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Pediatric Ultrasonography: Differentiating Acquired from Congenital Disease

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Introduction
Pediatric patients are commonly presented to the veterinarian because of signs referable to the abdominal cavity due to congenital anomalies, dietary indiscretion, parasitic infestation and infectious disease. Abdominal ultrasound provides valuable clinical information about the peritoneal cavity, great vessels, abdominal viscera and lymph nodes obtained in a non-invasive fashion and usually not necessitating sedation or anesthesia. Ultrasoundography thus greatly facilitates diagnostic evaluation of the pediatric patient. Ultrasound equipment already in place in many small animal veterinary clinics is appropriate for most pediatric cases. The use of ultrasound during evaluation of the pediatric patient provides valuable information obtained in a non-invasive fashion with no confirmed adverse biologic effects. Additionally, minimal or no sedation is generally required to complete an abdominal scan. Abdominal ultrasound provides useful data in a short period of time. The paucity of intra-abdominal fat in pediatric patients results in less informative abdominal radiography, but improves ultrasonographic imaging. Acquisition of special equipment for pediatric ultrasonography is usually not necessary as scanheads selected for small animal (especially feline) clinical use are appropriate for most pediatric cases.

Equipment
Pediatric patients are best evaluated using an ultrasound machine equipped with a curvilinear variable frequency scanhead (6.0-8.0 MHz). Many portable machines now have available a high frequency linear scanhead (8.0-10.0 MHz) which will improve quality and also allow evaluation of smaller regional anatomy (thyroid, parathyroid, cryptorchid testes).

Preparation
The pediatric patient should be placed in dorsal recumbency within a padded V-trough, and gently restrained by assistant(s) holding the forelimbs and hindlimbs. Sedation is rarely required for the basic abdominal scan unless marked pain or apprehension is present. Allowing the patient to become accustomed to this restraint before initiating clipping or scanning usually minimizes struggling and resultant aerophagia. Clipping the cranioventral abdominal hair using a No. 40 blade and wetting the skin with water, tincture of zephrin or 70% isopropyl alcohol, followed by a liberal amount of ultrasound gel permits the best acoustic coupling of the scanhead to the patient, improving the image obtained. Some pediatric patients have scant ventral hair coats and will not require clipping. Care should be taken to avoid excessive chilling of pediatric patients secondary to the application of room temperature liquids followed by evaporation. Electric warming devices (warm water blankets) may cause electronic interference with the ultrasound equipment; warm water bottles or their equivalent are superior.

Fasting as much as is safely possible in the pediatric patient minimizes gastric ingesta obscuring imaging of the liver and gastrointestinal gas accumulation interfering with visualization of other abdominal viscera. Preventing urination immediately prior to the examination permits better evaluation of the urinary bladder.

The Normal Abdomen
Regardless of the clinical history, the abdomen should be evaluated methodically with the animal in dorsal decumbency. Place the scanhead under the xyphoid with the beam in sagittal plane. Visualization of the liver is achieved by fanning the beam from right to left. The gall bladder is seen on the right; the left liver lobes are seen ventral and sometimes caudal to the stomach. Turning the beam to transverse allows for visualization of the liver between stomach and gall bladder. This view is good for evaluation of the hepatic border, echogenicity of hepatic parenchyma and portal architecture. The portal vessels have very echogenic walls.

Resuming the sagittal plane, scan to the left of the dog past the stomach to the spleen. The spleen will be visualized ventrally in the near field. Splenic border, parenchyma and shape should be evaluated. Following the spleen transversely down the left body wall, you will see the left kidney.

Once visualization of the kidney is achieved, turn to the sagittal plane and evaluate the renal border, cortical echogenicity and pelvic architecture. Dilatation of the renal pelvis is best seen in the transverse plane. The adrenal is located medial to the cranial pole of the kidney. In sagittal, maintaining strong hand pressure, scan medially to visualize the linear aorta and the renal
artery. The left adrenal is located cranial to the left renal artery and caudal to the left cranial mesenteric artery. The left adrenal is visualized as a bi-lobed structure with the phrenicoabdominal vein at its waist.

