

CVM 6105 Small Animal Ultrasound

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These supplemental notes should not replace ultrasound textbooks. Please refer to the syllabus for reference textbooks which can be used for additional case examples and more thorough description of findings and differentials.

Ultrasonography of the Upper Urinary Tract

Ultrasound of the upper urinary tract in veterinary medicine is a routine procedure which can provide important anatomic information regarding size, shape and internal architecture of the kidneys. Ultrasound can offer more information than conventional radiography, especially in the presence of emaciation, retroperitoneal and peritoneal effusion, and impaired renal function. Ultrasound can also be used to guide invasive procedures such as fine-needle and core biopsy, percutaneous pyelocentesis, and antegrade pyelography. It should be understood that ultrasound has its limitations. It can be difficult to image kidneys (especially the right kidney) in large/giant breed dogs and in patients with excessive bowel gas. The normal ureter cannot be imaged, and ultrasound does not provide information regarding renal function. Additionally, it can be more difficult to localize ureteral calculi than with radiographs, especially if the ureter is not especially dilated and the patient is not cooperative. An excretory urogram is superior to ultrasound for qualitative assessment of renal function, visualization of non-dilated ureters, identification of subtle pyelectasis and ureterectasis, and localization of ureteral trauma. Nuclear scintigraphy (GFR scan) can be performed for assessment of individual kidney GFR.

Indications: evaluation of abnormal radiographic findings (abnormal size, shape, position or non-visualization of kidneys), evaluation of internal renal architecture, azotemia/uremia, hematuria, recurrent urinary tract infections, cranial retroperitoneal mass, screening for PKD

Transducer: the highest frequency transducer (at least 7.5 MHz) should be used in order to obtain high-quality images of the kidneys, pelvis and ureters; occasionally a lower frequency transducer may be necessary in large patients or in patients with severe ascites

Scan Plane: position animal in dorsal recumbency, obtain sagittal and transverse images routinely – supplemental dorsal images are often obtained as well; the right kidney may have to be imaged through the right 11-12th intercostal space (dorsal and transverse images); the orientation of the kidney to the transducer can markedly alter the sonographic appearance

Artifacts: *bowel gas* can impede imaging and lead to imaging artifacts of the kidneys – considerable transducer pressure should be used to displace overlying intestine; *acoustic shadowing* can be seen due to the normal renal sinus fat; *edge shadowing* artifacts will often be seen at the edges of the round kidney poles

Normal Sonographic Appearance

Location:

Left kidney: caudal to greater curvature of stomach, medial and often ventral to spleen, lateral to aorta

Right kidney: lies in renal fossa of caudate liver lobe, more cranial than left, ventral and often medial to duodenum, lateral to cava

Renal Anatomy:

- the renal medulla is separated into multiple sections by pelvic recesses and interlobar vessels, which are represented by parallel linear hyperechoic structures; most tubules of the collecting system are located in the medulla
- the arcuate and intralobar arteries can be seen as discrete echogenicities at the corticomedullary junction and within the cortex, respectively
- essentially all glomeruli are located in the renal cortex
- both cortex and medulla contain renal tubules, vessels, and connective tissue

Normal Sonographic Appearance:

The kidneys are bean shaped structures with an indentation on the medial aspect at the level of the hilus. In the dog, the left kidney is more loosely attached than the right; and in the cat, both kidneys are more loosely attached than in the dog. Because of this, less transducer pressure may be needed so that the kidneys are not displaced from their normal location. The spleen can be used as an acoustic window to image the left kidney in the dog. The normal renal pelvis and ureter are almost never seen sonographically. They may sometimes be visualized as echogenic linear structures, but should not be distended.

Distinct echogenic regions of the kidneys can be recognized. 1) There is a bright central echogenic complex that represents the renal sinus and peripelvic fat. The fat may cause an acoustic shadow, and it is important to differentiate this from acoustic shadowing caused by mineralization. 2) There is a hypoechoic homogenous region surrounding the pelvis that is the medulla. 3) There is an outer zone of intermediate echogenicity and fine speckled echotexture which is the renal cortex. 4) There is a thin peripheral bright linear echo representing the fibrous renal capsule. The renal pelvic recesses and interlobar vessels are often seen as multiple, evenly spaced, linear echogenicities extending perpendicularly from the renal pelvic region. There should be distinct demarcation between the cortex and the medulla.

Renal cortical echogenicity is similar or slightly less than the liver parenchymal echogenicity. Renal cortical echogenicity should be quite a bit less than the splenic parenchymal echogenicity. It is important to compare the organs at the same depth. It is

also evident that the organ echogenicity relationship may vary with frequency and type of transducer used.

The feline renal cortex is more echogenic than the dog, with a marked difference from the medulla. This is due to fat vacuoles in the cortical tubular epithelium. The cortical echogenicity is also more variable in cats. Thus the relationship to other parenchymal organs is often different in the cat.

During diuresis (with furosemide) it has been shown that the medulla will increase in size, as well as decrease in echogenicity, likely from the increased fluid flow. Physiologic or therapeutic diuresis can lead to minimal bilateral or unilateral pyelectasis in many patients (2-3 mm). In one study, no ureterectasis was noted with saline diuresis in 25 dogs.

Kidneys can be measured from an ultrasound image optimized for length, width, and height. However, these measurements are best taken from radiographs. In dogs, although there is a great variation in kidney measurements, there is a positive correlation of kidney length and volume with body weight. Therefore, kidney size judgments in dogs are relatively subjective. Because cats have a more standard body size, sonographic measurements are more useful. In a small study of young cats, kidney length was 3.66 ± 0.46 cm, width was 2.53 ± 0.3 cm and height was 2.21 ± 0.28 cm. The renal cortex has been reported as measuring between 3-8 mm in the dog and 2-5 mm in the cat.

The medullary rim sign is a non-specific and often normal finding seen in dogs and cats. This presents as a thin linear hyperechoic band (1-3 mm thick) in the outer zone of the renal medulla, several mm inside and paralleling the corticomedullary junction. In cats it has been shown that this is caused by non-pathologic microscopic deposits of mineral within medullary tubular lumens. It is true that this finding can be seen with pathologic conditions such as hypercalcemic nephropathy, nephrocalcinosis, acute tubular or cortical necrosis, FIP, and ethylene glycol toxicity. The medullary rim sign can be due to mineralization, necrosis, congestion, and/or hemorrhage and attributed to an insult to the renal tubules in the deepest portion of the medulla, which is most metabolically active and therefore more susceptible to ischemia. In one study of 32 dogs, of dogs in which the medullary rim sign was the only sonographic finding in the kidneys, 72% had no evidence of renal dysfunction; of dogs that had the medullary rim sign in combination with other sonographic renal abnormalities, 78% had renal disease. Thus the medullary rim sign is not an accurate indicator of renal disease.

