderate or massive pelvic dilatation is readily apparent sonographically as a central anechoic region within the kidney. Long-standing ureteral occlusion results in various degrees of hydronephrosis, the most severe case being a fluid filled "sac", with only a thin rim of cortical tissue remaining. The differential list for causes of moderate or severe pelvic dilation includes congenital disease, pyelonephritis, and obstruction to urine flow. Renal, ureteral or bladder calculi are common causes, as are bladder masses. Determining if the condition is unilateral or bilateral is important in establishing an etiology. Asymmetric pelvic dilatation and distortion of the collecting system may occur from an intraparenchymal renal mass or cyst.

Renal calculi
Renal calculi are intensely hyperechoic foci with distal acoustic shadowing. Mineralized and non-mineralized (radiolucent) calculi will each cause acoustic shadowing. Small calculi may not show acoustic shadowing, as they are smaller than the width of the ultrasound beam. Anechoic pelvic dilatation makes imaging renal calculi easier, confirming their location within the renal pelvis or collecting system. Differentiating pelvic calculi from nephrocalcinosis is based on the location of the mineralization. Differentiating between the two conditions may alter the approach to therapy. Distribution of the mineralization on survey radiography or EU is useful.

Perinephric pseudocysts
Perinephric Pseudocysts in cats are large subcapsular or perinephric accumulations of fluid have been diagnosed in cats and occasionally dogs. The kidney floats in encapsulated anechoic fluid. Kidney size, shape, internal architecture and function may be normal, or there may underlying renal disease (e.g., lymphoma, FIP). Due to the presence of fluid, the kidney will appear more echogenic overall than normal. The fluid is usually a transudate or modified transudate.

Causes of renal subcapsular fluid
Causes of Renal Subcapsular Fluid include urine, blood, exudates or transudates. Coagulopathies or trauma may lead to retroperitoneal hemorrhage. Renal FIP and lymphosarcoma often show small accumulations of subcapsular fluid. Ethylene glycol toxicity can produce subcapsular, retroperitoneal and free peritoneal fluid.

Hydroureter
Hydroureter (dilated ureter) may be followed medially and caudally away from the kidney as a continuum of the dilated renal pelvis. The entire ureter, both ureters, or only a segment of ureter may be dilated, depending on etiology. Ureteral calculi, obstruction at the trigone of the bladder by mass lesions or cystic calculi, inflammation or infection, ectopia, may cause dilatation and rarely ureteral pathology caused by an ovariohysterectomy procedure or neoplasia. Diseases of the retroperitoneal (e.g., hemorrhage or neoplasia) and peritoneal spaces can affect the ureters. Hydroureter is a dilated tubular structure in long axis (sagittal plane) or as a round structure in cross-section. Dilated ureters are often tortuous and can generally be differentiated from two large tubular structures in the same vicinity, the caudal vena cava or abdominal aorta. Doppler examination readily distinguishes between vascular structures with characteristic blood flow patterns and a dilated ureter in which urine flow cannot be detected. Urine within the ureteral lumen is anechoic in uncomplicated cases of obstruction, but may become echogenic with infection or inflammation. The ureteral wall is normally a thin echogenic structure, but may become thick and irregular when inflamed or infected. Excretory urography is still the most sensitive imaging modality in detection of mild, subtle dilatation or distortion of the renal collecting system (mild hydronephrosis or pyelonephritis) and the ureters.

Ureteral calculi
Ureteral calculi are more commonly seen in cats than in dogs. Ureteral calculi are focal hyperechoic areas with acoustic shadowing whether or not they are mineralized or non-mineralized on radiographs.. The ureter is usually dilated, but this is not always the case. If the kidney and ureter are not dilated, identification of a ureteral calculus may be a daunting task. Acoustic shadowing is usually identified, but in some cases this is not present due to small size and/or low frequency transducers.

Cystitis
Bladder wall thickening due to cystitis is classically most severe cranioventrally, although thickening may certainly be generalized. Wall thickness depends upon the severity of pathology and the degree of bladder distention. Care must be taken when interpreting wall thickness in nondistended bladders, as the wall will be thicker than in a distended state.

Emphysematous cystitis
Emphysematous cystitis is seen as highly echogenic gas within the bladder wall or in the bladder lumen. Intraluminal gas will localize to the non-dependent portion of the bladder (e.g., along the near field ventral wall when the patient is scanned in dorsal recumbency). Intraluminal gas will redistribute dorsally if the patient is scanned from the ventral abdomen while standing. Gas in the urinary bladder wall is most commonly associated with cystitis caused by the presence of gas-forming bacteria (E. coli), secondary to diabetes mellitus. Glucose in the urine is an excellent growth media for E. coli. Rarely, gas-forming Clostridial infection will be encountered. If there is any doubt as to the presence of gas within the bladder, it can be confirmed with abdominal radiography.

