Ultrasound of the Small Animal Abdomen

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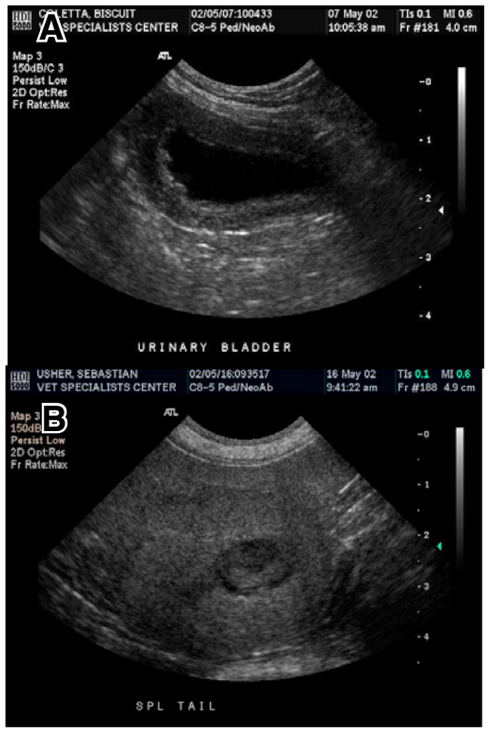
Introduction

Ultrasound has become a mainstay in imaging of the heart and the abdomen. It has shown its clinical utility for multiple applications in the abdomen and is considered an invaluable tool for evaluating the parenchyma of the abdominal viscera. It has become readily available for the practitioner as machines have become more cost effective. However, ultrasound is technically demanding and can be intimidating. A level of expertise must be gained prior to being able to obtain diagnostic quality images and appropriate video clips. This often frustrates the first time sonographer as they attempt to master both the technique of performing an examination as well as the interpretation of normal versus abnormal at the same time. The purpose of this handout is to guide the student and practitioner in a step-by-step approach to understanding the physics of ultrasound, the technical demands and a how a basic approach to scanning a dog or cat in lateral recumbency. In this manner, a more accurate assessment can be made resulting in concise differential diagnoses or even a specific diagnosis. This handout does not replace the excellent textbooks (Nyland, Mattoon and Penninck, d'Anjou) that are available today on small animal ultrasound. It is incumbent on the student or practitioner to read and throughly understand these textbooks.

The pitfalls of ultrasound include over interpretation, subjective nature of interpretation (hypoechoic vs. hyperechoic parenchymal changes), steep learning curve requiring years of commitment (Table 1: US Quest) prior to feeling comfortable in assessing abnormalities as well as opening "Pandora's Box" with the finding of abnormalities that are unrelated to the patient's original presentation or the original reason for doing the ultrasound, (**Figure 1**).

This brief overview of abdominal ultrasound is meant to be just that – an overview. If you are serious about ultrasound, you will take it upon yourself to review the ultrasound references listed including the one on physics by Fred Kremkau. Ultrasound images can become entirely artifact, when the technology or knob tweaking is applied inappropriately. Ultrasound examinations require time and effort on the part of the sonographer. Keys to success include: scan as many cases as possible, take 2 to 3 ultrasound classes each year for three years with different instructors and become familiar with your machine to the point that it is second nature to operate (**Table 1**). Most abdominal ultrasounds can be performed in 10 to 40 minutes; however, complex studies may require additional time. Ultrasound requires patience and technical expertise that is only learned after mastering your equipment, the physics of ultrasound and the nuances in identifying normal from abnormal sonographic anatomy.



Physics of Ultrasound

Figure 1. **A dog was scanned because of a clinical history of hematuria (A). The urinary bladder wall is thickened concentrically. However, a splenic mass with central necrosis was also found (B), thereby opening "Pandora's Box". The mass was removed and the diagnosis was hemangiosarcoma.**

Ultrasound is defined as a series of alternating waves of compression and rarefaction that travels through a medium, (**Figure 2**). The ultrasound waves are characterized by the length of a compression and rarefaction cycle called wavelength (measured in mm for ultrasound), velocity within the medium or tissue (defined as 1540 m/sec as an average in soft tissues) and the number of cycles of compression and rarefaction per unit time or frequency (defined in MegaHertz [MHz] or 1×10^6 cycles/sec). Ultrasound is then defined as sound above the normal human hearing range of 20 kHz.

The ultrasound energy as it travels through the medium can have one of two basic interactions. The first interaction is no interaction and the sound wave is propagated or transmitted through the medium. The second interaction is that the sound wave interacts with a medium that has different acoustic impedance and will be reflected, refracted, scattered or absorbed. If one looks at the overall intensity (Watts/cm^3) as the ultrasound waves are transmitted in the medium, one will find that the intensity decreases with depth of tissue being imaged. This is because of the basic tissue interactions that are occurring and thereby decreasing or attenuating the ultrasound beam. The physical density and the velocity of sound within the medium determines the acoustic impedance of the medium. Due to differences in acoustic impedance, there will be a scattering, reflection or refraction of the ultrasound waves. The actual change in acoustic impedance occurs at an acoustic interface. The returning or reflected ultrasound waves are what then makes up an image. Acoustic interfaces with large differences in acoustic impedance will result in total reflection of the sound waves, such as soft tissue – gas and soft tissue – bone interfaces.

Within each ultrasound transducer is a specialized material called a piezoelectric crystal, which will oscillate when an electrical voltage is applied to it. This oscillation creates the ultrasound wave within the tissue. Once reflected, the ultrasound wave will cause the crystal to oscillate that is then converted to an electrical signal. The transducer thereby acts as both a sender (1%) and a receiver (99%) of the ultrasound waves (called pulsed wave technology). There are many ways of defining a transducer characteristics, but several important issues include frequency of the transducer, type of transducer and resolution of the transducer in the near field and far field. The typical ultrasound transducers available today include frequencies between 2 and 15 MHz. As the transducer frequency increases the penetrability of the ultrasound beam decreases (higher attenuation at depth), but the overall resolution, particularly in the near field, increases. So a 8 MHz transducer may have

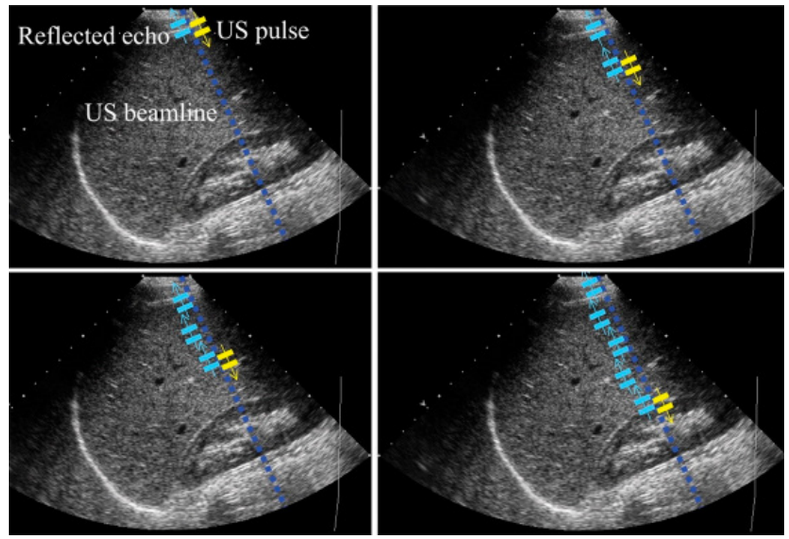


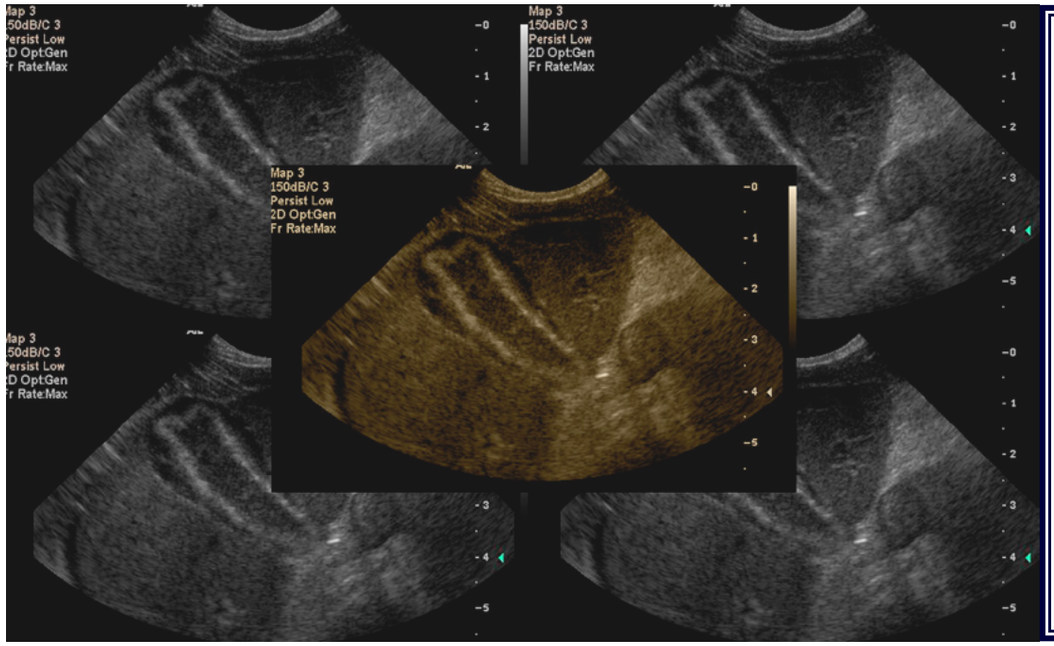
Figure 2: Pulse - echo style of image formation used in ultrasound. The ultrasound wave is transmitted through the soft tissues and reflected at a difference in acoustic impedance thereby generating a returning echo signal.

Table 1: US Quest

1. **3 years minimal commitment!!**
2. **A minimum of two short courses per year (bring specific questions/problem areas to each new short course)**
3. **Practice, practice, practice!!**

   Pick on organ or area/vessels/small part and ultrasound all routine surgical procedures (spays/neuters - with permission) for 5 minutes for each area for a minimum of 3 to 4 weeks.