Abnormal Sonographic Appearance

Ultrasonographic patterns and echogenicity are more specific for focal or multifocal renal abnormalities and are often non-specific for diffuse renal disease. Ultrasound has limited use in distinguishing between benign and malignant lesions. Additionally, findings may change with duration of disease. Because of the non-specificity of many renal sonographic abnormalities, the sonographic findings should be correlated with signalment, history, physical exam, and biochemical parameters in order to refine a differential diagnosis. Finally, a fine-needle or core biopsy may be indicated for a definitive cytological or histopathological diagnosis.

Diffuse abnormalities of renal parenchyma

Increased cortical echogenicity with preserved corticomedullary differentiation

- generally associated with diffuse infiltrative process
- this is an abnormal but *non-specific* change
- differentials include: glomerular and interstitial nephritis, glomerulosclerosis, acute tubular necrosis or nephrosis secondary to toxic agents or ethylene glycol, end-stage renal disease, parenchymal calcification (nephrocalcinosis), amyloidosis, FIP, often diffuse renal lymphosarcoma in cats or sometimes diffuse small cysts

Increased overall renal echogenicity with decreased CM differentiation

- chronic inflammatory diseases (pyelonephritis), renal dysplasia, GN disorders
- “end-stage” kidneys - these kidneys are typically small, irregular, diffusely echogenic with poor visualization of the CM junction and the internal architecture

Decreased echogenicity

- lymphoma may result in ill-defined multifocal hypoechoic nodules that appear as diffuse hypoechoic disease
- in people, may result from acute diseases associated with edema

Because of the non-specific nature of findings making it difficult to distinguish clinically normal kidneys from acute and chronic renal disease processes, the use of other ultrasound parameters, such as size, shape, contour and internal architecture can be helpful. Kidneys affected by chronic disease processes tend to become small, irregular, and more diffusely hyperechoic. Due to fibrosis, architectural distortions can be present, as well as dystrophic mineralization especially in the region of the collecting system. Kidneys affected by acute processes can become enlarged and hyperechoic with the contour generally remaining smooth. Protein-losing glomerular diseases, such as GN and renal amyloidosis, cannot be distinguished from other diffuse renal disorders. Affected kidneys can vary in size according to the chronicity of the disease but are commonly hyperechoic.

Focal abnormalities of renal parenchyma

Renal cysts:

- may be solitary or multiple, may involve one or both kidneys
- sonographic characteristics of true cyst: round or ovoid, echo-free contents, smooth, sharply demarcated thin walls with a distinct far-wall border, strong acoustic enhancement (through transmission)
- may be within medulla or cortex
- may deform the renal contour if they are large or if polycystic disease is present, may displace/distort/dilate the collecting system
- acquired: secondary to inflammation or obstruction of renal tubules
- **Polycystic kidney disease:**
 - » contain multiple fluid-filled cysts derived from renal tubules
 - » inherited: Cairn terriers, long-haired cats
 - » more common in cats, may have concurrent hepatic cysts
 - » often associated with clinical renal disease/failure as cysts displace normal functioning tissue
- Other differentials must be included if there are thick or irregular walls, internal septations, echogenic contents
 - » Ddx: complicated cyst, hematoma, infarct, granuloma, abscess, tumor
 - » Fine-needle biopsy would be necessary for diagnosis

Renal nodules and masses:

- Commonly neoplastic (primary or metastatic), may see granuloma (rare)
- Nodules and masses may appear hypoechoic, isoechoic, or hyperechoic; the pattern is non-specific, although uniformly hypoechoic masses have often been associated with *lymphoma*
- Renal lymphoma is generally effects both kidneys; there may be multifocal hypoechoic nodules and subcapsular infiltrate; there may be more uniform infiltrate as well
- Masses may contain some areas of hemorrhage or necrosis, which appears sonographically as mixed echogenicity with possible cavitory areas
- Most common pattern is complex or hypoechoic mass
- Although primary renal tumors are uncommon, the most common tumor is renal carcinoma, which usually begins at one pole of the kidney and generally produces focal hyperechoic lesions; often the other kidney will be affected
- must obtain fine-needle or core biopsy for definitive diagnosis

Renal infarct:

- wedge-shaped or triangular with a broader base at the capsular surface
- acute lesions are hypoechoic (1-7 days)
- lesions gradually become hyperechoic as they fibrose and eventually lead to depressions in the cortex

Focal hyperechoic areas in renal cortex:

- causes: neoplasia, calcification, fibrosis, gas
- FNA or biopsy necessary for definitive diagnosis

Specific Renal diseases

Acute Renal Failure:

- causes: ATN, cortical necrosis, acute interstitial nephritis, diseases of the glomeruli, lymphosarcoma
- sonographic findings are often unremarkable
- kidneys may be slightly enlarged
- echogenicity of cortex may range from hypoechoic to hyperechoic

Chronic Renal Failure:

- causes: GN, chronic pyelonephritis, polycystic renal disease, autoimmune disease, nephrotoxins
- sonographic findings are non-specific
- generally, ultrasound does not provide much information and may not be indicated except in cases of an acute crisis on top of chronic renal failure (evaluating for obstruction or infection)
- findings range from normal kidneys to hyperechoic, irregularly shaped kidneys
- renal function cannot be directly correlated with kidney size and echogenicity

Renal dysplasia:

- disorganized development of renal parenchyma due to anomalous differentiation; may be familial (Lhasa apso, Shih tzu, cats, to name a few) or secondary to fetal/neonatal infection or teratogenesis
- sonographic findings are similar to any chronic infiltrative renal disease, and the diagnosis is based upon the young age of the animal and renal biopsy
- generally the kidneys are small, misshapen, and hyperechoic
- the internal architecture is abnormal and there is poor CM differentiation
- cysts and dilated ureters may be present

Pyelonephritis:

- inflammation of renal pelvis and renal parenchyma
- acute pyelonephritis:
 - » possible renomegaly
 - » may have a generalized hyperechoic cortex or medulla, focal or multifocal hyper- or hypoechoic areas in the cortex and medulla
 - » generally there is poor CM differentiation
 - » may see a hyperechoic line paralleling the renal pelvis, renal recesses, and/or proximal ureter
 - » the renal pelvis may be dilated with anechoic or hyperechoic debris

- » mild cases may have no abnormalities
- chronic pyelonephritis:
 - » changes are generally secondary to fibrosis of the kidney
 - » often the kidneys are small and irregularly shaped
 - » may have increased cortical and medullary echogenicity with poor CM differentiation
 - » mild to moderate pelvic and proximal ureteral dilation with distortion of the collecting system generally present; urine may be anechoic or contain hyperechoic debris

Peri-renal pseudocyst:

- encapsulated accumulation of fluid surrounding renal cortex
- documented in both dogs and cats, more common in cats
- causes: trauma, neoplasia, ureteral obstruction, infections
- may be associated with primary renal disease
- sonographically appears as elliptical anechoic or hypoechoic fluid collecting subcapsularly and having marked distant enhancement
- may have internal septa or low levels of internal echoes

Disorders of the renal pelvis, collecting system and ureters

Renal pelvic dilation:

- recognized by separation of the normal, uniformly hyperechoic central renal sinus echoes by an anechoic space
- the degree of distention is from minimal to advanced; advanced cases are readily apparent because the dilated pelvic diverticula and proximal ureter are easily visualized
- differentiate the ureter from the renal vein; the renal vein can be followed to the vena cava
- excretory urography is the most sensitive method for detecting subtle pelvic and ureteral dilation
- mild dilation may be seen in states of diuresis
- Ddx: congenital disease, pyelonephritis, obstruction to urine flow by intraluminal, mural, or extramural causes
- Hydronephrosis:
 - » the most dramatic form of pelvic dilation – can be from mild to moderate degree
 - » causes include: ureteral obstruction from a bladder, urethral, or prostatic tumor involving the trigone; obstruction of the ureter by ureteral inflammation, calculi, extrinsic masses, or strictures; ectopic ureter
 - » in long standing cases only a thin rim of renal tissue remains (parenchymal atrophy) with several echogenic linear bands extending from the hilus toward the capsule representing vessels and associated fibrous tissue

- » sonographic appearance will be of dilated anechoic renal pelvis and recesses with distant enhancement; as pelvis dilates it will distort and gradually replace the medulla and finally the cortex; initially the dilation will take the shape of the renal recesses and will eventually become oval

Calculi:

- both radiopaque and radiolucent calculi will be seen sonographically
- sonographic appearance is an intense hyperechoic focus with strong acoustic shadowing; this may be within the renal diverticula, the renal pelvis, or the ureter
- the detection of shadowing is increased by having the calculus within the focal zone, using a high-frequency transducer, and by lowering the overall gain
- may see accompanying dilation of the pelvis or diverticula
- small calculi or renal parenchymal calcification may be difficult to distinguish from the normal shadowing of the walls of the renal collecting system (excretory urogram would be recommended)
- blood clots or masses within the pelvis are more rare and **do not** produce acoustic shadowing

Ultrasound-guided fine-needle and core biopsy:

As mentioned many times in these notes, many of the sonographic findings are very non-specific in renal disease. In certain cases, it will be necessary to obtain a fine-needle or core biopsy as part of the work-up of the case in order to establish a diagnosis, therapeutic plan, and/or prognosis.

A fine-needle biopsy of the kidney is a relatively safe procedure. The cortex, medulla, or pelvis of the kidney can be sampled. Suspicion of the following entities would indicate consideration of a fine-needle biopsy: lymphoma, metastatic or primary neoplasia, FIP, abscess, fungal infection, or to confirm a cyst.

A core biopsy of the kidney is a more invasive procedure requiring heavy sedation or anesthesia. Indications would include glomerular disease, acute renal failure that is not responsive to medical management, or renal neoplasia not diagnosed by a fine-needle biopsy. A biopsy should not be performed in patients with uncorrectable coagulopathy, uncontrolled hypertension, extensive infection, hydronephrosis, PKD, or chronic/end-stage renal disease. Complications can include hemorrhage, hematuria, fibrosis, and other less common problems. It should be noted that generally only the cortex is sampled; thus medullary disease cannot be diagnosed with this technique.

Doppler vascular studies:

Doppler examination of the kidneys has emerged from human studies. Doppler sonography utilizes the concept of the Doppler effect, an apparent shift in sound frequency as sound waves are reflected from the moving blood cells. If motion is toward the transducer, the frequency of the returning echoes will be higher than the transmitted sound; and if motion is away from the transducer, the frequency of the returning echoes will be lower than the transmitted sound. The difference between the received and transmitted frequencies is known as the Doppler shift. A greater velocity will result in a greater Doppler shift. Using pulsed-wave Doppler to investigate a specific vessel will result in a spectral wave-form plotting time versus velocity for the vessel. The ultrasound computer will have software to allow for calculations pertaining to the information gathered.

Doppler sonography can provide additional information in patients with urinary tract obstruction, acute renal failure, renal transplants and renal neoplasia. Commonly the renal vascular resistance is evaluated by calculating a resistive index (RI) with the use of Doppler sonography. The RI is calculated by subtracting the diastolic frequency from the peak systolic frequency and dividing the result by the peak systolic frequency. An RI of less than 0.70 is considered normal. With increased vascular resistance, the diastolic flow is reduced in greater proportion than the systolic flow and the RI will increase in value. The RI may be able to differentiate between pre-renal failure (normal RI) and acute renal failure or acute tubular necrosis (elevated RI). The amount of RI elevation and the return to normal may be able to offer a prognosis. The RI is often elevated in acute ureteral obstruction, which can help differentiate obstructive dilation from non-obstructive dilation of the collecting system. Finally, an elevated RI is may be seen with acute rejection of renal transplants.

Ultrasonography of the Lower Urinary Tract

The urinary bladder is ideally suited for the ultrasonographic examination because of the excellent acoustic properties of the fluid nature of urine and the superficial location of the urinary bladder. Ultrasonography can provide information relative to the capacity of the bladder, change in bladder outline, changes in the thickness and structure of the wall, identification of luminal structures and mural masses, and identification of extrinsic lesions which may displace the bladder or distort the wall.

Indications: chronic or recurrent UTI, stranguria, dysuria, hematuria, caudal abdominal mass

Transducer: the highest frequency transducer possible/available should be used in order to accurately assess the bladder wall – at least a 7.5 MHz transducer; occasionally a lower frequency transducer may be necessary for evaluation of adjacent structures in a large patient

Scan plane: position patient in dorsal recumbency, examine in sagittal and transverse planes

Artifacts: both useful and detrimental artifacts will be encountered during imaging of the urinary bladder

- **Detrimental artifacts:** slice thickness, near-field reverberation, side lobe (“pseudosludge”), hypoechoic pseudolesion or “wall defect”, colon mimicking stone or mass
- **Useful artifacts:** acoustic shadowing

Simple techniques such as repositioning the transducer, changing the imaging plane, using a stand-off pad or standing the patient and imaging from ventral may aid in identification of artifacts from true lesions.

Patient preparation: the urinary bladder should be moderately distended for accurate evaluation of mucosal detail and wall thickness, as well as to allow for evaluation of the bladder neck and proximal urethra. Imaging the patient first thing in the morning before urination is ideal. If the bladder is not distended enough for evaluation, a urinary catheter may be placed and the bladder distended with saline. Be careful not to introduce air, which could significantly hinder evaluation. Alternatively, the patient could be imaged at a later time after the bladder has naturally filled with urine.

Normal Sonographic Appearance

The urinary bladder is an echo-free cystic structure. The bladder shape varies from round to ovoid to oblong. There are four layers of the bladder wall: the mucosa, the submucosa, the muscular layer (inner longitudinal muscle, middle circular muscle, outer longitudinal muscle), and the serosal surface. These layers are not usually clearly demarcated.