Urachal diverticulum
Urachal diverticulum is a remnant of the urachus is a focal small out pouching in the apex of the bladder wall that can act as a nidus for chronic bladder inflammation and infection. The adjacent bladder wall will be thickened.

Mineralized or non-mineralized calculi
Mineralized or non-mineralized calculi are hyperechoic foci within the dependent portion of the bladder, usually exhibiting strong acoustic shadowing. Various sizes, shapes and number are possible. Shadowing sediment ("sand") may be suspended when the bladder is "bounced" with the transducer or the patient is repositioned. If in doubt, the patient may be scanned while standing, with calculi or sediment moving to the dependent ventral bladder wall. Occasionally with severe chronic cystitis, mural mineralization can occur, or small calculi may adhere to the bladder wall. This too can usually be diagnosed by repositioning the patient, as wall mineralization will not change position.

Gas in the colon may indent the bladder wall, and its crescent-shaped hyperechoic appearance with acoustic shadowing mimics a cystic calculus or may hide small calculi. Usually the colon is seen as a crescent-shaped, highly echogenic interface with acoustic shadowing in a transverse plane and as a long, linear shadowing structure on sagittal plane.

In addition to echogenic urinary sediment that is gravity dependent and "settles out" during the examination, it is not uncommon to encounter echogenic "particles" suspended within the urine. Normal canine and feline urine is anechoic. In some cats, tiny suspended lipid droplets can be a normal finding. Rabbits normally have extremely echogenic urine. The echogenic particles are evenly distributed in these cases and are quite numerous. However, particulate matter evenly suspended within the urine pool can be indicative of infection, hemorrhage, crystals, or casts and other debris arising from the kidneys. Fortunately, urinalysis nearly always provides a definitive diagnosis.

Blood clots
Blood clots may result from trauma, bleeding disorders, neoplasia or cystitis. Immature clots may be heterogeneous. As clots organize, they appear as more discrete, hyperechoic, non-shadowing structures of various size and shape. They may adhere to the bladder wall and difficult to distinguish from a polyp or mass lesion.

Free abdominal urine
Free abdominal urine will be seen as anechoic areas between intra-abdominal organs. The urinary bladder may be difficult to identify in severe cases of trauma. It will be seen as linear echoic bladder wall remnants "floating" in the free abdominal fluid. In other cases, the bladder may be partially distended and the disruption of the wall may not be apparent. The "drop-out" created by edge shadowing must not be mistaken for a site bladder wall tear. Positive contrast cystography remains the gold standard for assessment of bladder integrity.

The size of the urinary bladder
The size of the urinary bladder varies greatly, dependent on many factors. Time intervals since urination and fluid therapy are common considerations. Pathologically, a distended urinary bladder may be indirect evidence of an obstruction of the bladder neck or urethra, or indicate neurological disease. Patients with hyperadrenocorticism may have markedly distended bladders, a result of excessive urine production and reduced muscle tone. Chronic distention can lead to functional loss of bladder wall integrity, with urine literally oozing from the bladder. This can be seen in cats that have chronic urinary obstruction.

Bladder tumors
Transitional cell carcinomas are the most common type of bladder tumors, although other types exist. Focal and irregular bladder wall thickening is usually present. The trigone and proximal urethra are common sites, and extension from a prostatic neoplasm may occur. Many tumors are present in the body or apex of the bladder, so location alone is not enough to establish a diagnosis. Some tumors may be seen as a more diffuse thickening of the bladder wall and be difficult to distinguish from cystitis. Benign tumors cannot be reliably differentiated from malignancies using ultrasound; cytological or histologic samples must be obtained. The ureters and renal pelves may be dilated from obstruction by a trigonal mass. Examination of regional medial iliac lymph nodes for evidence of metastasis is warranted. Abdominal, spinal, and thoracic radiographs should be made in cases of suspected urinary tract neoplasia for local and distant metastasis.

Urethral calculi
Urethral calculi are identified as focal hyperechoic structures within the urethral lumen, with distal acoustic shadowing. The urethra may be distended proximal to the calculi. Calculi can lodge anywhere along the urethra, but accumulation within the prostatic urethra in male dogs is common. In obstructed cats, very small linear accumulations of calculi or sediment can be seen in the urethra. The urethra may be thickened from inflammation and edema. The membranous and penile canine urethra can be scanned transcutaneously using high frequency transducers. Survey and contrast radiography remain procedures of choice for urethral evaluation.

References/suggested reading

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