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Reproductive Ultrasound; It's More Than Just Pregnancy
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Normal (nongravid) female reproductive tract: bitch and queen
The normal uterus is best located by scanning transversely between the urinary bladder and the colon. The cervix and uterine body are seen as a continuous hypoechoic round structure dorsal to the anechoic urinary bladder and ventral to the hyperechoic, crescent shaped colon. Thinking of the urinary bladder as a clock face, the uterine body will be located at 5 o'clock or 7 o'clock. The full urinary bladder acts as an acoustic window to improve imaging the uterus. The cervix is located slightly cranial to the bladder trigone and is best seen when under hormonal influence rather than during anestrus. The cervix is an oblique hyperechoic linear structure in the sagittal view. The uterine body is smaller in diameter than the cervix and usually extends to the cranial one third of the bladder. The bifurcation of the uterus into the uterine horns can sometimes be imaged; the horns are typically difficult to image unless enlarged due to hormonal influence during the estrous cycle, pregnancy, or from pathology. The uterus is composed of three layers: the mucosa, the muscularis and the serosa. The endometrium and myometrium cannot usually be differentiated in the normal state. The uterine lumen is generally not seen, although it may be visible as a bright echogenic central area, representing a small amount of intraluminal mucus, or as a hypoechoic to anechoic region if fluid is present.

The normal ovaries are located caudal and slightly lateral to the caudal poles of the ipsilateral kidneys. Their location can be facilitated by the appearance of the artifactual distal enhancement dorsal to each ovary. The appearance of the ovaries varies with stages of the estrous cycle. Normal ovarian dimensions have been established for average sized dogs. During anestrus, the ovaries appear as small oval to bean shaped structures with a homogenous echogenicity similar to the renal cortex. The cortex and medulla are not usually differentiated in the bitch and queen. Multiple anechoic or hypoechoic cyst like structures can be visualized in the ovarian parenchyma during folliculogenesis, larger cystic structures are present during the luteal phase.

Ovulation Timing
Serial evaluation of the ovaries (3 times daily!) can be used to detect changes suggesting ovulation has occurred. During proestrus, multiple anechoic follicular cystic structures can be identified, enlarging with time (up to >1 cm in diameter). These structures ultimately have distinct walls and anechoic fluid centers with distal enhancement. The surface of the ovary may become irregular or lumpy. The anechoic fluid filled follicles acutely become hypoechoic to hyperechoic corpora hemorrhagica (CH) at the time of ovulation, progressing over several days to hyperechoic corpora lutea (CL). The ovarian follicles do not collapse in the bitch and queen. During diestrus the ovaries may be lobular, the corpora lutea are obvious hypoechoic structures of variable size. Precise ovulation timing is best accomplished with a combination of techniques: vaginal cytology, serum progesterone levels, LH assays, vaginoscopy, with ultrasound providing confirmatory information.

Pregnancy Diagnosis
Pregnancy detection by abdominal palpation (at approximately 30 gestational days) or radiography (43-46+ days post LH peak, the later the better) can confirm the presence of fetuses at these points in time. Prior to fetal skeletal mineralization, other causes for uterine enlargement (hydrometra, pyometra) cannot be ruled out radiographically. Radiography cannot be used to assess fetal viability in a timely fashion. Once profound post mortem changes have occurred, radiography can detect intra-fetal gas accumulation or abnormal skeletal arrangement suggesting fetal death. Early fetal resorption cannot be detected radiographically, only by ultrasound. Ultrasound is the best method to evaluate early in gestation for pregnancy (“yes or no”, fetal viability, litter size, and gestational age).

The normal uterus is best located by scanning transversely between the urinary bladder and the colon. The cervix and uterine body are seen as a continuous hypoechoic round structure dorsal to the anechoic urinary bladder and ventral to the hyperechoic, crescent shaped colon. Thinking of the urinary bladder as a clock face, the uterine body will be located at 5 o'clock or 7 o'clock. The full urinary bladder acts as an acoustic window to improve imaging the uterus. The cervix is located slightly cranial to the bladder trigone and is best seen when under hormonal influence rather than during anestrus. The cervix is an oblique hyperechoic linear structure in the sagittal view. The uterine body is smaller in diameter than

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Start the pregnancy check scan by transversely locating the urinary bladder, colon and uterine body as described earlier. Once the uterine body has been identified, sweep cranially, still in transverse, towards each kidney. You are trying to follow each uterine horn to its ovary. Each fetus is contained in an oval, fluid filled gestational sac. Then answer your 3 questions! First question; Yay or nay? Then, if she is pregnant, viability. Finally, how many are there? Finally, what is the gestational age? As for when, I like to perform the scan at 30-32 days post the last known breeding; for 3 reasons; First at 30-32 days post the vesicle is larger than transverse small bowel, making identification pretty easy. Second, the flicker of the heartbeat is regularly seen even without Doppler. Lastly, the vesicles are small enough to allow easy counting of fetuses within each uterine horn. In later gestation (>50 days) the fetuses are so large the uterine horns overlap making the correct count difficult.