   Create a *checklist* to ensure the entire abdomen is covered to build a normative data base.
4. **Consistent examinations no matter what. Create an *abdominal road map and stick with it!***
5. **Shared experience. Find another veterinarian that shares the same passion for learning ultrasound. Journal Club, Book reading, VIN reviews, etc., (should meet weekly to begin with).**



"Improved ultrasound technology and increased clinical applications for ultrasound have resulted in the use of ultrasound as an important imaging modality in many disease processes in veterinary medicine. The affordable cost of ultrasound equipment today has resulted in a tremendous increase in the use of ultrasound in private practice. Sources of error in imaging and interpretation of ultrasound are numerous and artifacts and pitfalls of ultrasound must be recognized by the sonographer to prevent misdiagnosis and mismanagement of our patients."

Paul M. Kaplan, DVM, Guest Editor
Problems in Veterinary Medicine, Ultrasound
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a maximum depth between 8 and 10 cm, but the near field axial (or y) resolution (ability to differentiate two adjacent structures from each other) increases, (**Figure 3**). Small curved transducers have a small area of skin contact (footprint) and is sector or pie shaped in the image they produce. Some probes produce a wide angle imaging beam (105 degrees) with the standard being 90 degrees. Linear (rectangular images) transducers can be used for abdominal imaging, but are not of any value in cardiac imaging. Linear transducers produce the best overall resolution because the crystals, being arranged in a line, do not diverge and interpolation at depth does not occur. Whereas, curved array or phased array transducers have beam divergence at depth and some interpolation takes place between adjacent lines of US information.

The resolution of the transducer is dependent upon the duty factor of the transducer or the amount of ultrasound pulses emitted per unit time. Axial resolution is dependent upon the pulse length or time a transducer is "on" and emitting an ultrasound pulse or wave. The axial resolution improves, as the actual pulse length is small so that structures next to each other along the ultrasound beam axis can then be resolved as long as they are bigger than the pulse length. Typical axial resolution by today's standards is around 100 µm or 0.1 mm. The lateral (x) resolution of a transducer is dependent upon the width of the piezoelectric crystal and refers to the ability of resolving two different structures adjacent to each other or perpendicular to the beam axis.

Mechanical sector transducers typically have two to three crystals that rotate within the transducer. Array transducers are electronically steered. Once the voltage impulse in the transducers has been produced by the reflected ultrasound waves, an analog to digital conversion occurs and then the signal is displayed in the image according to the depth processed for a given signal.

FATAL ASSUMPTIONS: Several assumptions go into making the assignment of ultrasound waves at depth and thereby the final image. The first is that the returning ultrasound wave is in fact a direct reflector from the original ultrasound pulse (not a second or third pulse). Second is that the speed of sound in the tissue is a constant (1540 m/sec). This average is an assumption and even though the differences between velocity of ultrasound in different tissues are small, there are differences and if these differences are extreme enough, erroneous depth information can be displayed which are called beam propagation speed errors, (**Figure 4**). Additionally, the machine assumes that there can be no side lobes or multi-path return possibilities (see artifacts) and in fact a straight out and back is the only possible path of return.

Ultrasound Image Fine Tuning: Driving the Ultrasound Machine for Dummies - Just press the buttons!!

Within the process of learning how to drive an ultrasound machine, one has to become familiar with the different knobs and buttons and how to fine-tune the image, (**Figure 5**). Making an image look good is what takes time and patience, a steady hand, a good technical assistant (that has patience with you while you tweak all of the knobs) and a cooperative patient. The goal is to obtain the best resolution of the area or organ in question for the x, y and z imaging planes, (**Figure 6**). There are a number of basic controls that one needs to familiarize themselves with and their location on the ultrasound machine. Each of these controls typically are displayed somewhere on the image (exact position is dependent on the manufacturer). All of these must be mastered in order to create high quality images. Make sure that there is the appropriate skin contact and remember that there are not going to be perfect imaging patients all of the time. Re-application of ultrasound gel and/or alcohol will happen multiple times during an exam. A fat Rottweiler can be a nightmare to ultrasound and you are probably better off with abdominal radiographs and a selective ultrasound evaluation based on your radiographic findings. ALWAYS start with your highest frequency transducer setting and maximize the penetration capabilities prior to shifting to a lower frequency setting.

First, after turning on the machine and entering the patient data, one needs to engage the automatic presets for the specific probe (annular, curved or linear array, **Figure 7**) that have been set up specific to the abdomen or cardiac study. The primary differences are that in an abdominal study, there will be more shades of gray (long gray scale or enhanced dynamic range) and there will be a higher degree of persistence or frame averaging when compared with a cardiac study. Additionally, when the screen is viewed the animal's head will be on the imager's left when viewing sagittal images. In the cardiac study, the persistence is set extremely low or completely off so that you have a high number of frames per second. Also, in the cardiac study you will engage a short gray scale or a high contrast image and the head of the animal will be on the imager's right when evaluating long axis images.

Second is the ability to switch back and forth between various frequencies of the multifrequency transducer or between transducers if a variety of transducers are available. Usually, beginner machines are sold with a single broadband transducer that has multifrequency capability. Making sure you know where the button is to change the various frequencies of a multifrequency transducer (standard equipment on ultrasound machines) is critical. You should become familiar with the depth at which each frequency is "maxed out" so that you do not over adjust the TGC curve (see below) or the overall gain as both of these are post-processing types of manipulations that basically increases the "brightness" to each pixel element of the picture or field of view. A standard small foot print, curved C8-5 (broad band frequency technology) will max out the 8 MHz band of the transducer at around 8 cm. This means that the next change needs to be a shift in frequency to the middle MHz frequency as the depth increases and ***not*** increasing the overall gain. If you have not reached the standard depth you would expect for the resolution portion of the multi-frequency transducer, then one should suspect a reason for hyperattenuation of the ultrasound beam. Some examples would include steroid hepatopathy or peritonitis associated with pancreatitis.

Third, one needs to be able to control the depth of the field of view. The area of ***interest*** (e.g. the left kidney or spleen) should take up about 60% of the entire field of view. On the left side of the image, there will be cm marks so you can tell your depth and also the depth (cm) will be displayed somewhere on the screen that is manufacturer dependent. Your non-dominant hand (the one without the transducer) should be on the freeze button at ALL times, but should also be ready to make field of view or depth and focal zone shifts. These two changes go hand in hand. Never assume the machine is doing the work for you. One can also adjust the size of the image (sector width) or with the newer linear probes expand the lateral limits with a partial sector type technology. As the sector width ultimately impacts frame rate, there is a trade off and one needs to balance a relatively high frame rate (20-40 Hz for the abdomen) with an appropriate sector width.

Fourth, one needs to control the overall brightness of the image. This has to do with the overall gain (typically a rotary dial with a "B" for B-mode brightness), the time or depth gain compensation curves, the amount of acoustic power or intensity "driving" the ultrasound transducer. These latter two may be two different knobs on the ultrasound machine. Typically, one keeps the acoustic power at 100% and varies the intensity. However, manufacturers may use these two terms as synonyms, which they are not. There will be at least one knob that you can increase the overall GAIN of the ultrasound transducer and make the image appear whiter or brighter. This gives one the false impression that you are improving overall image quality with a pre-processing (prior to formation of the image) type of adjustment. However, increasing gain is not the only answer

to improving an ultrasound image. It is in fact the last resort in my mind. There is a large percentage of information on the ultrasound screen that is artifact and by increasing the gain, all one is doing is increasing the artifact. The gain amplifies the signal from all areas imaged in an equal fashion. If you remove the transducer and place it on a phantom or on a homogeneous structure, one can see the increase in signal, but also there is an increase in noise that takes place at the same time. There comes a point where the noise gain exceeds the signal gain and the overall image quality is decreased. Therefore, one should never operate the gain above the 70%. An alternative to using the overall gain is to use the TGC or time gain compensation curve. This is a series of knobs that can be used to amplify signal from the far field while diminishing the near field reflected echoes. This creates a more homogeneous image. One of the easiest places to see the effects of the TGC and overall gain is using a homogeneous phantom (that can be created using Jell-O within an old intravenous fluid bag or a true ultrasound phantom) or imaging a normal liver in a large dog, such as a greyhound.

Fifth, is the use of the focal zone. The focal zone narrows the beam in the z-plane of the ultrasound beam. The focal zone can be seen on the image as a triangle or symbol of some form and typically is moved up and down the image as you would change the depth. The track ball or a specific know can be used to change the focal zone. Usually you want to place the focal zone at the level of the area of interest or just beneath the area of interest (**Figures 8**).

In summary, the x-resolution is defined by the pulse duration, a function of the MHz of the transducer so that the higher resolution transducers have a shorter pulse duration and thereby can distinguish smaller parts that are closer together. The y-resolution is defined by the line density which is usually at the highest setting. A linear transducer will always have the best y-resolution because of the rectangular format of the ultrasound beam and the lack of beam divergence as seen with the curved probes. The z-resolution is determined by the thinnest part of the US beam which will always be at the focal zone.

A comment regarding the sector width (90 vs. 105 degrees), image depth and multiple focal zones. For abdominal imaging, a standard screen refresh rate called the ***frame rate*** (defined in Hz or number of updates per second) is usually 30 o 40 Hz. No matter what, the machine is always limited by the ability to process only a certain amount of information no matter what type of machine you use (high end vs. low end). The frame rate is impacted by the three previously mentioned factors and the use of other imaging modalities such as Color Doppler, pulse-wave Doppler or Continuous wave Doppler. As you engage more and more of these features the frame rate decreases meaning that you are not looking at things in real time anymore. Focal zone, depth and sector width will also impact the frame rate. We tend to use 1 to 2 focal zones for this very reason. Also, a focal zone where 2 are engaged can not "hold" the beam as tight as a single focal zone, because the computer processor has to do more computations and thereby decreases the frame rate (**Figure 6**).