Generally two thin, parallel, hyperechoic lines separated by a hypoechoic line are seen: 1) hyperechoic serosa/perivascular fat interface, 2) hypoechoic muscularis, and 3) hyperechoic line of lamina propria submucosa paralleling mucosal interface. When the bladder is nearly empty, the mucosal and submucosal layers may be able to be differentiated. The proximal urethra in the female can be imaged, but the middle and distal portions will not be imaged due to acoustic shadowing from the pubic bone. Almost the entire prostatic portion of the urethra can be imaged in the male (it is not always well demarcated from the prostatic parenchyma), and the membranous and penile urethra, where not within the pelvic canal, can also be imaged.

The normal bladder wall thickness is **1-3 mm** in dogs and **1.3-1.7 mm** in cats. The mean thickness is 1.4 mm with moderate distension and 2.3 mm with minimal distention in dogs. The bladder wall thickness decreases as the bladder distension increases and increases as the size of the patient increases (can be 1 mm thicker in a larger dog). The bladder wall is fairly uniform in thickness throughout.

The entrance of the ureters may be recognized by a small elevation of mucosa located on either side of midline at the trigone region (*the ureteral orifices*). One may see periodic streaming of bright, specular echoes at the entrance of the ureters, as the ureters intermittently empty into the bladder. This is known as *ureteral jet effect*. This can be detected both with real-time gray scale sonography, as well as color-flow Doppler sonography. The most likely reason for the ureteral jet effect is due to temperature or density difference between ureteral and bladder urine; however other theories include microbubbles of particulate matter in urine and turbulence or cavitation at the ureteral orifice. To facilitate viewing of the ureteral jets, have the patient urinate, withhold water for several hours and then allow free access to water prior to imaging. Alternatively, a diuretic may be given to assist in finding the ureteral orifices. The ureteral jet effect can be helpful in demonstrating patency of the ureters or identifying the ureteral orifice in cases of ectopic ureters.

Abnormal Sonographic Appearance

Heterochoic urine:

- mobile echogenic particles floating freely within the lumen
- **Ddx:** crystals, proteinaceous material, cellular debris, fat droplets (especially cats), gas
- a large amount of sediment may accumulate in the dependent portion of the bladder
 - » urinary “sludge”: cellular debris, mucin, blood
 - » agitation of the bladder will demonstrate the mobility
- **Gas bubbles:**
 - » occur secondary to catheterization, cystocentesis, gas-forming bacterial infection
 - » may appear as floating, hyperechoic foci in the lumen
 - » found in the non-dependent portion of the urinary bladder
 - » generally cause a reverberation artifact or “dirty shadow”

Cystic calculi:

- both radiopaque and radiolucent calculi are detectable with ultrasound
- **ultrasound appearance** is focal, dependent, hyperechoic, curvilinear echogenicities which generally change position as patient position changes
- associated acoustic shadow
 - » not all stones will shadow (but most will!)
 - » the degree of shadowing correlates with chemical composition, the location of the calculus in respect to the focal zone, and the frequency of the transducer
- an accurate count of calculi and accurate measurement of calculi is difficult sonographically (double contrast cystography is recommended) – higher frequency (7.5 MHz) transducer more accurate
- one may identify shadowing mineralized dependent sediment, such as that found with feline lower urinary tract disease
- false negative examinations can occur
 - » empty bladder
 - » sand/calculus too small to resolve (< 0.1-0.2 cm)
 - » poor exam

Blood clots:

- generally the ultrasonographer is expecting this finding based upon history
- clots occur secondary to trauma, bleeding disorders, infection, neoplasia
- **ultrasound appearance** is generally medium echogenic to mildly hyperechoic, nonshadowing echogenicities, with an irregular/amorphous shape
- bladder lumen may be filled with lacy echogenic material
- generally are mobile and settle to the dependent portion of the bladder

- may be adherent to the bladder wall and have associated mucosal irregularity (Ddx: mural mass); look for underlying bladder wall thickness which more likely indicates neoplasia
- one may agitate the bladder or do positional studies to assess attachment

Cystitis:

- can be sterile or septic
- **ultrasound appearance** is generally a thickened bladder wall decreased in echogenicity, often with a smooth outline of the mucosal surface, although the mucosa may be irregular; there can be a rounded intraluminal mass
 - » wall thickening is usually most pronounced cranioventrally
 - » gradual transition to normal mucosa
 - » thickening may become generalized in severe cases
- the urine may be heterochoic or contain suspended or dependent echogenic material which represents cellular debris (Ddx: crystals, fat droplets) or calculi
- **Polypoid cystitis:**
 - » rare; cause unknown but is due to chronic inflammation of mucosa
 - » multiple small polypoid or larger pedunculated masses projecting into lumen which are generally isoechoic to the bladder wall
 - » may be short or long and located cranioventral and/or craniodorsal
 - » generally associated bladder wall thickening
 - » must confirm with biopsy to rule-out neoplasia – polyps have no histologic evidence of neoplasia
- **Granulomatous cystitis:**
 - » will have a very irregular bladder internal surface
- **Emphysematous cystitis:**
 - » caused by gas-forming bacterial infection (for example, *E. coli*)
 - » multifocal hyperechoic areas of intramural gas with variable shadowing and reverberation
 - » gas doesn't change with positional change of patient
 - » may have intraluminal gas as well

Neoplasia:

- only 1% of all canine tumors; cats also get bladder neoplasia
- the most common neoplasia in the dog is transitional cell carcinoma (TCC); other tumor types: squamous cell carcinoma, adenocarcinoma, undifferentiated carcinoma, rhabdomyosarcoma, metastatic disease
- **ultrasound appearance** is generally of a focal echo-complex hypoechoic or medium echogenicity (to bladder wall) mass with abrupt transition between tumor and normal mucosa

- » characterized by focal wall thickening with an irregular, sessile mass extending into the bladder lumen; the mucosal surface is often irregular; may see dystrophic mineralization
- commonly, bladder neoplasia occurs at the trigone region, bladder neck, and urethra; however, neoplasia can occur at any location within the bladder
- the size of the lesion is the most important factor in the rate of detection; bladder distention also plays an important role; ventral lesions may be missed due to imaging artifacts
- carefully evaluate for metastasis to regional lymphnodes, obstruction of ureters, involvement of urethra

Bladder rupture:

- may see defect of bladder wall at level of rupture (or urinary catheter protruding into peritoneal space)
 - » be wary of the hypoechoic pseudolesion previously described
- bladder wall may be thick from edema and/or hemorrhage
- may utilize contrast cystosonography
 - » this involves the injection of microbubbled saline (saline and air agitated together) through the urinary catheter
 - » visualize microbubbles in fluid around the bladder
- positive-contrast cystography may be more reliable for diagnosis of rupture

Distal ureter:

- only seen with ultrasound if the ureter is dilated from ectopia, ureteritis, or obstruction
- commonly, primary neoplasia of the bladder, urethra, or prostate causes ureteral obstruction
- occasionally calculi or masses obstructing the ureter near the bladder are identified
- ureterocele: a congenital dilation of the terminal ureter resulting from stenosis of the ureteral meatus; seen as a smooth, well-defined cystic structure within or near the bladder wall in the trigone region; the affected ureter may be ectopic and hydroureter or hydronephrosis may be present

Urethral pathology:

- ultrasound has limited usefulness
- may detect urethral tumors, evaluate for local invasion, localize calculi
- urethral tumors generally appear as symmetric wall thickening with irregular mucosal surface, may extend into the neck of the bladder
- retrograde positive contrast urethrography or cystography is the best method to characterize the location and extent of pathology

Ultrasound-guided fine-needle and core biopsy:

A fine-needle or core biopsy may be very important in the work-up of bladder/urethral disease as one cannot differentiate polypoid cystitis, granulomatous lesions, and neoplasia by appearance alone.