The determination of gestational age can be of vital importance. An accurate determination of gestational length can be difficult, especially if numerous copulations occurred and no ovulation timing was performed. Prolonged gestation is a form of dystocia. Gestation in the bitch is more challenging to calculate than in the cat, because bitches are spontaneous ovulators. Normal gestation in the bitch is 56 to 58 days from the first day of diestrus (detected by serial vaginal cytologies, defined as the first day that cytology returns to <50% cornified/superficial cells), 64 to 66 days from the initial rise in progesterone from baseline (generally >2ng/ml), or 58 to 72 days from the first instance that the bitch permitted breeding. Predicting gestational length without prior ovulation timing is difficult because of the disparity between estrual behavior and the actual time of conception in the bitch, and the length of time semen can remain viable in the bitch reproductive tract (often up to >7 days). Breeding dates and conception dates do not correlate closely enough to permit very accurate prediction of whelping dates. Additionally, clinical signs of term pregnancy are not specific: radiographic appearance of fetal skeletal mineralization varies at term, fetal size varies with breed and litter size, and the characteristic drop in body temperature (typically less than 99 degrees Fahrenheit) may not be detected in all bitches and varies in many. Breed, parity and litter size can also influence gestational length.

Because the queen is an induced ovulator (ovulation follows coitus by 24-36 hours), gestational length can be predicted more accurately from breeding dates, assuming copulation provided adequate coital stimulation for the LH surge and subsequent ovulation, and a limited number of copulations were permitted. The gestational length of queens ranges from 52-74 days from the first to last breeding. The mean gestational length is 65-66 days. Because of the poor outcome with the delivery of premature puppies and kittens, elective intervention is best delayed until stage I labor has begun, or prolonged gestation confirmed.

Definite ultrasonographic diagnosis of pregnancy in the queen based on the appearance of a “fetal pole” can be made at 15-17 days post coitus, although gravid uterine enlargement (4-14 days) and the presence of a gestational sac (11-14 days) can be detected even earlier. Ultrasonographic detection of the canine blastocyst (a 2-3 millimeter spherical hypoechoic structure surrounded by a hyperechoic rim within the uterus) occurs at 19-20 days post LH peak. Ultrasonography permits evaluation of early fetal cardiac motion (21-22 days post LH peak), fetal movement (31-32 days post LH peak) and the fetal heart rate, enabling assessment of viability. By 30 days gestation (30 days after the LH surge) pregnancy diagnosis with ultrasonography is straightforward.

Fetal age determination by ultrasonography is accomplished in two ways:

1. the first appearance of visible structures
2. the measurement of certain parameters.

Predicting fetal age by noting the first appearance of visible structures corresponding to gestational length is often more accurate than measurements. Measurements such as the gestational sac diameter, fetal occipitonasal (crown-rump) length and fetal skull (biparietal) diameter can be obtained ultrasonographically, relate closely to
fetal age, and permit estimation of gestational length and parturition dates, especially useful if ovulation timing was not performed. Variation in breed size (especially in the dog) and individual variation in measuring technique are sources of inaccuracy in predicting fetal age with ultrasound. Ultrasonography is less accurate than radiography in estimating litter size, particularly later in gestation, due to its dynamic nature. Keep in mind that fetal resorption or abortion can alter litter size after early ultrasound estimates are made.

### Table 1
Formulas to Predict Gestational Age and Days before Parturition in the Dog and Cat

<table>
<thead>
<tr>
<th>Gestational Age in the Dog (+/- 3 days)</th>
<th>Gestational Age in the Cat (+/- 2 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 40 days</td>
<td>Greater than 40 days</td>
</tr>
<tr>
<td>GA = (6 x GSD) + 20</td>
<td>GA = 25 x HD + 3</td>
</tr>
<tr>
<td>GA = (3 x CRL) + 27</td>
<td>GA = 11 x BD + 21</td>
</tr>
<tr>
<td>Greater than 40 days</td>
<td>Days before parturition in the dog</td>
</tr>
<tr>
<td>GA = (15 x HD) + 20</td>
<td>DBP = 65 - GA</td>
</tr>
<tr>
<td>GA = (7 x BD) + 29</td>
<td>Gestational age in the cat (+/- 2 days)</td>
</tr>
<tr>
<td>GA = (6 x HD) + (3 x BD) + 30</td>
<td>Greater than 40 days</td>
</tr>
<tr>
<td>Days before parturition in the dog</td>
<td>GA = 25 x HD + 3</td>
</tr>
<tr>
<td>DBP = 65 - GA</td>
<td>GA = 11 x BD + 21</td>
</tr>
<tr>
<td>Gestational age in the cat (+/- 2 days)</td>
<td>Days before parturition in the cat</td>
</tr>
<tr>
<td>GA = 25 x HD + 3</td>
<td>DBP = 61 - GA</td>
</tr>
</tbody>
</table>