There are now three "fine tuning" knobs that can be used to help clear up the image and provide individual sonographers with their personal preferences on how an image looks. The first of these is shifting the center frequency of the transducer you are using if the transducer has mul-

Figure 4 **Propagation speed error. As the ultrasound waves travel through the area of fat (hyperechoic nodule in the deep liver), their speed is slowed to 1450 m/sec. This results in distal displacement of the diaphragm due to the longer return time for the echoes through this area of fat, that has a slower speed of sound than the average soft tissue speed of sound assumed by the ultrasound machine.**

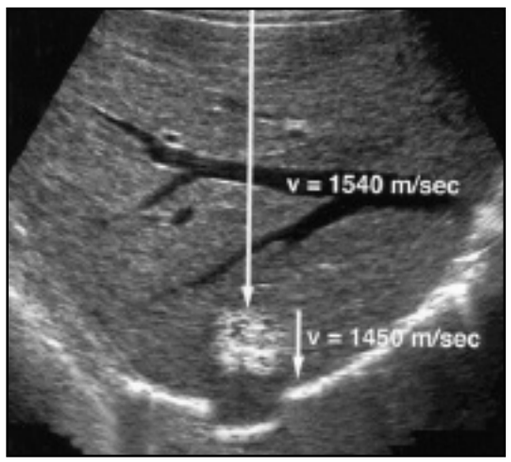
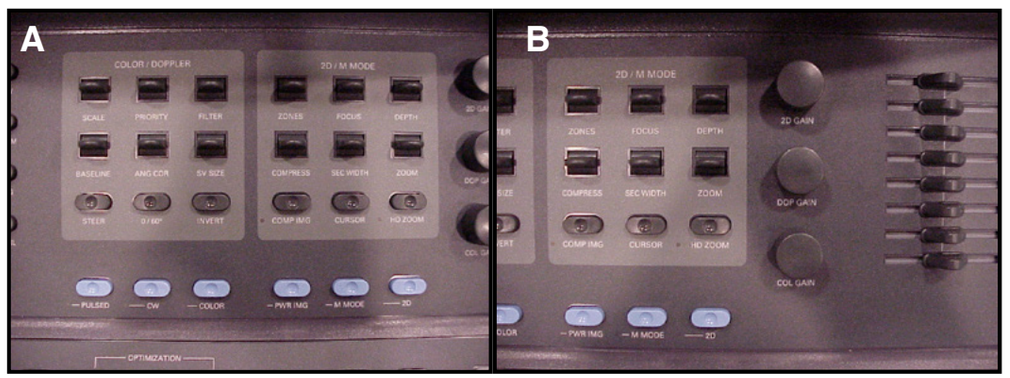


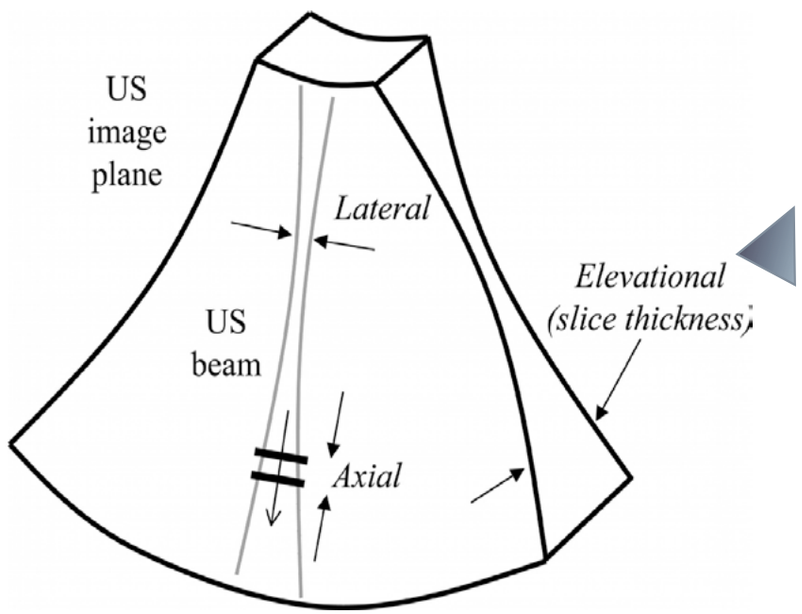
Figure 5 **(A). Instrument panel from a Philips HDI-5000. This part of the panel controls Doppler and Color settings on the right and the 2D gray scale settings on the left. (B). Continuation showing the gain and TGC curve for the Philip's control panel.**



tifrequency capability. Currently, most transducers emit a broad band of ultrasound frequencies. One can shift the transducer frequency to a higher frequency if one is interested in the near field or to a lower frequency if one is interested in the far field. The second of these fine-tuning knobs is called the dynamic range, which is defined in amount of variation in dB that is evaluated within the image. A low dB dynamic range of 40 means a greater degree of contrast within the image whereby all of the differences between the various ultrasound echoes that are returning are displayed within this range. This is typically black than versus white with very little shades of gray. This would be commonly used for cardiac imaging, however, can be helpful when bringing out the adrenal gland and contrasting it with the surrounding echogenic fat or in bringing out an isoechoic lesion within the liver. A long dynamic range results in a long gray scale and typically has a value of 65 to 70 dB. This allows for more subtle gray scale evaluation of general hepatic parenchyma. Finally, there are a variety of preset pre and post processing curves that can be applied to the image and can help improve image quality. One must remember that some dogs (particularly large ones) image poorly no matter what one does. However, even in these patients, one should be able to evaluate all of the major structures.

In summary, the check list for patient processing includes the following: selection of transducer type (dependent upon area to be imaged and size of the patient); choose appropriate preset (abdomen versus cardiac); patient preparation (clipping if using ultrasound gel or liberal application of alcohol); evaluation of the structures in question and answer any questions generated by lab work, physical examination and thoracic or abdominal radiographs. Once you have started to evaluate the structure, remember to use the appropriate depth setting, focal zone centered

Figure 6. **Schematic representation of an ultrasound beam (left) with a single focal zone. The best x (lateral), y (axial) and z (elevational slice thickness) occurs with the highest resolution transducer, the transducer perpendicular to the area of interest, the area of interest close to the surface (near field location) and a single focal zone set either at or just beneath the area of interest. If you increase the focal zones by two (right), the distance (length) of the area of focus will be increased, but the elevational thickness will also be increased thereby decreasing z-resolution.**



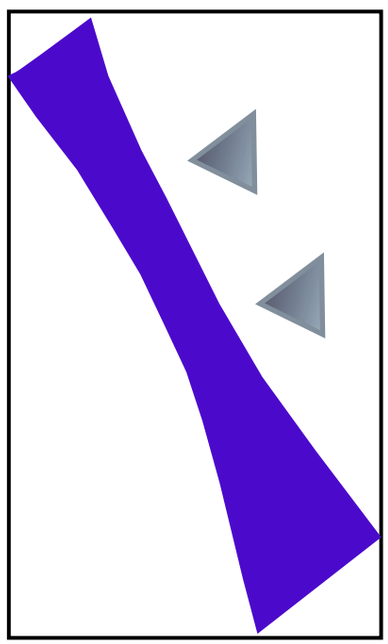


Figure 7 **Various transducer heads including a small curved array, phased array (cardiac), large abdominal curved array and a linear array (from left to right).**

on the area of interest, appropriate degree of gain and TGC, dynamic range and pre and /or post processing curves. Once these have been done, the image should be as good as it is going to get. Image degradation over time is usually secondary to contact problems. Liberal application of the contact gel, appropriate hair clips or re-application of alcohol may be necessary multiple times during the ultrasound examination. In medium and large dogs, the use of both the 7.5 and 5.0 MHz transducers may be necessary for complete imaging of the abdomen.

Sixth, contrast resolution is based on changes in the degree or way the gray scale is mapped and displayed and the number or shades of gray that are displayed. On some machines this is called "log compression" or dynamic range. The values are displayed in dB and usually have a range between 40 and 100 dB. the lower the dB number, the higher the contrast so that a black and white image is displayed with very little shades of gray as would be true for a cardiac image. With a higher dB number, a longer gray scale is displayed as would be used in the abdomen, (**Figure 9**). Typically, an average of 60 to 70 dB is used for the abdomen. This becomes somewhat personal preference as to displaying a higher contrast versus a higher latitude image. A high contrast image can be used in abdominal ultrasound for increasing the conspicuity of an "isoechoic" nodule within a solid organ such as the liver or spleen or increasing the conspicuity of a small part such as a lymph node or adrenal gland.

Seventh, there are a variety of gray scale maps and color maps that can be used to adjust the image. These maps are best evaluated using a phantom or an section of uniform organ parenchyma such as the liver (greyhound in lateral recumbency using an intercostal approach). The gray scale maps that appear the best to the sonographer can be saved as a preset for the abdomen so that this adjustment is not made each time a new patient is scanned. This is true for all of the US knobs including depth and focal zone number and placement.

Eighth, the frame rate needs to be maintained at 20 to 40 Hz for an abdominal scan. The frame rate is the refresh rate and is impacted by the depth, number of focal zones engaged, depth, addition of Doppler or color Doppler settings, sector width, etc. There is limited computer pro-