With a transverse beam back in the middle of the abdomen, scan caudally to a large hypoechoic structure, the urinary bladder. Evaluate bladder wall and lumen contents, and, dorsal to the bladder, the major vessels (caudal vena cava and aorta). Sub lumbar lymph nodes will be seen at the aortic bifurcation into the iliac arteries, adjacent to the bladder wall. Sagittal scanning of the urinary bladder caudally will allow visualization of the urethra (and prostate in the male).

At the edge of the right ribcage at the renal fossa of the liver the right kidney will be found. The right kidney should be evaluated as was the left (renal border, cortical echogenicity and pelvic architecture). By scanning sagittally between the right kidney and the caudal vena cava with a fanning technique, the right adrenal is visualized just lateral to the caudal vena cava. In transverse, find the right kidney, and lateral to the kidney, the duodenum.

At the cranial end of the kidney medial to the duodenum will be the right limb of the pancreas. The right pancreatic limb is identified by visualizing the caudal pancreaticoduodenal vein within the structure. Turning to the sagittal plane, follow the pancreas, scanning mediially to the angle of the body and left limb, or sagittally scan the caudal border of the stomach. The pancreatic body is seen caudal to the stomach, cranial to the splenic vein. The left limb is found caudal to the splenic vein and midline to the cranial pole of the left kidney. Returning to the transverse plane in mid abdomen at the mesenteric root, scan for mesenteric lymph nodes and small bowel wall changes. It may take 2-3 passes to evaluate the entire abdomen scanning in a uniform serpentine fashion.

Disorders of Urogenital Development
Veterinary pediatric ultrasonography has been hampered by the small size of neonatal organs, but advances in pediatric veterinary ultrasonography have been encouraging. Abdominal ultrasound can facilitate the diagnosis of congenital urogenital disorders, because ectopic, distented ureters and changes in renal architecture are usually readily seen. The presence and location of cryptorchid testes can often be detected with ultrasound. Ultrasonographic examination of the bladder disclosing urolithiasis can provide information suggesting congenital hepatic vascular anomalies. The most common familial disorders in cats and dogs include renal agenesis, renal dysplasia, polycystic kidneys, renal amyloidosis, basement membrane disorders, and tubular dysfunction (Fanconi's syndrome).

Renal Agenesis
Congenital renal agenesis resulting in the absence of a kidney can be confirmed with ultrasound. The contralateral kidney typically has normal internal anatomy, but is enlarged as a consequence of obligatory hypertrophy. Renal function of the pediatric patient does not equate that of the adult until 4-6 months of age, compensatory renomegaly may not be apparent until that time.

Renal Dysplasia
Until reliable genetic markers are available for the various breed specific congenital renal dysplasias, ultrasound provides the best method of screening young dogs and cats for these likely heritable disorders. Early ultrasonographic screening is possible in breeds in which morphologic changes are grossly evident (i.e. Persian cats, Cairn Terriers, German Shepherd Dogs).

Ectopic Ureter
Congenital ectopic placement of the distal ureter into the urethra, vestibule or vagina is usually associated with ureteral dilation with or without renal pelvic dilation. Dilation of the ureter improves the sensitivity of the ultrasound study; however, the diagnosis can be elusive. Visualization of a non vascular fluid filled structure with a hyperechoic wall passing dorsal to the urinary bladder, or obvious insertion of the structure into the proximal urethra suggest the diagnosis. Visualization of the ureteral jets in the bladder suggests normalcy, however some ectopic ureters insert initially into the bladder and additionally tunnel distally to terminate in an abnormal site. Visualization of the dilated ureter usually occurs near the urinary bladder. Visualization of the bladder neck and proximal urethra may be obscured by pubic bone, making identification of such termination difficult. Hydronephrosis can eventually result from an uncorrected ectopic ureter due to flow impedance at the abnormal site of insertion. Urinary tract infection is commonly associated with ectopia, due to accompanying urethral sphincter mechanism anomalies, and if not detected and treated, can progress to pyelonephritis and ureteritis. Infection and its associated inflammation in the tract can further alter the ultrasonographic appearance of the kidneys, bladder, ureters and urethra (see below).