Table 2

**Novel Feline Gestational Aging Using Crown-rump length**

- \[ Y = 0.2423 \times GA - 4.2165 \]
- \[ Y \text{ is mean litter CRL (cm)} \]
- \[ GA \text{ is the gestational age} \]

(Solve for GA)

**Pregnancy Termination:**

Purposeful induction of abortion with drugs (prostaglandins, dexamethasone, antiprogestins) also requires serial ultrasonographic evaluations to determine the endpoint of therapy, as most protocols will result in delivery of viable neonates if terminated prematurely. Loss of fetal viability usually precedes expulsion of fetuses by 12-48 hours.

### Disorders of the reproductive tract

In the bitch and queen, documented abnormalities of the estrous cycle, pregnancy and the periparturient period, and even disorders of the residual reproductive tract in ovariohysterectomized females call for ultrasonographic evaluation of the uterus and ovaries. Serial examinations may be necessary during various parts of the estrous cycle to evaluate differences in ovarian and uterine appearance with normal hormonal fluctuations (i.e. ovarian ‘cyst’ vs. normal corpora lutea) and parturition (i.e. post partum metritis vs. subinvolution).

**Cystic Endometrial Hyperplasia/Pyometra, Post Partum Metritis**

Ultrasoundographic evaluation of the uterus provides important information concerning uterine wall thickness and composition (presence of cystic structures), lumen size and content, and overall organ symmetry and position. Cystic endometrial hyperplasia is characterized by endometrial thickening with focal anechoic structures noted in the uterine wall representing dilated cystic glands and tortuous glandular ducts. With advanced disease, these changes do not disappear ultrasonographically during anestrus. Fluid accumulation in the uterine lumen may represent hydrometra, mucometra or developing pyometra, and can be very difficult to differentiate (echogenicity may suggest cellularity). Because of the potential for peritonitis, centesis is not generally advocated. Cytology (+/- culture) of vaginal secretions is preferred. Because pyometra is
associated with diestrus, measurement of a serum progesterone level can support the diagnosis and help differentiate if from hydrometra and mucometra, both of which can proceed to pyometra. Additional hematologic and biochemical abnormalities associated with pyometra (leukocytosis, azotemia, polydipsia/polyuria) should be sought.

Uterine enlargement with pyometra is variable. Evaluation of the uterine lumen post partum for retained placenta, mummified fetuses or masses is best accomplished with ultrasound. Post partum metritis is best differentiated form the normal post partum uterine enlargement by a failure of normal progressive decrease in uterine lumen contents and horn width. The bitch involutes and repairs for 16 weeks, making the normal post partum uterus prominent. The diagnosis and medical management of the cystic endometrial hyperplasia/pyometra complex or post partum metritis (usually with prostaglandins, progesterone inhibitors and antiprolactins) is best monitored by serial evaluations of uterine luminal contents with ultrasound along with hematology, biochemistry and clinical parameters (appetite, fever, vaginal discharge). The therapeutic use of prostaglandins should always be preceded by an ultrasound evaluation for pregnancy, due to their action as effective abortifacients.

Infertility
Differentiation of infertility due to a failure to conceive vs resorption or abortion can only be accomplished with serial ultrasonographic examinations of the uterus after breeding. Early resorption of fetuses can be documented by serial ultrasound evaluations of the gravid uterus.

The ovaries can be imaged to evaluate their presence, size and echogenicity. Fluid filled, pathologic follicular, luteal or nonfunctional cysts within ovaries can be readily imaged and persist over time, supporting the diagnosis of cystic ovarian disorders causing abnormalities in the estrous cycle (prolonged estrus, prolonged interestrus intervals). Pathologic ovarian cysts can be unilateral or bilateral, single or multiple, but must be differentiated from normal cystic structures during appropriate parts of the estrous cycle (follicles, CLs).