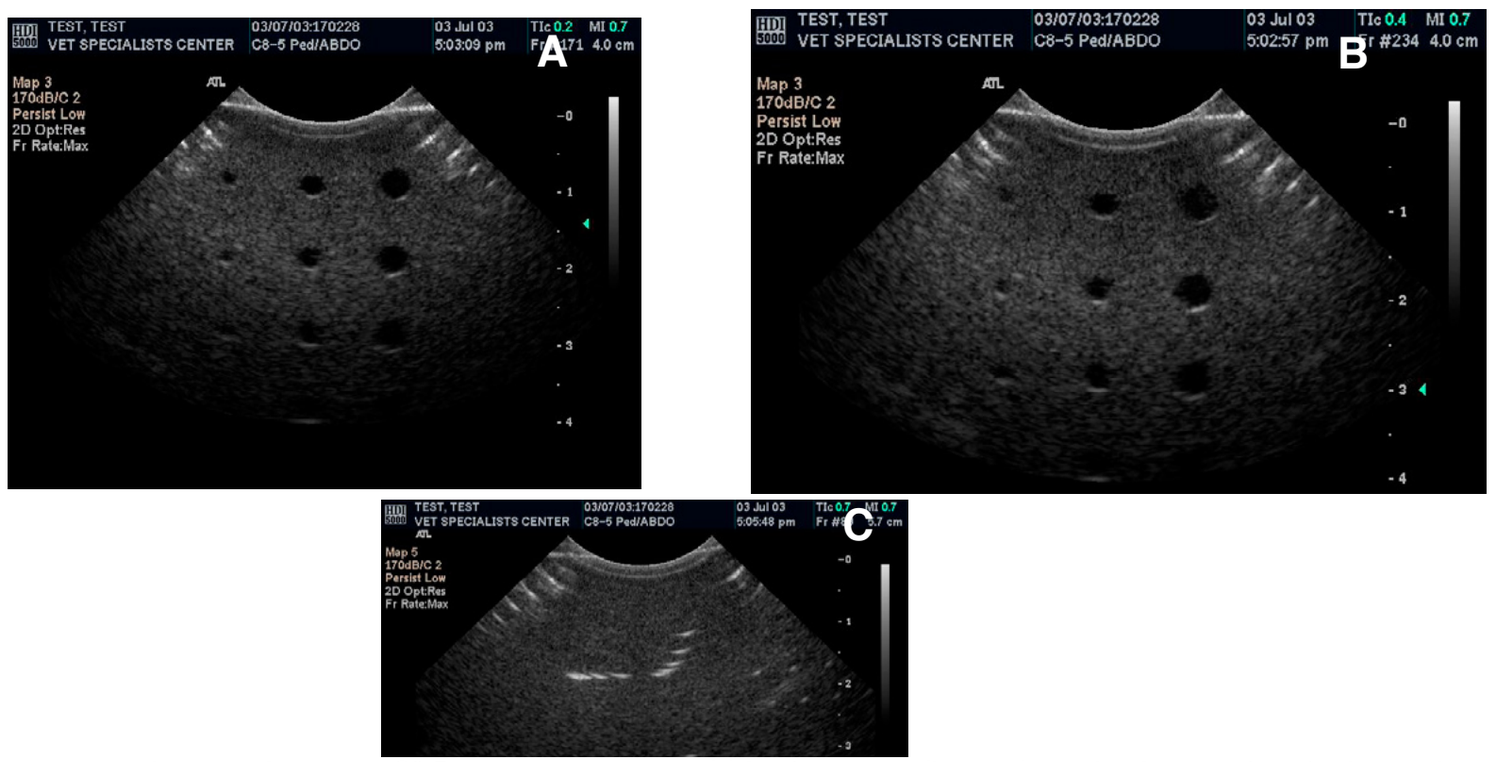


Figure 8 **Images obtained using a resolution phantom and a C8-5 curved array probe. (a) the focal zone (triangle) is set in the near field for the best visualization of the hypo to anechoic circles. (b) the focal zone has been adjusted deeper so that the deeper circles are clearer and sharper (better x and z resolution). (c) the curved probe creates a curved appearance due to interpolation of the phantom "pins" which are true circles in the US phantom.**

cessing capability and the US machine should be set so that the area of interest is visualized and the image quality is maintained, but not at the expense of the frame rate.

Ninth, frame averaging or smoothing is where there is a temporal average of the frames in front of and behind the frame that is displayed (eg, not real time, but slightly delayed). Frame averaging or smoothing will improve the overall image appearance but at the expense of true timing of image formation. In a dog that is panting, the frame averaging or smoothing should be low (as in cardiac); whereas one can increase the degree of smoothing if the dog is quiet and has a resting normal respiratory rate.

Finally, there are a number of newer technologies that are somewhat machine specific. These include image compounding ("sonoCT" for Philips) and harmonic imaging where a band pass filter is used to filter out the first harmonic or the nominal frequency and then process the second harmonic or the returning US waves with a frequency of twice the nominal frequency, (**Figure 10**). These newer probe technologies are used to increase the true signal and decrease the overall noise of an US image and are machine specific.

ULTRASOUND TERMINOLOGY

Overall, descriptions of various structures within the abdomen are related to the relative echogenicities of one structure as it relates to another. Fluid is anechoic or hypoechoic (black). The liver, spleen and renal cortex are hyperechoic. The relative echogenicities are a constant that can vary somewhat with transducer frequency, but should be used as one of the key factors for determining whether a structure is normal or abnormal. This, however, is also one of the most subjective interpretative principles used in ultrasound, so it is the one that has diminished importance in my mind (diminished, NOT of no importance!!). Just like an under exposed thoracic radiograph can mimic interstitial lung disease, an ultrasound image with the gain inappropriately adjusted can mimic diffuse liver disease as seen in steriod hepatopathy (overall increased echogenicity).

The standard structural differences in the echogenic characteristics going from hypoechoic to hyperechoic include lumen of vessels, bladder and gall bladder lumen (urine and bile), renal medulla, renal cortex, liver, prostate, and spleen.

Just as the tools of interpreting a radiographic study include evaluation for changes in: position, margin, opacity, number and shape, abnormalities within the ultrasound examination should be evaluated for similar changes in position, margination, internal echogenicity, number and shape. A simple pneumonic to remember is ***F***or ***M***ost ***C***ats ***L***ove ***S***unny ***P***laces. Starting from ***F***luid (black or anechoic) the renal ***M***edulla, renal ***C***ortex, ***L***iver, ***S***pleen and ***P***rostatic hyperplasia or inflamed peritoneal fat (white or hyperechoic).

Differential diagnostic lists should be formulated for each of the areas and organs as any abnormalities are identified. Just as there are radiographic changes that are non-specific as to a disease process, there are very little ultrasound changes that are 100% sensitive and specific to a given disease process. Tissue characterization for specific disease processes has yet to be realized in any of the diagnostic imaging arenas and appropriate next steps should be taken to establish a definitive diagnosis.

Finally, *words of warning* when one is performing general abdominal examinations (which is the appropriate thing to do). You are opening Pandora's box in that you may get more information than what you expected or bargained. In other words, multiple abnormalities may be identified that may or may not be related to the current clinical presentation. These changes all need to be processed in terms of the clinical importance of the finding (established by the differential diagnostic list) and appropriate steps at establishing an accurate diagnosis should be the next step.

Ultrasound Artifacts

The understanding of the artifacts created by different materials and media present in the abdomen presents a number of possible obstacles and opportunities. Some artifacts are important (useful) and allow the sonographer to establish a more accurate diagnosis such as mineral within a calculus resulting in distal acoustic shadowing or a truly anechoic structure with distal acoustic enhancement resulting in the diagnosis of a true fluid filled cystic structure. Other artifacts are non-useful and can impact the overall image quality and result in misdiagnoses (false positive or negatives) based on the type of artifact.

Reverberation or "ring-down" artifact (**Figure 11**) is created by two highly reflective interfaces. Reverberation basically implies that the ultrasound wave bounces back and forth between the two interfaces. If an extreme contact artifact occurs, multiple, repeatable white (hyperechoic) lines are present at regular distances from the near field (most extreme) into the far field (less apparent). The most common external interface is the external reverberation is the skin – transducer interface. The most common internal interface where reverberation occurs is within the gastrointestinal tract, such as gas in the duodenum. Sound is absorbed by fecal material, but reflected at gas interfaces. The comet tail artifact is a reverberation artifact where the ultrasound wave is trapped within a gas bubble and parts of the ultrasound echo is transmitted back to the transducer during each bounce within the gas bubble. This results in a focal thin hyperechoic line extending from the gas interface distally into the far field.

Mirror image artifacts (**Figure 12**) are non-useful artifacts that result from errors in interpretation of where the actual organ or structure is located. This occurs when the ultrasound beam interacts with a large curvilinear interface such as the diaphragm-lung border. The echoes are reflected into the liver, back at the diaphragm/lung interface and then back to the transducer. The distance traveled is then assumed to be to the other side of the diaphragm resulting in a mirror image on the distal side of the diaphragm. This should not be confused with a diaphragmatic hernia.

Refraction artifacts (**Figure 13 and 14**) also occur along curved structures that have variable acoustic impedances such as the gall bladder and urinary bladder wall or along the distal and lateral margins of cystic structures. The sound beam is refracted away from the area distal to the curved cystic structure and is thereby absent from the remainder of the image. An area void of echoes distal to the curved structure will be seen.

Side lobe artifacts (**Figure 15**) result from minor or secondary lobes of the ultrasound beam that spread in directions that are different than the primary beam. Curved structures such as the urinary bladder and highly reflective interfaces cause these side lobes to be interpreted as ultrasound waves within the primary beam, there by resulting in lateral displacement secondary structures not within the primary incident beam into the image

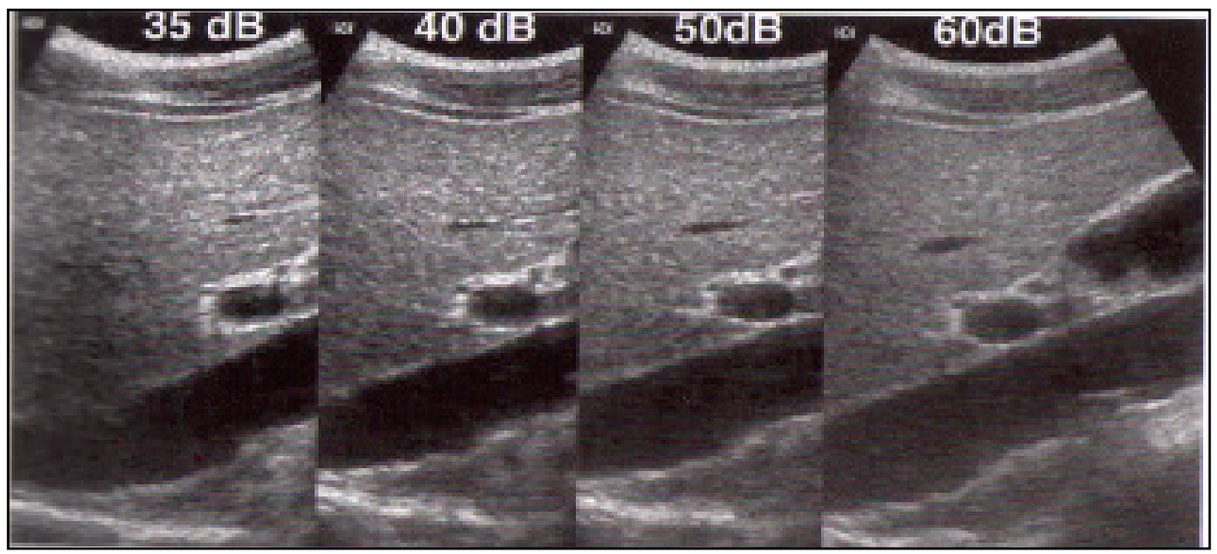


Figure 9 **Dynamic range or contrast resolution changes using a C8-5 curved array probe and a the liver. The lower dB is a higher contrast image, whereas the higher dB provides more shades of gray or higher latitude.**

of the primary incident beam.