Complications of this procedure include tumor seeding along the tract of the biopsy. This is a rare complication (estimated frequency of 0.009% in humans), but has been reported in dogs. It is more common with certain tumors, such as urologic tumors and prostate tumors. The likelihood may increase with larger bore needles and increasing number of needle passes.

Consider using ultrasound to guide a catheter or endoscopic biopsy via urethral access to avoid the complication of tumor-track seeding. In this procedure, one attempts to displace the lesion toward the instrument using transducer pressure on the bladder. If urethral access is impossible, then utilize percutaneous fine-needle or core biopsy if it is important to obtain a histopathologic diagnosis.

Ultrasonography of the Reproductive Tract

Female Reproductive Tract

Indications: pregnancy diagnosis, fetal viability, pyometra, ovarian or uterine tumor, infertility

Transducer: 7.5 MHz is ideal for evaluation of normal ovaries and uterus; 5.0 MHz is adequate for most disease states

Scan plane: multiple scanning planes and positions may be needed to visualize the entire reproductive tract

- owners of show animals may object to clipping the hair coat; application of alcohol prior to applying acoustic gel may improve image quality
- a negative sonogram under this less-than-ideal condition in early pregnancy should be repeated several weeks later to confirm a false-negative diagnosis
- scan the caudal pole of the kidney and the adjacent area in transverse and sagittal planes to locate the ovary
- a distended urinary bladder is an acoustic window for imaging the uterus
- the uterine body is close to midline; the uterine horns are difficult to identify in the normal patient

Normal Uterus

- composed of three layers: mucosa, muscularis, serosa
- dorsal to urinary bladder, ventral to descending colon
- a normal, small, nonpregnant uterine body and cervix can sometimes be imaged
- identified as a solid, homogenous, relatively hypoechoic structure; layers are usually not differentiated; lumen usually not seen
- difficult to identify the horns

Normal Ovary

- the ovaries are small and oval to bean shaped
- the ovaries measure approximately 1.5 cm in length, 0.7 cm in width, and 0.5 cm in thickness (25 lb dog); cat ovaries are somewhat smaller
- the ovary has a cortex and a medulla; the cortex contains the follicles
- sonographic appearance varies during the estrous cycle
 - anestrus/early proestrus: homogeneous, echogenicity similar to renal cortex
 - proestrus: follicular cysts identified at day 2-7; initially see multiple, diffuse, small anechoic cysts that enlarge with time until ovulation; may reach 1 cm

ovulation: detected sonographically when there is a decrease in the number and size of follicles from one day to the next; requires daily serial scanning

metestrus: multifocal, anechoic-to-hypoechoic areas, as well as hyperechoic areas are present; these may represent corpora hemorrhagica or corpora lutea

Pregnancy

- ultrasound has been used to detect pregnancy in the bitch as early as 10 days post breeding and in the queen as early as 11 days post breeding
- accurate determination of fetal number is unreliable; most accurate between day 28 to 35
- at day 10-20 a gestational sac confirms pregnancy; seen as an anechoic round structure with variably echoic walls; surrounding uterine tissue is focally thickened
- at day 23-25 the embryo is first seen as an oblong echogenic structure eccentrically located within the enlarging gestational sac
- at day 28 cardiac activity is readily seen; approximately two times the maternal heart rate
- fetal orientation is easily recognized by day 28
- limb buds noted about day 35
- fetal skeleton is identified by day 33-39; seen as hyperechoic structures with acoustic shadowing
- urinary bladder seen by day 35-39
- kidneys and eyes are seen by day 39-47
- there are formulas to estimate gestational age
- slowing of fetal heart rate to less than twice the bitch's heart rate and decreased fetal movement indicate fetal stress

Uterine Pathology

Pyometra:

- sonographic findings include an enlarged uterus and uterine horns; enlargement is usually symmetric, but may be focal or segmental
- luminal contents are usually homogenous and echogenic, but may be anechoic with strong distal enhancement
- the uterine wall is variable in appearance, from very smooth and thin to thick and irregular

- Ddx: hydrometra and mucometra; these conditions may be suspected if the luminal contents are anechoic and the uterine wall is thin; also if clinical signs are lacking

Stump pyometra:

- classically a large, complex mass lesion is identified in the region of the uterine remnant
- need to evaluate for ovarian remnant

Neoplasia:

- rare in both dog and cat
- sonographic appearance will be a mass lesion projecting into the uterine lumen
- if large and necrotic, may be complex in internal architecture

Ovarian Pathology

Cystic ovarian disease:

- sonographic appearance is that of true cystic lesions, characterized by anechoic contents, a thin wall, and distant acoustic enhancement
- generally quite large, >2.5 cm
- may be solitary or multiple
- associated changes include pyometra, cystic endometrial hyperplasia, or hydrometra

Neoplasia:

- uncommon in dogs and cats
- may be unilateral or bilateral
- recognized ultrasonographically as a mass lesion in the location of the ovary
- variably sized; if large, they are usually complex in architecture with mixed echogenicity
- often is a diagnosis of exclusion by ruling out splenic, renal or lymph node masses

Male Reproductive Tract

Indications: clinical signs of urogenital disease, constipation, prostatomegaly, infertility

Transducer: use high frequency transducer whenever possible, 7.5 MHz; imaging within the focal zone is important for optimal resolution

Scan plane: scan in transverse, longitudinal, and dorsal planes; may need a stand-off pad for the testicles

Normal Prostate

- surrounds the pelvic urethra, beginning at the level of the trigone; the urethra may be eccentrically located dorsally in the gland, or may course through the center
- seen as a bilobed structure
- sonographically has a homogeneous parenchymal pattern
- echogenicity is variable, moderate echogenicity is most common (similar to the spleen)
- the normal prostate should be symmetrical and well margined by the thin echogenic capsule

Prostatic Pathology

Benign hyperplasia:

- sonographically appears as an enlarged prostate gland
- enlargement may be symmetric or asymmetric, smooth or nodular, may distort the margin
- echogenicity varies; may be hypoechoic to hyperechoic
- scattered hyperechoic foci may be present (fibrosis)
- intraparenchymal cysts can be present, varying in size and number
- in general, changes are less severe than with infection or neoplasia
- if heterochoic, Ddx: infection or neoplasia
- hyperplasia should not disrupt the capsule, nor should there be lymphadenopathy
- common to have multiple processes, need FNA

Prostatitis:

- may be acute or chronic
- sonographic appearance may be similar to that of benign hyperplasia
- may see symmetric or asymmetric enlargement
- overall appearance is usually a heterogeneous, mixed pattern of varying echogenicity
- cysts or cystlike structures may be present, including abscess formation
- capsule is usually intact
- uncommon to detect more than mild lymphadenopathy

Neoplasia:

- manifests in a variety of sonographic appearances
- typically, the gland will be enlarged, irregular in shape, have a heterogeneous echotexture
- mineralization may be present
- cavitory, cystlike lesions may be present
- differentiation from infection may be difficult; both may be present
- strongly suggestive of neoplasia is extension of changes to urethra or trigone, disruption of the capsule with extension to surrounding tissues, lymphadenopathy
- **biopsy**

Paraprostatic cysts:

- fairly common
- may be attached to the prostate by a stalk
- sonographically are anechoic, fluid-filled structures
- wall thickness can vary
- contents of cyst may contain focal echogenicities
- may be septated
- differentiate from urinary bladder by careful examination

Normal Testicles

- testicle appears homogeneous with a coarse medium echopattern
- the tunic forms a thin hyperechoic peripheral echo
- the mediastinum (rete) testis is seen as a very echogenic central linear structure on the midsagittal plane
- the epididymis is less echoic and may be nearly anechoic
- the tail is the most consistently imaged portion
- maximum width of epididymis is 1/4 that of testes width

Testicular Pathology

Neoplasia:

- three common types: interstitial cell, Sertoli cell, and seminoma
- sonographic appearance of testicular tumors is variable; not specific for tumor type
- interstitial cell tumors may be focal hypoechoic lesions less than 3 cm dia
- large lesions generally have a mixed or complex pattern; this may be secondary to hemorrhage and necrosis
- focal and multifocal lesions occur
- Sertoli cell tumors most common in cryptorchid

Orchitis/epididymitis:

- sonographically appears as diffuse, patchy, hypoechoic pattern
- usually see testicular and epididymal enlargement (concurrent epididymitis)
- abscesses can occur
- may see extratesticular fluid
- increased thickness and hyperechogenicity of tunics

Torsion:

- sonographically see testicular enlargement, characterized by diffusely decreased parenchymal echogenicity
- see concurrent enlargement of the epididymis and spermatic cord
- will have loss of the Doppler signal (lack of blood flow)

Retained testes:

- identify an abdominal or inguinal mass as a testicle
- look for rete testis (mediastinal testis)
- generally small, may be atrophied
- evaluate for neoplasia

Ultrasonography of the GI Tract

Ultrasonographically, the stomach wall is 3-5 mm thick in the dog. In the cat, the mean thickness of the inter-rugal region is 2 mm and the mean thickness of the rugae is 4.4 mm. It has been shown that small intestinal wall thickness varies with weight in the dog, and the duodenal wall is always thicker (mainly due to the mucosal layer) than the jejunum. The duodenal wall thickness in dogs is ≤ 5.1 mm in dogs < 20 kg, ≤ 5.3 mm in dogs 20-30 kg, and ≤ 6.0 mm in dogs > 30 kg (95% confidence interval). The jejunal wall thickness in dogs is ≤ 4.1 mm in dogs < 20 kg, ≤ 4.4 mm in dogs 20-40 kg, and ≤ 4.7 mm in dogs > 40 kg (95% confidence interval). In cats the duodenal wall thickness ranges from 1.5-3.5 mm (average 2.4 mm) and the jejunal wall thickness ranges from 1.5-3.5 mm (average 2.1). In both species the colon wall is generally thinner than the adjacent small intestine, especially when the colon is distended. In cats specifically, the mean colonic wall thickness is 1.7 mm (range 1.1-2.5 mm). Thicker walls should be viewed with suspicion during ultrasound examinations. The appearance of ultrasonographically is not etiologically specific. Guided aspiration, endoscopy (if possible), or full thickness biopsy (at laparotomy) will be necessary for further definition. Lesions are classified by ultrasound as intramural, extra mural, annular or intraluminal just as they are for radiography.

Lesion identification in the alimentary tract by **ultrasound** can be “hit or miss” as the entire intestinal tract cannot consistently be evaluated due to many factors, including normal or abnormal gas in the alimentary tract and operator skill. Additionally, often a lesion cannot be precisely localized to a specific bowel loop. However, a sonographic study has the advantages of needing no special preparation (other than a recommended 12 hour fast), is non-invasive, allows evaluation of the entire gastrointestinal wall rather than just the mucosa, yields more consistent wall thickness measurements, gives real-time assessment of motility without ionizing radiation, provides assessment of regional disorders (metastasis, peritonitis), and can guide sampling of diseased tissues. Be careful of using ultrasonographic techniques to “screen” the alimentary tract for **intramural or intraluminal lesions** because there are numerous false negatives due to gas interference. However, masses can be localized to alimentary tract structures (particularly stomach, small intestine and colon) by the presence of a **bright (echogenic) stripe**.

Normal stomach and bowel have 5 layers identifiable on high-frequency ultrasonography, but only 3 may be seen with some equipment. The mucosal surface-luminal interface is seen as a thin hyperechoic line. The mucosa itself is a relatively thick hypoechoic layer. The adjacent submucosa is a thin hyperechoic line. In the ileum, the submucosa is more prominent and can allow specific localization of the ileum, particularly in the cat. The next layer, the muscularis propria is a thin hypoechoic line. The outer subserosa-serosa is a thin hyperechoic interface. All five layers are generally distinguishable in the stomach, but in the small intestine the muscularis propria and subserosa-serosa may not be identifiable. The most notable layers are the **echogenic submucosa** and the **echogenic complex** of the mucosa and luminal air interface. These same bright stripes can be seen within alimentary tract-associated masses imaged by ultrasonography. These echogenic “stripes” may be distorted, thickened, or irregularly

interrupted by infiltrative disease depending on the origin. Fortunately, there is almost always normal gut in the region for comparison. It is important to remember that not distinguishing all of the layers does not necessarily indicate pathology, as gas artifact and limited resolution can lead to a false loss of the normal layering. In addition to the layers, different intestinal patterns can be seen with ultrasound. The mucous pattern is seen with a collapsed bowel that has an echogenic lumen without shadowing. A fluid pattern is when the bowel lumen contains anechoic luminal contents, thus optimizing visualization of the bowel wall. A gas pattern shows intraluminal highly echogenic reflective surface with shadowing that prevents deep structure evaluation. The alimentary pattern is gut containing food particles. Excess fluid with floating luminal material is suspicious for at least partial obstruction at ultrasonography.

SPECIFIC ORGAN CONSIDERATIONS – ULTRASONOGRAPHY

Esophagus:

- 1) The esophagus is only rarely identified sonographically at the level of the cardia.