Post Ovariohysterectomy Disorders/Abnormal Vaginal Discharge
Ultrasound permits evaluation of the cervix, complementing vaginoscopic evaluations in which the caudal os can be the only part visualized. Uterine stump pyometra (if functional ovarian tissue is present), stump granuloma (secondary to local disease) or hematoma (coagulopathy or surgical error) can be visualized just cranial to the pubis, between the bladder and colon as a complex mass lesion. Vaginal foreign bodies (grass awns) can be imaged ultrasonographically in the cranial vagina and cervical area.

Neoplasia
Finally, uterine neoplasia is typically of altered echogenicity to the surrounding uterine tissue, having complex internal architecture and may project into the uterine lumen. Alterations in ovarian dimensions or echogenicity can occur with neoplastic disorders, necessitating laparotomy and biopsy. Tumors of the ovaries can also be unilateral or bilateral and can be functional causing estrous cycle abnormalities. Histopathology is usually required to differentiate pathologic ovarian cysts from neoplasia, both can occur simultaneously.

Basic Abdominal Ultrasound in Dogs and Cats
Can Your Technician Perform the Scan?
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Introduction
The use of ultrasound during evaluation of the patient with signs referable to the abdominal cavity 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 in the non painful patient. Abdominal ultrasound provides useful data in a short period of time.

Today, many veterinary practices are extremely busy, as many families have multiple pets. The large caseloads result in veterinary technicians performing skilled tasks such as anesthesia, dentistry and radiography. I believe technicians can be trained to perform ultrasound scans and document both normal and abnormal findings in the abdomen for veterinary interpretation. By learning the
basic abdominal scanning procedures, technicians could become the primary ultrasonographers in many veterinary clinics in the future, just as occurs today with radiography. Performing the scan, documenting findings and reporting back to the doctor, as is currently the practice in human medicine, will become the norm in veterinary medicine as well. Today’s lecture outlines the technique to train technicians to perform abdominal ultrasound.

**Equipment**

Small animal 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 small animal patient should be placed in dorsal recumbency within a padded V-trough, and gently restrained by assistant(s) holding the forelimbs and hindlimbs. (Figure 1) 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 zephiran or 70% isopropyl alcohol, followed by a liberal amount of ultrasound gel permits the best acoustic coupling of the scanhead (8.0 -10.0 MHz) which will improve quality and also allow evaluation of smaller regional anatomy (thyroid, parathyroid, cryptorchid testes).

Fasting as much as is safely possible in the small animal 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.

Serial evaluations can provide useful information when the clinical status of the small animal patient has changed; clinicopathologic deterioration, progressive lethargy or obtundation, acute pain, changes in abdominal palpation findings or refractory vomiting or diarrhea warrant repeat evaluation for ultrasonographic signs indicating intussusception, perforation and/or peritonitis have evolved.

**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 phrenicoadominal 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).
Companion Animal Programme

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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 medially 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.

ULTRASONOGRAPHY OF UNUSUAL BODY PARTS: THERE IS MORE THEN TO EVALUATE THE THORAX AND ABDOMEN
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Ultrasonography involves exposing part of the body to high frequency sound waves to produce images of the inside of the body. Ultrasound images are captured in real-time showing structures and movement and peristalsis of the body’s internal organs as well as blood flowing through blood vessels or bowel movements for instance. Small organs cannot be detected on radiographs, unless severely enlarged or mineralized. CT or MRI could be used for this purpose, but are not routinely performed, as these imaging modalities are more expensive, less available in veterinary medicine and require deep sedation or even general anesthesia. Therefore, in small animals, US is the method of choice for imaging small organs, whether these are located superficially or in one of the body cavities. For imaging these small organs, ultrasonographic equipment with a high-frequency transducer (10-12 MHz) is required to increase spatial resolution of the images.

Abdominal and cardiac US are performed routinely in human and veterinary medicine, but there are more body parts that can be imaged efficiently by US. Additionally to diagnostic purposes, US is frequently used to guide procedures, such as FNA’s, core biopsies or placement of stents or coils.

In human medicine clinicians of different specialties perform more often US to examine particular organs, diseases, or procedures that is directly relevant to their area of expertise. In veterinary medicine most patients usually undergo a “full” examination. Since non-imaging specialists push for imaging their area of expertise with US, radiologists are challenged to image more unusual body parts, as for instance the intraocular and orbital structures, the neck area, with the thyroid glands, search foreign bodies, neuroimaging, such as the brain and somediseasesofthevertebralcolumnandmusculoskeletal disease, including joints, bones and soft tissues.

It is a well-recognized fact that the quality of an US examination is operator dependent, also true for the evaluation of unusual body parts. However, it is important to know, that US of these body parts is possible and may give valuable information for prognosis and treatment. In addition, US may guide FNA’s and therapeutic interventions.