Slice thickness artifacts is a volume averaging of the signals returned within the given slice thickness. An ultrasound beam can be focused to a certain extent, but ultimately will diverge within the far field. This beam divergence allows for more information and echoes to be placed into the beam at a given depth thereby adding information that may in fact be out of the imaging plane. If one looks at a urinary bladder in sagittal section and gets close to one lateral edge of the bladder there will be artificial echoes placed into the bladder giving one the impression of urinary sediment.

Distal acoustic shadowing can be seen in structures that have highly reflective materials such as mineralized calculi (**Figure 16**). Here, due to the reflective acoustic interface, there is a lack of ultrasound echoes in the far field distal to the mineralized structure.

Distal acoustic or through enhancement (**Figure 17**) is when there is localized increase in overall echogenicity distal to a cystic structure. This is due to the lack of attenuation of the fluid material within the cystic structure and the relative increase in speed of transmission. The most common area where this is identified is within the liver distal to the gall bladder. The liver parenchyma on either side distal to the gall bladder has a relative decreased echogenicity when compared with the increased hepatic echogenicity distal to the gall bladder.

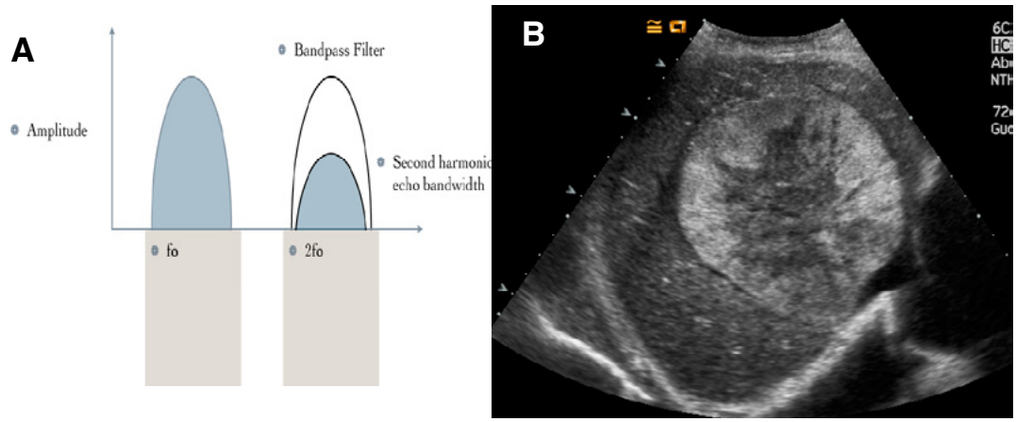


Figure 10 **(A). Harmonic imaging diagram where a band pass filter will by pass or pass over the nominal frequency and just "read" or process the second harmonic (2x the nominal frequency, fo). (B). Example of a liver mass. Note the detail of the mass, particularly at the edges of the lesion.**

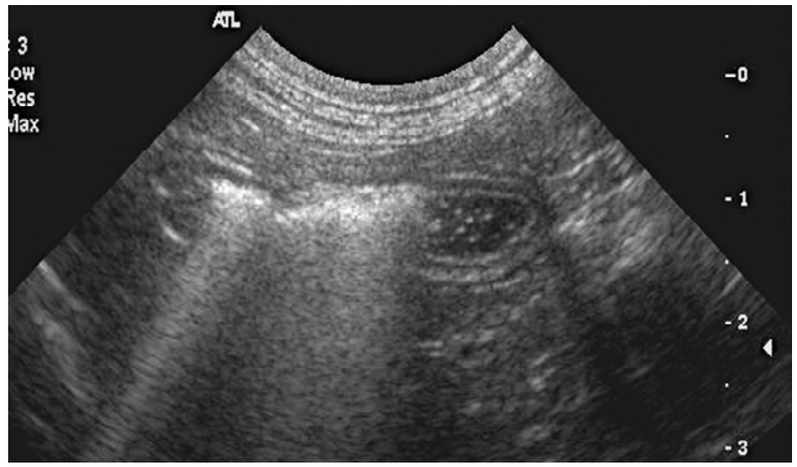
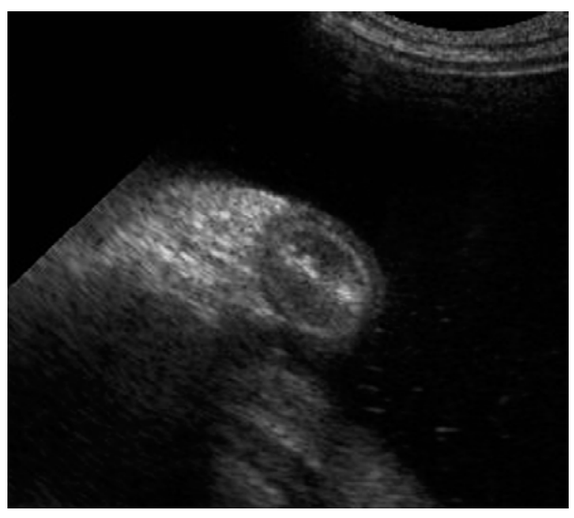


Figure 11. Reverberation artifact. See text for details.

Figure 12. Mirror image artifacts. See text for details.

Figure 13 Refraction artifact where the US beam diverges deep to a curved surface. This results in lack of US waves to adequately interrogate the area deep to the refraction artifact. This can be solved by repositioning the probe.



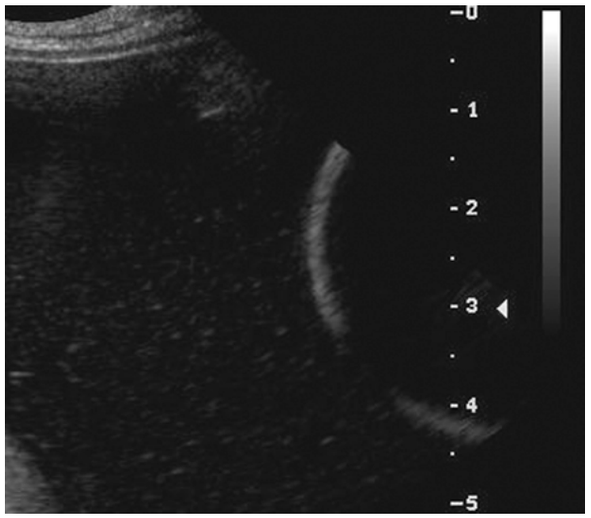


Figure 14 Refraction artifact where the US beam diverges deep to a curved surface. This results in lack of a wall in the urinary bladder in this patient with ascites. This "drop out" of the US waves creates the impression of a "hole" in the urinary bladder.

Figure 15. Side lobe artifact within the urinary bladder. See text for details.

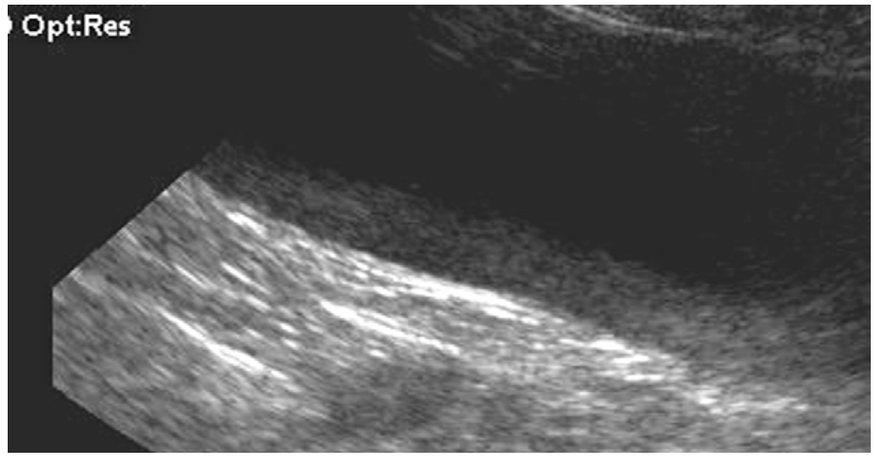
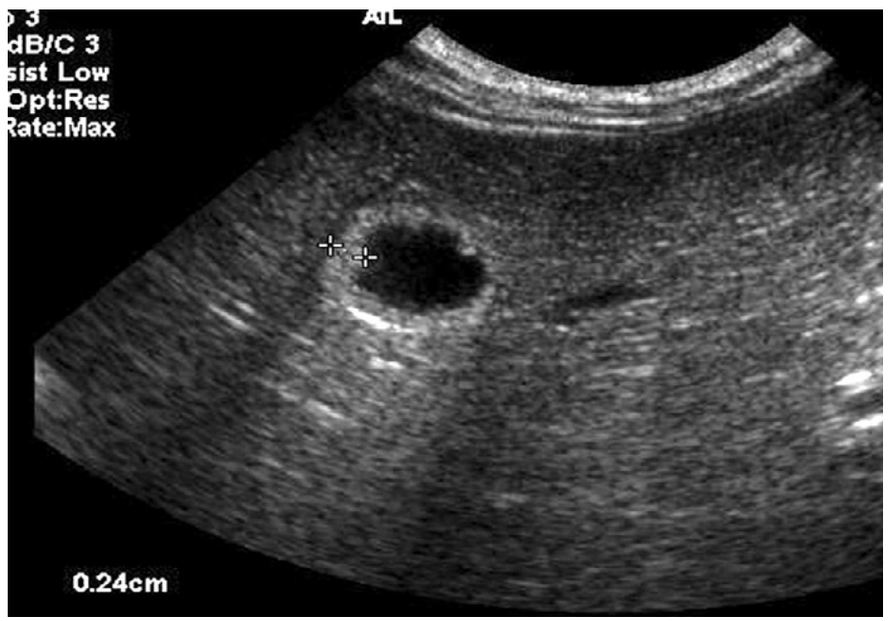


Figure 16 Distal acoustic shadowing where the US beam is totally reflected at a soft tissue-mineral interface. The black void deep to the surface of the calculus is secondary to this complete reflection.

Figure 17 Distal acoustic enhancement from the fluid in the gall bladder that does not attenuate or reflect the US beam as does the surrounding tissues. This results in a "brighter" area of signal deep to the cystic structure or in this case, the gall bladder.