Stomach:

- 1) Appearance varies with content and degree of distention.
- 2) Stomach gas causes reverberation and/or comet tail artifact and interferes with imaging of the deep portion.
- 3) The stomach can be emptied of gas and distended with fluid for improved evaluation, especially of the mucosal layer.
- 4) The mean number of gastric contractions is 4-5 per minute. This is influenced by many factors. For an accurate estimate of gastric contractions, the stomach should be observed for 3 minutes.
- 5) All five layers of the stomach wall are generally distinguishable. Beware of artifactual thickening of the stomach wall due to rugal folds, imaging plane, and degree of distension. Rugal folds are seen when the stomach is empty and tend to disappear when the stomach is distended.
- 6) A thick wall is the most common abnormality identified. It can be difficult to recognize diffuse thickening.
- 7) Tumors and granulomas generally produce focal, asymmetrical thickening with disruption of normal wall layering. Other inflammatory or infiltrative diseases generally produce diffuse thickening and generally maintain wall layering.
- 8) Lymphoma generally produces a more focal mass than adenocarcinoma. Lymphoma also often produces transmural circumferential thickening, is hypoechoic and has regional loss of motility. Carcinoma may appear as a pseudolayered lesion of a moderately echogenic zone surrounded by outer and inner poorly echogenic lines. Leiomyosarcoma tends to be exophytic, large and complex.
- 9) Beware of the gastric content pseudomass. A mural mass will be seen as a discrete rounded or lobulated lesion that is fixed in position despite peristalsis or changes in patient position.

- 10) Hypertrophic pyloric gastropathy produces uniform, circumferential thickening of the hypoechoic muscular layer – generally the normal wall layering is preserved. The stomach is fluid distended and reduced passage of gastric contents is seen.
- 11) Uremic gastritis presents as a thick wall and thick rugae with decreased definition of the wall layers. The fundus and body are most often affected. The mucosa may be mineralized – appearing as a thin very echogenic line at mucosal-luminal interface.
- 12) A gastric foreign body is a sharply defined, hyperechoic interface with distal shadowing and generally moves in position.

Small intestine:

- 1) Complete assessment of the small intestine includes assessment of the size, shape and wall thickness. The transverse axis is often preferable for measuring as there is less chance of error. Measurements are more accurate when wall layers can be seen so that calipers can be precisely placed. Wall thickness and luminal diameter do vary with peristalsis. Remember that not seeing the wall layers does not necessarily indicate pathology.
- 2) Intestinal contractions are generally 1-3 per minute.
- 3) Using an acoustic window such as the spleen can enhance imaging of the intestine.
- 4) Peyer patches in the duodenum may be visible as outpouches from the lumen. Do not mistake these as ulcers – the wall will be normal in thickness and layering.
- 5) Obstructive ileus has segmental dilation with increased peristalsis acutely. With chronic obstruction, decreased peristalsis will be present. Causes identified with sonography may include foreign bodies, regional inflammation and adhesions, intussusception or neoplasia.
- 6) Non-obstructive ileus has mild to moderate generalized dilation with decreased motility.
- 7) Most foreign bodies will be a sharply defined hyperechoic interface with distal shadowing. These can be masked by air but manipulation of bowel with the transducer and changes in patient position should aid in evaluation of that portion of bowel. Proximal fluid or gas distention and hyperperistalsis generally accompanies – therefore these findings should mandate careful search for the obstructing lesion. Linear foreign bodies have a classic “ribbon candy” appearance caused by the plication of the small intestine. Do not confuse a spastic loop of bowel with plication.
- 8) Intussusceptions appear sonographically as a multilayered lesion with linear streaks of hyperechoic and hypoechoic tissue in long section and concentric rings (“ring” sign) in cross-section. The outer segment is often thickened and edematous.
- 9) Wall thickening is most easily detected when asymmetric.
- 10) Inflammatory diseases in general have extensive, symmetrical mild to moderate wall thickening with maintenance of wall layering. Regional affected lymph nodes will only be mildly enlarged and generally of normal echogenicity.
- 11) An ulcer may appear as a localized thickening. Perforation may be identified by focal gas dissection in the thickened wall with echogenic regional fat, fluid accumulation, or free gas.

- 12) IBD may present as mildly thickened bowel (one or more segments) that is hypomotile and rigid. Generally the mucosa and submucosa are the thickened layers and may have altered echogenicity. Wall layering may be indistinct.
- 13) Neoplasia in general presents as focal, asymmetric, moderate to severe wall thickening with loss of wall layering. Regional moderate lymphadenopathy with altered echogenicity is common.
- 14) Lymphoma most commonly presents as transmural, circumferential, homogenous, hypoechoic thickening with loss of normal wall layering. Lymphoma tends to involve a long bowel segment or multiple bowel segments. Regional moderate, hypoechoic lymphadenopathy is generally present. Lymphoma is less likely to cause obstruction of the lumen.
- 15) Carcinoma is localized, irregular, often mixed echogenicity thickening of bowel wall with loss of layering. Often a shorter segment of bowel is affected than with lymphoma and has associated obstruction. Carcinoma can present as an annular constrictive lesion. Generally only one segment of bowel involved in comparison to lymphoma.
- 16) Smooth muscle tumors often appear as eccentric, poorly echogenic masses that are exophytic and rarely cause obstruction. Masses greater than 3 cm are often cavitory.

Colon:

- 1) The wall layers of the colon are not easily identified.
- 2) Diffuse thickening may be observed in inflammatory and infiltrative processes such as infectious or lymphocytic plasmacytic colitis. This finding is non-specific.
- 3) Focal wall thickenings, disruption of wall layering and heteroechoic masses may be neoplasia or granulomas.

Ultrasonography of the Adrenal Glands

Ultrasound has quickly become an important modality for the evaluation of adrenal glands in the small animal patient. The advantages of adrenal sonography include the ability to image both normal and abnormal glands, the ease and rapidity of the procedure, the lack of the need for anesthesia, and the availability of ultrasound to practitioners. However, the challenge of imaging the adrenal glands should not be underestimated. Even for an experienced sonographer, the small size of the glands, the deep and sometimes variable position of the glands, the interposition of bowel gas, the obese nature of many patients, and the lack of patient compliance can lead to a frustrating and sometimes unrewarding examination.

Indications: hyperadrenocorticism, cranial retroperitoneal mass

Transducer: the highest frequency transducer available should be used in order to assess the adrenal glands – at least a 7.5 MHz transducer should be routinely used; occasionally a lower frequency transducer may be necessary in a larger patient

Scan plane: position animal in dorsal recumbency, obtain sagittal and transverse images, at times you may need to image the patient in lateral recumbency for the nondependent adrenal gland

Artifacts: bowel gas will invariably lead to imaging artifacts of the adrenal glands; considerable transducer pressure should be used to displace overlying intestine

In general, both adrenal glands can be imaged in all patients, but the examination can be difficult and time consuming for the normal adrenal gland. The right adrenal gland tends to be more difficult to image than the left adrenal gland. If necessary, the patient may need to be sedated for optimal imaging.

Normal Sonographic Appearance

Location: The adrenal glands are retroperitoneal structures.