Ocular US is routinely used for evaluation of the eye when the optic media are opaque. Cause for opaque media include corneal edema, hyphema, or cataract. US may help to evaluate the obscured intraocular structures, and in some cases even aid to make a diagnosis. US findings, such as vitreum degeneration, lens subluxation or luxation, retinal detachment, persistent hyaloid artery or persistent hyperplastic primary vitreous/persistent hyperplastic tunica vasculosa lentis, intraocular tumors, and/or subretinal bleeding enable a better assessment for the prognosis of therapy. In patients with corneal edema, the cause may also be an intraocular tumor and the intraocular structures can be fully visualized with US. The orbit is difficult to examine clinically. Exophthalmos is

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CHAPTER 2

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the most frequent clinical finding, but the cause is often difficult to diagnose. Several diagnostic-imaging techniques may be used to image the orbit, such as CT, MRI, and US. CT and MRI give the most detailed information on the normal and changed anatomy of the orbit, however these techniques are expensive, require sedation or anesthesia and are not widely available. US, however, is relatively cheap, widely available and may be performed in the awake patient. Disadvantage is that the quality of the US examination is very operator dependent and often for presurgical evaluation CT or MRI are necessary. On the other hand, US can give a first impression over the character and extension of the lesion and therefore essential information on the prognosis of the disease, giving the owner the possibility to decide whether they want further investigation or not.

Thyroid US may be used to assess canine thyroid carcinomas, canine hypothyroidism and feline hyperthyroidism. The normal thyroid is composed of paired well-delineated lobes, located adjacent to the lateral walls of the trachea with a homogenous structure and a hyperechoic capsule. The parenchyma is usually more hyperechoic compared with the surrounding musculature and the size is correlated with the body weight. Each lobe has a triangular shape on the transverse plane and a fusiform shape on the longitudinal plane.

The diagnosis of canine hypothyroidism and its differentiation from euthyroid sick syndrome is still a major diagnostic challenge. In a study, by Reese et al. healthy dogs, dogs with euthyroid sick syndrome, thyroglobulin autoantibody-positive (TgAA-positive) hypothyroid dogs, and TgAA-negative hypothyroid dogs were examined by thyroid US. The data revealed that thyroid US is an effective ancillary diagnostic tool to differentiate between canine hypothyroidism and euthyroid sick syndrome. Other studies have shown that thyroid gland US can be useful in differentiating some dogs with hypothyroidism from those with non-thyroidal illness. If the thyroid gland size is less than the reference range, hypothyroidism is the most likely diagnosis, whereas a normal measurement provides little useful information. The possible origin of undifferentiated cervical masses, include lymphadenopathy, abscess, granuloma, salivary gland inflammation and neoplasia. To determine the origin of the mass, both thyroid glands should be identified in order to rule out a mass of thyroid origin in or out. Foreign bodies may cause extensive inflammation of the cervical region, which may be located precisely with US, which helps surgical removal. In some case intraoperative US guidance is advised for the removal of a foreign body.

Use of US in musculoskeletal disease are various, reaching from investigating a soft tissue mass (including US guided FNAB) within muscles to evaluating ligaments, joints, tendons and bony surface. Often US is used for guidance of FNAB or puncture of a joint. In contrary to the equine practice, musculoskeletal US is not as widespread in small animals, probably due to the better accessibility of the musculoskeletal structures to the clinical examination. However, there have been several reports published illustrating that US is an useful technique to confirm clinical suspected diagnosis such as, meniscus tears, muscle, ligament and tendon injuries and also fracture healing.

In neuroimaging, US is mainly used to diagnose a hydrocephalus, especially if the fontanelle is still open. However, it has been demonstrated that the correlation between ventricular size and clinical signs was poor. But in cases suspected of hydrocephalus clinically, US may be a quick technique to confirm this diagnosis. In conclusion, this lecture will demonstrate that there is more to US the imaging thoracic and abdominal structures.

ULTRASONOGRAPHY 2012

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Over the last five decades, ultrasonography (US) has emerged as one of the most important imaging techniques in modern human and veterinary medicine. Its place and utility in equine and small animal clinics is more than established and it is routinely used. US is a safe and effective form of imaging that has been used for more then half a century to aid diagnosis and guide procedures. Over the past two decades, ultrasound equipment has become more compact, higher quality, and less expensive, which has also facilitated the growth of non-radiologists performing US examinations. Since

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US is a user-dependent technology, and as usage spreads, there is a need to ensure competence, define the benefits of appropriate use, and limit unnecessary imaging and its consequences. Both new developments in US technology and quality of the US examinations are being discussed in the year 2012.