A Tour of the Abdomen: Lateral Recumbency

One of the most difficult aspects of abdominal ultrasound imaging is establishing a set pattern of "exploration", especially compared with echocardiography, where well established imaging planes are preset. The goal in echocardiography then is to evaluate the heart from these imaging planes and take specific measurements. In abdominal imaging, conventional windows are not pre-established. Each structure or organ does have a characteristic echogenicity, shape, pattern, location, margin and number. Each organ should be evaluated using multiple imaging planes. Any abnormalities when identified should also be evaluated in multiple orthogonal imaging planes. The two most common methods used for evaluating the abdomen include dorsal and/or lateral recumbency. There are advantages to each. In Nyland and Mattoon, there is an excellent chapter that speaks to an imaging approach with the patient in dorsal recumbency. For the sake of these notes, we will discuss how to image the patient in lateral recumbency. Recognize, that both techniques are useful and it is probably a wise idea to be comfortable enough to do patients in both lateral and dorsal recumbency. If a particular structure or a possible abnormality requires a more complete evaluation, then rolling the patient into dorsal or an oblique position may facilitate the examination. Aspirates and biopsies are done with the animal in the appropriate recumbency that puts the area of interest the closest to the surface with the least amount of possible structures between the area of interest and the skin.

Abdominal radiographs are still the best way to "survey" the abdomen and should be used as the first line for evaluating abdominal disorders. In a study of 100 prospective patients that received both ultrasound and abdominal radiographs, it was found that both imaging modalities were complimentary, providing different types of information. Ultrasound can then be used to evaluate specific structures for specific reasons based on the radiographs. However, this should not negate a systematic complete evaluation of the patient. If needed Torbugesic® at 0.2 mg/kg IV or Dexdomitor at 0.5 µgm/kg IV can be given for sedation. **Remember, that if you do not put your probe over the lesion, you will not see it**. This is still considered an operator error so make sure that you time to do a thorough job when scanning patients in a systematic fashion.

Transducer placement and eye-hand coordination as well as getting used to making adjustments while looking at the screen takes practice. There are three basic movements of the ultrasound transducer that one needs to master. The first is a ***distance motion***. This means that the transducer moves along the skin surface in a cranial or caudal direction and thereby passes over fixed abdominal structures moving from one position to the next. It is at this time that more ultrasound gel and/or more alcohol need to be applied for better skin contact. The other distance motions include dorsal and ventral directions and oblique directions.

The second type of transducer motion is a ***non-distance, angular motion***. In this case, the transducer stays in the same position on the animal, but is angled in a cranial and caudal, or a dorsal and ventral direction. The third type of transducer motion is a ***non-distance, rotational motion*** whereby the orientation of the beam is rotated in a clockwise or counterclockwise fashion. This type of motion would be one used when moving from a right, parasternal long axis image to a right, parasternal, short-axis image of the heart for echocardiography. As the imager, you need to get used to holding the transducer with multiple positions and need to get used to moving the transducer in subtle combinations of non-distance motions; however only do one at a time. These subtle non-distance motions will result in elongation of structures at depth, such as the adrenal glands. At depth your surface motions are exaggerated due to the pendulum effect of a diverging ultrasound beam. Usually you do not have to press very hard with the probe. Tweaking the transducer can be just as much of an art form with technical expertise as playing with the ultrasound instrumentation. One should remember that more often than not, one is using an oblique imaging plane versus a true dorsal, sagittal or transverse imaging plane. On every transducer is a small point or marker that gives the orientation of the primary ultrasound beam. On the ultrasound screen, there is also a marker that identifies the mark on the transducer. Place one finger on this marker on the transducer so that you always know the appropriate image orientation and you do not get lost during the scan. For orientation purposes, when scanning in long axis (dorsal or sagittal plane), cranial is on the viewer's left of the screen and caudal is on the right, (**Figure 18**). For transverse imaging, the orientation depends on where the probe is locat-

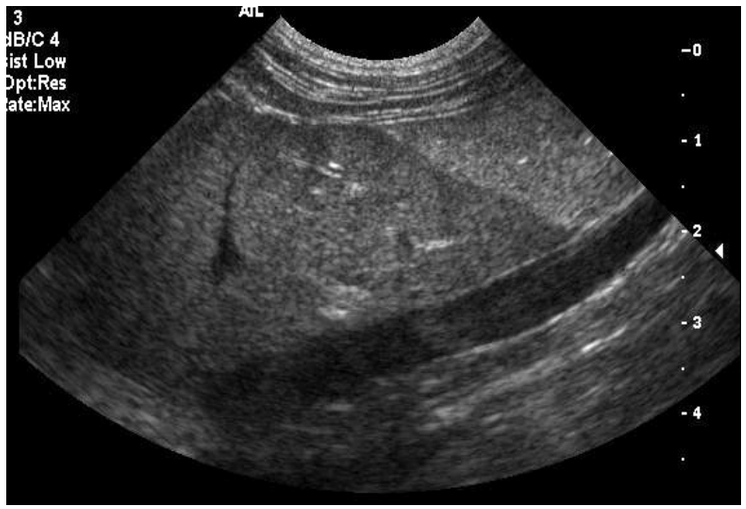


Figure 18 **Long axis orientation such that the patient's head or cranial is to the viewer's left and the patient's tail or caudal is to the viewer's right.**

ed. When positioned along the animal's side dorsal should be do the left and ventral to the right (eg, probe mark is up). When the probe is positioned along the animals mid line (as in dorsally recumbent scans), the marker should be to the animals right like you are viewing a ventrodorsal abdominal radiograph.

To start, place the animal in right lateral recumbency with the limbs facing the sonographer and the head facing to the sonographer's left, (**Figure 19**). Place the ultrasound machine to the left of the sonographer independent of the dominant hand so that the right hand that will drive the transducer. Then place the left hand on the machine so you are ready to make any adjustments.

As a starting point, image the urinary bladder in long axis. This may take you lifting the left leg of the patient particularly to get at the trigone region of the urinary bladder (**Figure 20**). Once the urinary bladder is identified, evaluate the complete luminal surface from the dorsal and transverse imaging planes. Remember that this is where the side-lobe artifact will become apparent on the electronic transducers and not to mistake this for urinary sludge or debris. To completely evaluate the caudal abdomen, one will have to shift the position of the ultrasound transducer (distance motion) from a cranial position between the legs, to a caudal

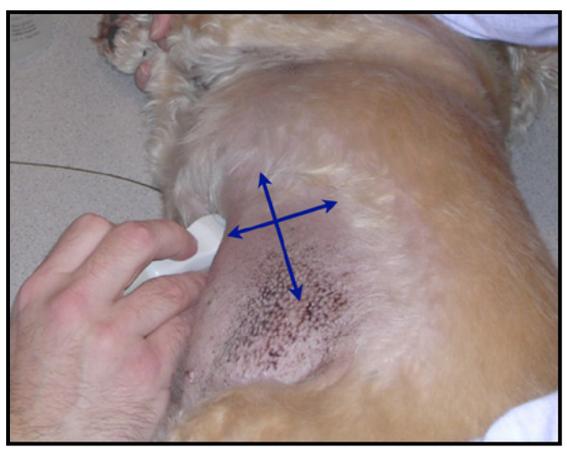


Figure 19 **The dog is initially placed in right lateral recumbency and the left side of the patient is scanned. Distance motions include moving the probe in a cranial and caudal direction or a dorsal and ventral direction along the skin.**

and ventral abdominal position. Again, lifting the animal's left leg and then evaluate in the caudal pelvic region for the prostate in the male, and the proximal urethra and uterus in the female. In male dogs that have been neutered, the prostate can be difficult to find, (**Figure 21**). It may be easier to image the bladder transversely and move the transducer in a caudal direction through the trigone to the urethra. The first structure after the urinary bladder in line with the urethra will be the prostate. Once imaged in the transverse plane, you can turn the transducer into the dorsal or sagittal plane and longitudinalize the prostate. The same is true for the uterus (rounded structure between the urinary bladder or urethra and the colon in the left of the imaging screen). However, the normal non-gravid uterus is inconspicuous and difficult to identify in the dog and rarely seen in cats.

The prostate is a bilobed gland located in the caudal abdomen/cranial pelvis/pelvic inlet just caudal to the trigone of the urinary bladder. The prostatic parenchyma normally has a uniform echogenicity, being slightly hyperechoic to surrounding tissues. In older dogs that were neutered at an early age, the prostate can be very small and isoechoic to the surrounding tissue. The prostate gland will appear as a focal enlargement of the urethra when evaluating the urethra in the long axis or transverse planes. Abnormalities in size, shape, echogenicity and position can be detected sonographically. In dogs with benign prostatic hyperplasia, the prostate gland will be hyperechoic and uniform in echogenicity, (**Figure 22**). In dogs with the suspicion of prostatic cancer, thoracic radiographs should be obtained to evaluate for pulmonary metastasis. If medial iliac lymph node enlargement is noted, then abdominal radiographs should be obtained to evaluate for metastatic spread to L6, L7 and the sacrum. Hyperechoic changes most commonly are associated with benign prostatic hypertrophy and fibrosis within the gland. Hypoechoic changes are less common, but are often associated with prostatic adenocarcinoma. Other differential diagnostic considerations for hypoechoic lesions in the prostate include intraparenchymal cysts, hemorrhagic cysts, glandular cystic hyperplasia and abscess formation. Anechoic or cavitary cysts can also be present in glands that are hyperplastic. Prostatic mineralization is feature of prostatic carcinoma although chronic inflammatory prostatic disease may also result in dystrophic mineralization of the prostate, (**Figure 23**). Anechoic or hypoechoic cystic structures adjacent to the prostate gland are consistent with paraprostatic cyst formation.

estes are uniform in echogenicity and hyperechoic with a median hyperechoic mediastinum testes. The epididymis and pampiniform plexus (**Figure 24**) are more heterogeneous and will be seen along the dorsal and cranial aspects of the testicle. Retained testes can have the same echogenicity, have a higher incidence of testicular torsions (no blood flow) or higher incidence of sertoli cell tumor development. Most testicular tumors are hypoechoic nodules and can not be differentiated based on ultrasound features along (interstitial cell vs. leydig cell vs. seminoma tumors; **Figure 25**). Features of heterogeneous echogenicity can be suggestive of several tumor types in the same testicle at the same time. Epididymitis is seen as enlargement of the epididymis and can be hypoechoic and hypervascular on color Doppler evaluation.