Contrast enhanced computed tomography is the most sensitive and specific modality for the diagnosis of ectopia, but, like double contrast radiography, requires...
anesthesia, making initial evaluation with ultrasound desirable when ectopia is suspected clinically. The condition is thought to be heritable, and is more common in females.

**Ureterocele**
An ureterocele is an uncommon congenital dilation of the ureter near the bladder, appearing as a cystic structure within the bladder lumen or wall. The ureterocele occurs most commonly in association with an ectopic ureter. Diagnosis can be made by scanning the urinary bladder in the transverse plane and watching for strong peristalsis of the adjacent ureter.

**Patent Urachus**
The urachus permits the flow of urine from the bladder into the allantoic sac of the fetus, and normally atrophies at birth. A patent urachus in the neonate is characterized clinically by urine dribbling from the umbilicus. The fluid filled urachus can be identified ultrasonographically, extending cranially from the craniocentral bladder wall. If an incompletely patent urachus is present in the neonate, a urachal diverticulum may result, seen as a divot in the apex of the bladder. Urachal diverticula can predispose the bladder to recurrent infection because of abnormal bladder flow in the region, surgical excision can be indicated.

**Cryptorchidism**
Ultrasound localization of cryptorchid testis (es) can confirm the condition in pediatric patients with bilateral involvement whose neutering status is unknown, and assist the surgeon in planning the approach (i.e. inguinal vs cranial abdominal). The retained testis can be positioned anywhere between the ipsilateral kidney and the scrotum. A systematic evaluation of the region from the caudal renal pole to the inguinal canal can identify an oval, homogenously echogenic structure with a mildly hyperechoic border representing the parietal and visceral tunics. The epididymis is usually distinctly less echoic than the testicular parenchyma, as in the scrotal testis. The cryptorchid testis will maintain the anatomic structure, the median testes (a hyperechoic slash), and normal testicular echogenicity despite being reduced in size as compared to a scrotal testis.

Ultrasound is also the test of choice to detect non descended testicles in adult dogs and cats. Ultrasound may also detect non palpable testicular tumors which are more prevalent in this group of patients.

**Disorders of the Digestive System Development**
**Hernias**
Congenital peritoneopericardial diaphragmatic hernias occur in both the dog and cat; ultrasonography provides an additional modality for their diagnosis. As with other diaphragmatic hernias, careful evaluation for continuity of the echogenic diaphragm differentiates a true hernia from mirror image artifacts. Evaluation of the pericardial contents can be made from the subcostal (across the liver) or intercostal (using the heart as an acoustic window) approach. Abnormal pericardial contents can include falciform fat, liver, gall bladder and/or intestines. Congenital inguinal hernias can similarly be confirmed by ultrasonographic identification of intestines in the subcutaneous space of the affected groin. This can be a dynamic finding. Mesenteric fat may alternatively be entrapped through the hernia.

**Patent Urachus**
Congenital hiatal hernias are more difficult to confirm with ultrasound because of the inherent difficulty imaging the gas filled stomach and the intermittent nature of the disorder. Stomach wall with characteristic rugal folds can be imaged crossing the diaphragm into the thoracic cavity. Fluoroscopic evaluation can be more informative in these cases.

**Enteric Anomalies**
**Pyloric stenosis** secondary to hypertrophic gastritis has been reported in a pediatric dog. Focal circumferential thickening of the pylorus primarily involving the muscularis is typical.