From the days of early grey scale imaging in the late 60s and 70s, US has developed to modern sophisticated grey scale equipment, also integrating color, power, continuous and spectral Doppler imaging possibilities.

Also in animals, US has become one of the most frequently used diagnostic imaging technique, besides radiography, because of its real time capabilities and diagnostic yield of soft tissues. Furthermore US is used more often as a guide for procedures and follow-up examinations during cause of treatment. Advantages as compared to other imaging techniques are no ionizing radiation, relative low cost, availability and low risk to the patient. Disadvantages remain the fact that US is very operator dependent, since the diagnosis is made during performance of the examination.

So, where do we stand in 2012 in veterinary US?
The inquisitive human mind never rests, so there is always searching for newer and more innovative inventions, making diagnostic and therapeutic US easier and quicker. Reasons why the industry as well as medical and veterinary personnel is working hard for technological advances and innovations are:

- improving diagnostic capabilities – new indications
- “seeing structures” which cannot be seen otherwise
- artifact reduction for improving the interpretation possibilities, for instance when a lesion is difficult to identify
- Improved visualization of pathological details, also in relation with the surroundings, for instance for surgical planning
- narrow down differential diagnosis
- therapeutic possibilities
- cost effectiveness and ease of usage, for instance bedside and intraoperative US
- assessment of usefulness for patient, especially when the development implies a more expensive machine
- earlier detection of lesions.

The ultimate goal of the invention of newer and more sophisticated techniques is to be able to make an almost definitive diagnosis or be as close as possible to the underlying pathology only on the diagnostic imaging technique. When CT and MR became more and more sophisticated in human medicine, and nowadays also in veterinary medicine, it was almost believed that US will die a quick death. Due to cost effectiveness and relatively quick performance, US still plays an important role in medicine. It is still widely accepted as the first imaging modality and development in US leads to an improvement in transducer quality and US technology, extending the diagnostic and therapeutic usage of US in human and veterinary medicine.

In human medicine several new US techniques have been introduced, which might also be very useful in veterinary medicine. Amongst these, the following are some of newer developments that have firmly established their importance as today. Some of these techniques are also used routinely in veterinary medicine, such as color, power, continuous flow and spectral Doppler techniques, some are used in certain universities and clinics, such as contrast enhanced, tissue harmonic imaging, transosophageal, transrectal, transvaginal, endoscopic and intraoperative US, and some are not yet established in veterinary practice, besides for research studies. These include acoustic radiation force impulse (ARFI) or Fibroscan, Elastography, extended field of view (Siecape, Panoramic view), tissue equalization, high intensity focused ultrasound (HIFU), volume and fusion imaging. This illustrates that development goes on in the field of US, as well in CT and MRI, not just in human medicine but also in veterinary medicine.

Furthermore, there is another development taking place concerning the question, who should perform the US examination? In human medicine “point-of-care” US has grown due to development of US technology (US machines are more compact, of higher quality and less expensive). The concept of focused (“limited” or “goal-directed”) examination is important in point-of-care US. Clinicians from diverse specialties may become very adept at using US to examine a particular organ, disease or procedure that is directly relevant to their area of expertise, whereas imaging specialists typically perform more comprehensive examinations. In contrary to humane medicine, veterinary patients are usually examined ultrasonographically by veterinarians themselves. Human technicians work with US protocols focused on evaluation of individual organs or indication, whereas in our veterinary patients we often examine the entire abdomen or thorax and less protocolized. In veterinary medicine, US is performed by practitioners,
Over the last five decades, ultrasonography (US) has emerged as one of the most important imaging techniques in modern human and veterinary medicine. Its place and utility in equine and small animal clinics is more than established and it is routinely used for the examination of many body parts. With the increase of popularity, one could consider US as the “stethoscope of modern imaging”, even though a good clinical examination is still necessary for gaining the maximal information of an US examination.

Abdominal and thoracic US are performed routinely in human as well as in veterinary medicine. Abdominal US includes evaluation of all abdominal organs, such as evaluation of the liver, spleen, kidneys, urinary bladder, gastro-intestinal tract, pancreas, lymph nodes, adrenal glands and the uro-genital tract. Thoracic US usually implies echocardiography and sometimes evaluation of the cranial mediastinum. Ultrasound penetrates well through fluid and soft tissues, but does not penetrate well through bone or air, limiting its usefulness in the skull, chest, and areas of the abdomen where bowel gas obscures the image.