Figure 20 **The urinary bladder (A) and trigone region (B) from a male dog in long axis.**

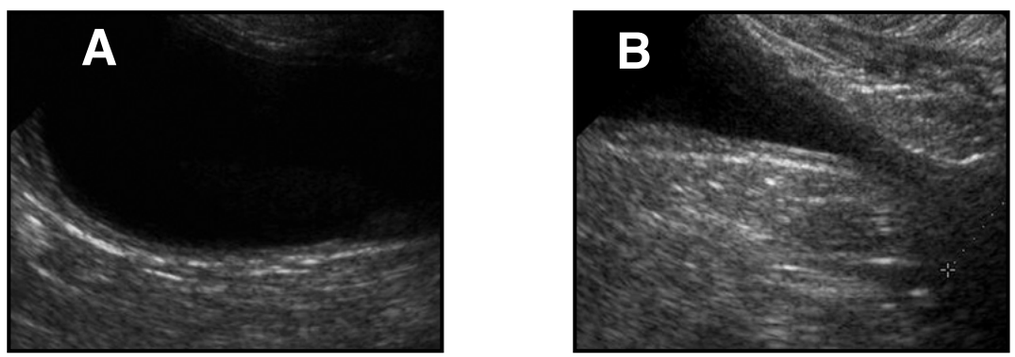


Figure 21 The ultrasound appearance from a dog that was neutered early. The prostate gland is hypoechoic and fusiform in shape encompassing the urethra.

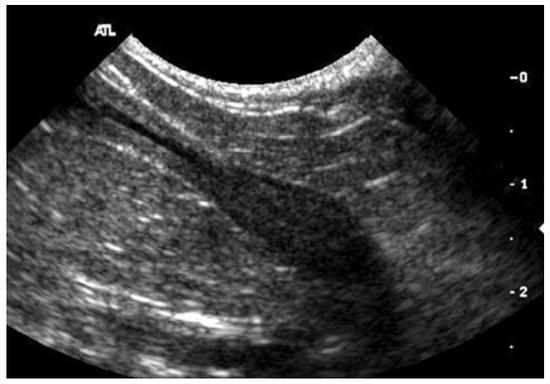


Figure 22 The ultrasound appearance from a dog with benign prostatic hyperplasia. Note the hyperechoic uniform appearance of the prostate gland.

Figure 23 The ultrasound appearance from a dog with a prostatic adenocarcinoma. There is focal dystrophic mineralization and a heteroechoic appearance.

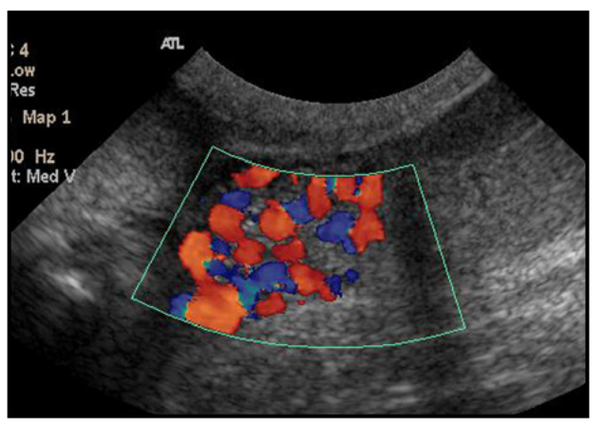


Figure 24 Color Doppler imaging of the pampiniform plexus. Note the mixture of an arterial and venous signal within a "cooling" mechanism for the testicle.

Figure 25 (A). Normal testicular echogenicity. (B). Complex heteroechoic tumor of the testicle. This was a sertoli cell tumor on histologic evaluation. (C). Simple hypoechoic nodule within the testicle that was a seminoma on histologic evaluation.

Evaluation of the testicles should be done in any intact male dog. The evaluation of the uterus can be difficult when the dog is not pregnant, not in estrus and not postpartum. Typically the non-gravid uterus in estrus will be tubular and hypoechoic and measures 3 to 8 mm in diameter. Early diagnosis of pregnancy can be done evaluating for vesicles and/or heartbeats between 16 to 20 days in dogs and 11 to 16 days in the cat post ovulation and breeding. Fetal viability late in gestation can also be assessed. Sonography provides a poor method for counting fetuses and typically a lateral and VD abdominal radiograph after ossification has occurred (day 42) should be used to determine actual fetus number and pelvic positioning if a dystocia is suspected to be present. Uterine enlargement can be assessed via ultrasound. Pyometra (hydro and mucometra) can be assessed as fluid accumulations within the uterus. The uterine walls can become thickened in chronic endometritis, in cases where open drainage to the vagina is present. Numerous tiny cysts can be seen within the uterine wall in dogs or cats with glandular cystic hyperplasia, endometriosis or endometritis.

The left leg can be released and now one is going to image the left paralumbar fossa and great vessels with the transducer oriented in a long axis direction. The easiest way to find the great vessels is place the probe perpendicular to the skin in long axis at the level of the hypaxial muscles. Then angle the probe 45 degrees away from you so that the US transducer cable is closer to you. Slowly slide the probe into the paralumbar fossa. This motion should be done looking at your hand and not at the screen. Now look at the screen; find and orient the aorta (near field) and the caudal vena cava (far field, **Figure 26**) longitudinally (along the long axis of the body or in an oblique dorsal plane). You may not be able to place the aorta or caudal vena cava in the same imaging plane (will depend on your angle of the probe). Trace these vessels caudally to the triforcation of the caudal abdominal aorta into the sacral (continuation of the caudal abdominal aorta) and the external iliac arteries. The left external iliac artery will be readily visualized whereas the other two branches may not. The way to tell if you are at the triforcation is that the aortic lumen will narrow in diameter and there will be an obtuse angle (around 160 to 170 degree) to the vessel toward the near field. The triforcation occurs at this angle, (**Figure 27**). At this branching, evaluate for the presence of medial iliac lymphadenopathy. The lymph node will lie either just in front of, on top of or just caudal to the triforcation in the near field on top of the caudal abdominal aorta or left external iliac artery. A normal lymph node will be fusiform in shape, iso- to hyperechoic to the surrounding fat and should not be thicker than a cm at it's midpoint. If an enlarged lymph node is present, freeze the image and measure it. Abnormal lymph nodes can be reactive or metastatic. This is going to be true for all abnormalities that you identify during the ultrasound evaluation. If you stop moving the transducer at this point you can see the pulsatile nature of the aorta and its caudal branches. When evaluating this area from the right side, too much compression will result in the luminal collapse of the caudal vena cava. From the right side, the lymph nodes will still be adjacent to the aorta and right external iliac artery. With a distance or non-distance, angular motion, trace caudally the caudal abdominal aorta until it triforcates again into the internal iliacs and the median sacral arteries. The hypogastric lymph node lives in this region and is one of the first lymph nodes to receive metastatic disease from peri-anal gland, anal and rectal adenocarcinomas. Typically you will not see this gland. Remember, the objective is to look in the correct area and make sure that there is not lymph node enlargement. A small lymph node means nothing. In a recent study, it was shown that spectral waveform analysis, specifically the Doppler index (systolic:diastolic ratio) of 3.22 or greater of the intranodal artery in abnormally enlarged superficial lymph nodes (including the medial iliac lymph nodes) was 91% sensitive and 100% specific for a diagnosis of a neoplastic disease versus chronic reactivity and inflammatory enlargement of the lymph node.

From the caudal abdomen, reposition the transducer in the left paralumbar fossa and longitudinalize the caudal abdominal aorta and caudal vena cava. Using the aorta, move the transducer (distance motion) cranially keeping the aorta in the middle of the screen and in long axis from your oblique dorsal plane. Occasionally sweep in a dorsal and ventral direction to image for the possibility of ureteral stones or ureteral ectasia. When the ureter becomes mildly to moderately distended, it takes on a tortuous course and depending on your probe orientation, can be located with a leftward angulation (lateral) of the probe away from the abdominal aorta. Continue cranially until the position of the kidney has been reached.

In intact females, evaluation for the ovaries can be difficult in anestrus. The ovaries are normally small structures that are

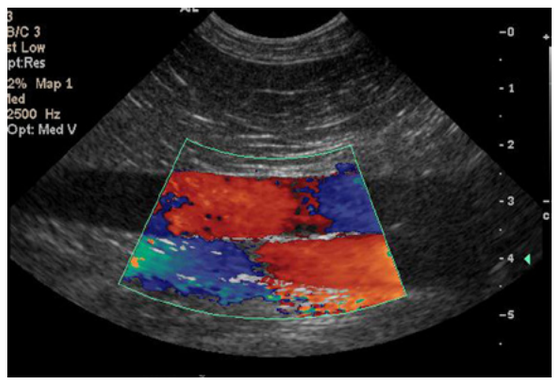


Figure 26. The aorta (near field) and caudal vena cava (CVC, far field) as viewed from the left paralumbar fossa. Color Doppler indicates flow in the aorta toward the transducer (red) and then away from the transducer (blue). The opposite is true for the CVC deep to the aorta.

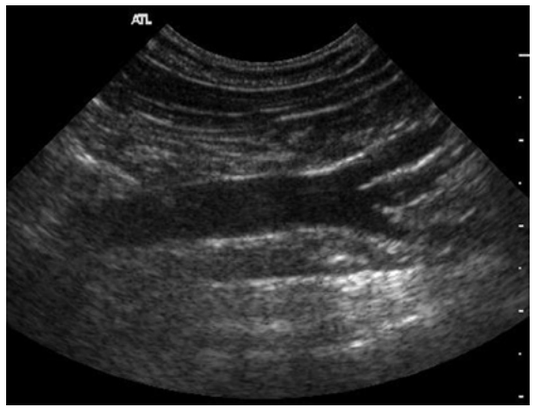


Figure 27. The aorta and the left medial iliac lymph node located at the triforcation of the caudal abdominal aorta.

Figure 28. Hypoechoic ovary with cystic follicles in a female dog just during estrus.

located caudal and somewhat lateral to the kidneys. When the dog is in lateral recumbency the left ovary may wind up just being caudal to the left kidney and in a very superficial position (within cm of the abdominal wall). Under optimal scanning conditions, the ovaries may be visualized, however, more often than not, will be only seen unless there are multiple cysts, the dog or cat is in estrus (**Figure 28**) or are abnormally enlarged. Ovarian tumors are rare and are usually heteroechoic. When one sees mineralization within an ovarian mass, a teratoma should be considered.