Enteric duplication or agenesis can be confirmed ultrasonographically in pediatric patients. Duplication is rare, can occur anywhere in the intestinal tract and the clinical signs may be nonspecific. A fluid filled juxtaintestinal formation with variable peristalsis and contents can be seen. Enteric agenesis usually results in severe clinical signs in the neonatal period. Ultrasonographic findings usually include marked fluid and gas distention of bowel proximal to the defect.

Several breeds of dogs have a reported genetic predilection to small intestinal disease. Normally, the small bowel appears sonographically as four distinct layers. The bowel lumen is hyperechoic, as gas and ingesta are compressed. The layer just outside the lumen is the mucosa; it is hypoechoic and normally the thickest appearing section. Outside the mucosa is the submucosa, it is hyperechoic to the mucosa and about one third the thickness. The muscularis, the bowel muscle layer, is outside of the submucosa and appears as a very thin hypoechoic black line. An immunoproliferative enteropathy is seen in the Basenji breed which is characterized by lymphohistocytosis, intermittent diarrhea, weight loss, hypoalbuminemia and hyperglobulinemia, and lymphoplasmacytic mucosal infiltrates throughout the GI tract. Histopathology is diagnostic, however abdominal ultrasonography can identify bowel in which disruption of the normal layering...
Chinese Sharpei dogs have been identified with a lymphoplasmacytic-eosinophilic infiltrative enteropathy that is characterized by poor weight gain, weight loss, or intermittent diarrhea episodes, with onset of signs typically between 2 to 6 months of age. Infiltrative enteropathies can be characterized ultrasonographically as having changes in the normal bowel wall layering.

**Portosystemic Shunts**

Portosystemic shunts (PSS) are congenital malformations of the hepatic portal venous drainage system and can have either a familial, i.e. genetic, or random occurrence. Congenital PSS can be either intrahepatic or extrahepatic; breed predilections for extrahepatic shunts include Yorkshire terrier, Maltese, Poodle, Miniature Schnauzer, Dachshund, Lhasa Apso, Pekingese, Pug, and Shih Tzu, whereas intrahepatic shunts are more commonly identified in large breed dogs such as Golden Retrievers, German Shepherds, Irish Wolfhounds, Irish Setters, and Samoyeds. PSS are uncommon in cats.

Ultrasonography provides a rapid and noninvasive method for screening patients suspected to have congenital portosystemic shunts. Although scintigraphy (transcatheter portal scintigraphy or transplenic portography) is considered the most reliable noninvasive method of documenting a portosystemic shunt, its availability is limited to specialty and university practices, and its use dictates special handling of the radioactive patient for at least 12 hours. Mesenteric portography, although more invasive and requiring general anesthesia, is a highly reliable method of confirming and localizing PSS.

Abdominal ultrasonography is a useful diagnostic and is routinely done when PSS is suspected. It is non-invasive and requires no anesthesia however diagnostic accuracy is highly operator dependent, and the PSS will be confirmed in only approximately 60-80% of cases. The liver may be small and difficult to image in patients with congenital portosystemic shunts. Imaging the liver from the standard ventral approach can be improved in some cases by using the left ventral intercostal and right dorsal intercostal approaches. The presence of ascites can facilitate the study, as can adding fluid to the stomach, and positioning the patient to shift gas away from the scanhead and shift abdominal organs caudally. Ultrasound evaluation of portosystemic anomalies can be facilitated by positive pressure ventilation under anesthesia for the same reason. Post operatively, ultrasound can be used to evaluate portal blood flow following surgical banding or coil embolization. Intrahepatic shunts most commonly arise from the portal vein, splenic vein or left gastric vein in the dog, and from the left gastric vein in the cat. Identification of a shunting vessel emptying into the caudal vena cava is difficult but confirmatory. Intrahepatic shunts can be more difficult to identify because of patient size, bowel gas and liver size. Clipping the hair coat intercostally on the right can allow for transverse vessel stacking (of the aorta, vena cava and portal vein) and allow visualization of ductal shunts. There can be right and left shunting of the ductus.

**Selected References**