Many cases appear to be straightforward in US examination, but when unusual images show up, questions may arise. Furthermore, sometimes some indications are forgotten. This plays especially in thoracic US a role. Usually, lungs cannot be evaluated with US, because of the artifacts caused by the air in the lungs. But most diseased lungs contain less or no air, and then US may give additional information over the character of the disease and enables guidance for performing FNA’s. In a normal lung, the visceral and parietal pleura are closely associated, and ultrasound shows shimmering or sliding at the pleural interface during respiration. The absence of sliding indicates a pneumothorax. A small pneumothorax may be missed and blebs or scarring may result in false positives, leading to incorrect diagnosis.
positive findings. Comet tails are an US artifact that arises when US encounters a small air-fluid interface, making sonographic identification of alveolar interstitial infiltrations possible. Alveolar infiltrates appear as homogeneous or heterogeneous infiltrates with resemblance to hepatic tissue. Also for the evaluation of the chest for pleural effusion and/or consolidation of lung lobes, US has been proven a valuable technique. In this lecture, several interesting cases will be demonstrated showing some unusual US images of the thorax and abdomen. In some of these US cases also radiographic, CT or MR examinations were performed for further understanding the US changes and therapy planning of these patients.

Positioning and projections
Standard thoracic radiography includes a potential of four views, a right or left lateral and a VD or DV projection. Use of a single recumbent lateral view only is a serious error.

The appearance of the dependent hemidiaphragm on the lateral views and the appearance of the diaphragm on the DV/VD view vary markedly. The level of inspiration affects the appearance of the lung fields.

Method of evaluation
It is a good rule to read the radiograph using the same method consistently. Evaluate the periphery of the thorax first examining the spine, sternum, diaphragm, ribs and fore limbs. This is followed by an evaluation for potential pleural lesions. Next is an evaluation of the mediastinum, studying the esophagus, trachea, lymph nodes, and heart shadow. Finally is the evaluation of the lungs. The appearance of a normal thorax is based on breed, age, and state of respiration, obesity, and secondary pulmonary fibrosis.

Radiographic signs
The opacity of the lung fields may be decreased or increased. Hyperlucent lung fields may be due to breed conformation, overinflated lungs of temporary physiologic cause, or may also be of pathologic origin, e.g., asthma or emphysema. Increased lung opacity could be due to hypoinflation due to breed or level of respiration or could relate to a pathologic situation. “Infiltrate” within the lungs refers to any poorly marginated increased opacity of the lung parenchyma, which does not distort the architecture of the tissue. The opacity can be diffuse (generalized) or focal, lobar, peribronchial, patchy or scattered, perihilar or peripheral, and ventral or dorsal.

Size of lung lobes may be described as collapsed, although the term atelectasis is used also. Normal elastic recoil (relaxation atelectasis) occurs with pleural lesions such as effusion or pneumothorax. This type of collapse develops rapidly in the lower lung of an anesthetized animal, and even in the conscious animal. Compression atelectasis occurs with positive pleural pressure. Obstructive atelectasis occurs when airways are obstructed. Adhesive atelectasis is collapse that results from increased recoiling tendency when the alveolar surfactant is damaged. Restrictive atelectasis occurs if pleural adhesions or thickening prevent re-inflation. Cicatrization atelectasis occurs with lung fibrosis after chronic collapse, such as with a diaphragmatic hernia. Consolidation, however,
Special pulmonary lesions
Lung fibrosis is a well-documented characteristic of aged dogs’ lungs and typically appears as a fine woven (reticular) interstitial pattern.

“Shock lung, or acquired respiratory distress is a severe widespread infiltrate developing occasionally in dogs after severe trauma or shock.

Eosinophilic pneumonitis or pulmonary infiltrates with eosinophilia (PIE) is a condition usually manifested as an unstructured interstitial opacity often with accompanying bronchial pattern.

Location and distribution
Location and distribution of a pulmonary lesion can be helpful in diagnosis with bilateral symmetrical and dorsal distribution strongly suggestive of pulmonary edema in a dog. Peracute neurogenic edema commonly has a caudodorsal location. For unknown reasons, the alveolar edema of chronic mitral valve endocardiosis and regurgitation is sometimes predominantly in the right caudal lung. Cranioventral distribution suggests both aspiration and airway origin pneumonia.

The right middle lobe is often the only lobe affected with pneumonia, and is the one most likely to become atelectatic. It has the greatest surface-to-volume ratio of all the lobes, and thus the worst collateral ventilation, and is thus the most prone to bronchial obstruction.

Focal, scattered, peripheral and dorsal location that is asymmetrical suggests hematogenous distribution such as infarct (e.g., post heartworm treatment) or hematogenous pneumonia or lung contusion, and is also seen as a typical manifestation of granulomatous diseases, including severe...
volume overload, or primary or secondary pulmonary arterial hypertension.