Left adrenal: craniomedial to left kidney, ventrolateral to aorta between origin of cranial mesenteric and left renal arteries

Right adrenal: craniomedial to hilus of right kidney, dorsal or dorsolateral to caudal vena cava, cranial to right renal artery and cranial mesenteric artery

The phrenicoabdominal artery is dorsal to each adrenal gland, and the phrenicoabdominal vein is ventral to each adrenal gland.

In the cat, the adrenal glands seem to be located more cranial with respect to kidney.

The adrenal glands are small, elongated, hypoechoic structures. The glands are surrounded by hyperechoic fat. With optimal imaging and high-frequency transducers, one can appreciate the less echogenic outer cortex and the more echogenic inner medulla as striation of the adrenal gland. It is important to distinguish the adrenal glands from hypoechoic vessels. The adrenal glands will have a definite beginning and end, whereas the vessels will be able to be followed from a great vessel (aorta or cava) to a parenchymal organ.

The **left adrenal** gland is centrally constricted with enlarged extremities, having a “dumbbell” or “peanut” shape. In order to image the left adrenal gland in a true longitudinal plane, the transducer should be rotated approximately 10-15° clockwise. The **right adrenal** gland is “comma”, “wedge”, or “boomerang” shaped. Often the entire gland cannot be imaged in one plane. The extremities of the adrenal glands (cranial and caudal poles) are often asymmetric.

Several studies have assessed the normal size of the adrenal gland, yielding a large range for normal length and diameter. The range of normal length has been documented from 10.7-50.0 mm, the maximum transverse diameter up to 16.0 mm, and the minimum transverse diameter down to 3.0 mm. In practice, the transverse maximum diameter is generally the most sensitive and specific for adrenal gland enlargement. An upper limit of **7.4 mm** has been proposed as a cut-off for the normal adrenal gland. A recent study has suggested that in dogs < 10 kg, a cut-off of **6.0 mm** should be used as the criterion for differentiating a normal adrenal gland from adrenal hyperplasia. It is important to remember that there is a population of normal dogs which will have greater measurements. The left adrenal gland is generally larger in both length and transverse diameter than the right adrenal gland.

In the cat, the adrenal glands are small hypoechoic structures of oval or cylindrical shape. Occasionally, the shape will be similar to dogs. The striation of cortex and medulla is more difficult to distinguish. Again, it is important to distinguish the adrenal glands from regional vessels, as well as from lymph nodes. One study of 10 cats determined that the length of the adrenal glands is 10.7 ± 0.4 mm, the maximum transverse diameter is 4.3 ± 0.3 mm, and the minimum transverse diameter is 3.9 ± 0.2 mm. Another study of 20 cats showed a range of length from 4.5-13.7 mm and a range of width from 2.9-5.3 mm.

Adrenal Gland Pathology in Dogs

Pituitary-dependent hyperadrenocorticism:

- Classically, the adrenal glands are bilaterally, uniformly, symmetrically enlarged
 - » Using a maximum transverse diameter of 7.4 mm yields a sensitivity of 77% and a specificity of 80% and 91% for hyperadrenocorticism; using 6.0 mm in dogs < 10 kg yields a sensitivity of 75% and a specificity of 94%
 - » May see mild bilateral or unilateral adrenomegaly (if unilateral, must differentiate from primary or metastatic tumor)
 - » Adrenal size may be normal – remember that there is a great overlap between the size of normal and abnormal adrenal glands
- Shape is generally normal, may see nodular hyperplasia (small mass lesion or shape change in one or both glands)
 - » Severe hyperplasia can result in bilaterally masses
- Echogenicity is generally uniform and often hypoechoic to the normal expected adrenal gland
 - » may see hyperechoic, hyperplastic nodules
- Evaluate for steroid hepatopathy (generally uniform increase in echogenicity of liver)
- Interpret ultrasound findings in conjunction with clinical findings and results of hematological, serum biochemical and endocrine tests

Adrenal-dependent hyperadrenocorticism:

- Generally see a unilateral, well-defined shape or mass change
 - » Mass is generally round or oval as the abnormal tissue grows in roughly a concentric fashion
 - » Small masses may involve only a portion of the gland, whereas large masses often cause spherical enlargement
- Variable echogenicity – solid to complex
- DDx: adenoma vs. adenocarcinoma (the latter tend to be larger)
- May see hyperechoic, shadowing foci (mineralization); more common with adenocarcinoma (adrenal mineralization is a normal finding in up to 30% of the population)
- The contra-lateral gland may be normal size or small (atrophied)
- Evaluate for local extension to kidney or nearby vessels, as well as for metastasis – malignant tumors
- Adrenocortical tumors are reported more frequently in females and larger breeds

Pheochromocytoma:

- Tumors of chromaffin cells of medulla; produce epinephrine
- 50% found incidentally; clinical signs are often vague and nonspecific, patient may have concurrent disease
- Generally see a unilateral, well-defined shape or mass change of variable echogenicity (difficult to distinguish from adrenocortical tumor)

- » Mass is generally round or oval as the abnormal tissue grows in roughly a concentric fashion
- » Small masses may involve only a portion of the gland, whereas large masses often cause spherical enlargement
- Less likely to mineralize than adrenocortical adenocarcinoma; frequently invade regional vessels and metastasize

Incidental adrenal nodules/masses:

- DDX: pheochromocytoma, non-functional or subclinically functioning adrenocortical tumor, metastatic neoplasia, hyperplastic nodule
- Variable appearance
- Benign processes should not be invasive; regional or vascular invasion is highly indicative of malignant tumor
- Approach will depend upon clinical presentation, other findings, and owner
 - » Surgically remove, surgical or ultrasound-guided biopsy, wait and re-evaluate

Adrenal masses in general:

- In presence of adrenal tumor, observation of normal contra-lateral gland may indicate a pheochromocytoma, nonfunctional adrenocortical tumor, metastatic neoplasia, or potentially a functional adrenocortical tumor
- A combination of all of the above may occur and can be confusing
- In one study, masses >4 cm were malignant; masses 2-4 cm tended to be malignant, masses <2 cm were as likely to be benign or malignant
- A nodule (<1 cm) was non-specific

Small adrenal glands:

- One study showed that dogs with hypoadrenocorticism had adrenal glands smaller than normal, healthy dogs
- No real established lower normal limit
- DDX: exogenously administered steroids, hypoadrenocorticism

Diseases of the Adrenal Glands in Cats

Diseases of the adrenal glands are fairly rare in cats. Pituitary-dependent and adrenal-dependent hyperadrenocorticism has been documented in cats. Metastatic disease to the adrenal glands can also occur.

Ultrasound-guided Fine-needle and Core Biopsy of the Adrenal Gland

These procedures are routinely performed in people with quite low complication rates. These procedures are performed in dogs and cats, but there is not much information in the literature regarding complications. It should be noted that there is the possibility of a hypertensive crisis or fatal hemorrhage after sampling of a pheochromocytoma. It should also be noted that small samples of the adrenal glands may not yield enough tissue for accurate cytological or histopathologic determination of underlying processes.

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