Large veins are a sign of pulmonary venous hypertension, caused by mitral regurgitation, dilated cardiomyopathy, and feline hypertrophic cardiomyopathy. In chronic hypertension the veins may appear tortuous.

Tracheal disease
Radiologic signs of tracheal disease are characterized by abnormal size, shape, position, and margination. Normal tracheal diameter is approximately three times the diameter of the proximal third of the third rib. The tracheal lumen may become stenotic due to a tracheal wall lesion, intraluminal foreign body, or extramural mass.

Acute upper airway obstruction will cause pulmonary edema. However, the slight pressure swings in normal respiration have only a slight effect on tracheal diameter.

Hypoplasia of the tracheal wall is an occasional cause of upper airway obstruction. An overinflated cuff of an endotracheal tube can result in a stenosis. Bite wounds, penetrating wounds, and car accidents may cause laceration of the trachea.

Tracheal collapse
With tracheal collapse the tracheal rings open out, the dorsal ligament stretches, and the trachea becomes flattened. During inspiration, the cervical trachea collapses, as intratracheal pressure is negative relative to the neck muscles. The thoracic trachea is expanded, as pleural pressure is negative to intratracheal pressure. The opposite happens during expiration: pleural pressure is positive and the thoracic trachea collapses, while the pressure of the exhaled air expands the cervical trachea.

Some larger dogs not prone to tracheal collapse sometimes have an infolded dorsal tracheal membrane called a redundant dorsal membrane, which resembles true collapse.

The pleural cavity
The pleural cavity is not normally visible, as the layers of pleura and the thin lubricating fluid are too thin to attenuate sufficient photons to cast a shadow.

Pleural fluid
A minimum of 50-100 ml is required in the medium-sized dog to be detectable radio graphically. On the DV view the fluid gravitates to the dependent ventral region.
adjacent to the sternum. On the VD view, the fluid moves dorsally where is lies in the paraspinal gutters formed by the ribs.

Asymmetrical location of the fluid is said to be “trapped” by hydrostatic forces or adhesions caused by lobar lung disease or a collapsed lobe. Purulent fluid may be so viscous that it will not move by gravity and its appearance on the VD and DV views will look essentially the same and is considered as trapped fluid.

Fat in the cranial mediastinum and surrounding the cranial lung lobes may have an opacity that resembles minimal pleural effusion on both lateral and DV/VD views.

**Pleural mass**
Diaphragmatic hernia is the most common type of pleural mass.

**Pleural air**
The third lesion within the pleural space is that of air. The radiographic signs of pneumothorax are retraction of the ventral parts of the lung from the sternum, displacement of the heart dorsally from the sternum by gravity, and retraction of the dorsal lung from the thoracic wall.

**The mediastinum**
The mediastinum can be divided into sections that are cranioventral, craniodorsal, perihilar, and caudal.

The radiologic sign of pneumomediastinum is the outlining of normally ill-defined mediastinal structures such as the cranially located vessels, trachea, and esophagus. The “mediastinal stripe” sign is caused by the compression of the ventral wall of the air-distended esophagus onto the dorsal wall of the trachea.

**Esophagus**
The thin lines of the esophageal walls crossing the dorsal lung field identify a dilated esophagus. A diffuse opacity in the region of the esophagus indicates that it is dilated with liquid or foreign material. A contrast study shows ventral displacement of a dilated esophagus.

Esophageal foreign bodies have a variation of opacity. The most common are bone. A barium esophagram is helpful in identification of an esophageal obstruction. Dorsal esophageal displacement is usually caused by enlarged cranial mediastinal lymph nodes, most commonly lymphosarcoma. A unique cause of cranial dilatation of the esophagus is a persistent vascular ring anomaly with esophageal distention cranial to the restriction when filled with ingesta.

**Trachea**
A displaced trachea plus a wide and dense mediastinum often suggest cranial mediastinal masses.

Perihilar lymphadenopathy may cause a sharp ventral bend of the trachea at the carina. Esophageal foreign bodies can lodge dorsal to the heart causing a swelling or diffuse opacity in the perihilar region. Left atrial enlargement is a common cause of perihilar opacity.

Caudal mediastinum contains the accessory lung lobe and assorted lesions of the gastroesophageal junction.

Mediastinal shift refers to the movement of the mediastinum and its contents away from the midline. The most obvious sign is a displaced heart. Unequal pressures and shift are caused by unilateral pleural effusion, a primary lung tumor that may expand a lung lobe, a tension pneumothorax, or a unilateral diaphragmatic hernia.

**Cardiac disease**
Routine thoracic radiography permits evaluation of cardiac disease. Echocardiography is a more accurate method of evaluation.