The next structure to be evaluated is the left adrenal gland. There are many anatomic landmarks that will help in the finding and evaluation of the left adrenal gland. The first is to ignore the renal position itself (the left kidney is mobile and you can displace it with a distance motion) and find the left renal artery coming off of the aorta (**Figure 29**). As you have the aorta in long axis, the left renal artery is the first major vessel that can be seen leaving the aorta and coming laterally into the near field (after the iliolumbar artery). Just cranial to this vessel and within the left renal artery "hook" is the first place to start looking for the caudal pole of the left adrenal gland. The renal artery forms the caudal delimiter of the search for the left adrenal gland. The left adrenal gland will not be caudal to this vessel. Rarely, there will be two renal arteries feeding the left kidney. The left adrenal gland is typically a bilobed or peanut shaped structure in small dogs, ovoid in cats, long and narrow in medium sized dogs and sometimes thin or curvilinear ("lawn chair appearance") in large dogs, (**Figure 30**). The left adrenal gland is hypoechoic relative the hyperechoic retroperitoneal fat. In certain cases one can differentiate the outer hypoechoic cortex of the adrenal gland with the inner hyperechoic corticomedullary interface. A thin hypoechoic line may be seen within this central echogenic portion of the gland representing the adrenal medulla. Once the adrenal is visualized, fine-tuning the image will consist of two motions. The first is a non-distance motion, most probably angling the transducer cranially. The second motion is a rotational motion of the transducer so that the transducer's marker is in an oblique dorsal plane with the reference marker of the transducer pointing in a dorsal and cranial direction.

If the left adrenal gland could not be identified within the retroperitoneal fat just cranial to the left renal artery, continue moving the transducer slightly cranial and sweep in a non-distance dorsal and ventral motion. These motions are not big adjustments, but we are talking several cm of directional changes in the dorsal and ventral direction keeping the transducer in a dorsal imaging plane. From the ventral surface of the aorta, you will visualize two circular arteries that originate just cranial to the left kidney position. These vessels are the celiac artery and the cranial mesenteric artery in a cranial to caudal direction respectively, (**Figure 31**) and have been termed the "cat eyes" when adjacent to each other just ventral to the abdominal aorta. These two vessels form the cranial delimiter of the search for the left adrenal gland and typically in dogs, the left adrenal can be triangulated between these two vessels as the cranial markers and the left renal artery as the caudal marker. If the left adrenal gland is not seen in this area on any initial sweeps, then look for these two cranial vascular markers and start with non-distance rotational and dorsal ventral angular motions (slight) to find the left adrenal gland. In dogs with Addison's disease the left adrenal can be difficult to

Figure 29. **The left renal artery or the "shepherd's staff or renal hook" comes off the abdominal aorta around the level of L3 in a caudal direction and immediately turns 180 degrees toward the kidney. The celiac and cranial mesenteric arteries are cranial to the left renal hook.**

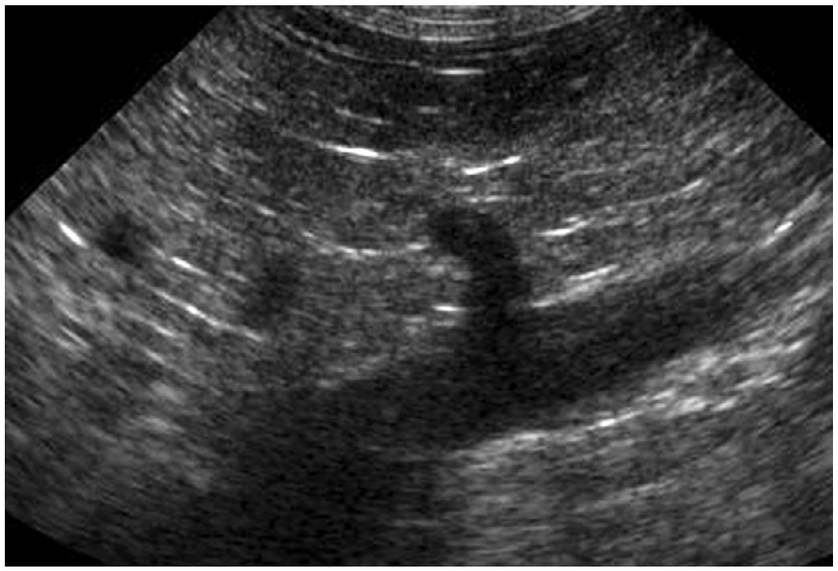
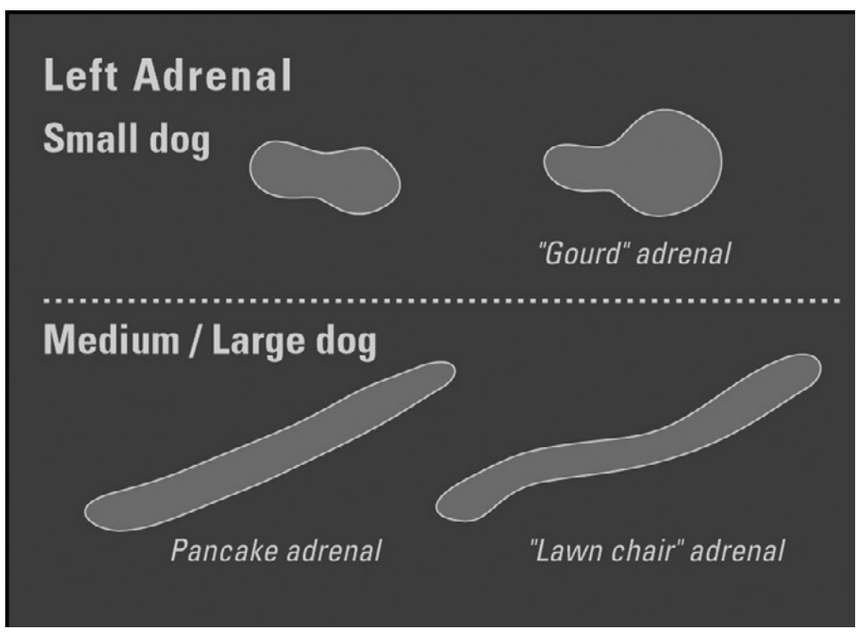


Figure 30. **Adrenal shapes seen in the dog and cat for the left and right sides based on ultrasound imaging in a long axis section.**



identify and will be very thin (< 3 mm). If one has still not found the left adrenal gland, back up and find the long axis image of the mid abdominal aorta and start again. The easiest dogs to start identifying the adrenal gland are the Miniature Schnauzer or Dachshund breeds or small dogs such as the Poodle. Practicing to identify the left adrenal gland will help you as a sonographer develop your eye-hand coordination for optimizing the image. Remember to continuously adjust the image as needed. When evaluating the medial iliac lymph nodes, the image depth may have only been 2 cm for most animals. When evaluating for the left adrenal gland, you may have increased the depth now to 2 to 4 cm.

In cats, the quickest way to find the left adrenal gland from the left is to place the transducer dorsal to the left kidney and angle ventrally with the transducer in long axis. The left adrenal gland will sit on top (near field) or just adjacent to the "cat eyes" of the celiac and cranial mesenteric vessels, which are in the transverse plane. The renal artery is not used as an anatomic vascular landmark for finding the left adrenal gland in cats (**Figure 32**).

Evaluation of the left kidney is next in line. Longitudinalize the left kidney and optimize the image so that you can see the entire kidney, (**Figure 33**). Sweep in a dorsal and ventral direction to evaluate the entire kidney from cortex to cortex. Renal size varies with patient size, however, most cat kidneys are between 3.2 and 4.0 cm in length. Sonographically, the kidney can be divided into three different zones. The outer hyperechoic renal cortex, the middle hypoechoic medulla and the inner renal sinus and pelvic area (hyperechoic due to fat in the renal sinus). The renal cortex is usually slightly hypoechoic (or isoechoic) to the liver. The normal cortical to medullary ratio is around 1.5:1. The size of the medulla can increase physiologically as a result of iatrogenic diuresis as well as slight dilation of the renal pelvis. Differential diagnostic considerations for increased echogenicity of the renal cortex includes glomerulonephritis, interstitial nephritis, acute tubular necrosis, ethylene glycol toxicity (really bright cortex) nephrocalcinosis, nephrosclerosis, lymphoma, amyloidosis and chronic pyelonephritis. Definitive diagnosis requires cytological evaluation. Focal renal changes can include cyst formation, previous renal infarct, renal metastasis, granulomas and abscessation. Severe hydronephrosis can be caused by renal obstructions secondary to a number of causes. Unilateral hydronephrosis may also be caused by ascending recurrent infections secondary to an ectopic ureter. Subcapsular fluid accumulation can be seen in trauma (hemorrhage or urine accumulation) or perinephric cyst formation in cats. Neoplastic renal disorders usually have complex sonographic patterns with internal derangement, septation and a heteroechoic appearance. Cystic adenomas can also have multiple cysts within the renal parenchyma. Congenital renal disorders consist of small hyperechoic kidneys with lack of normal

Figure 31. **The celiac and cranial mesenteric arteries form the cranial delimiter for the search for the left adrenal gland in the dog. The phrenicoabdominal vessels lie on top of the adrenal glands. (Color Doppler Image).**

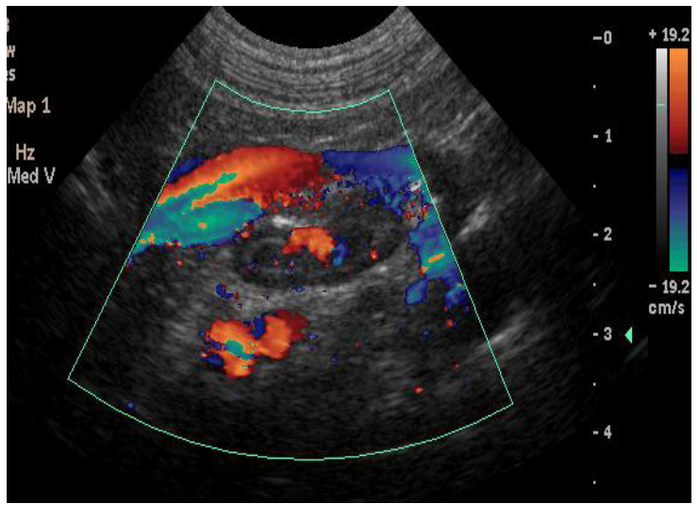
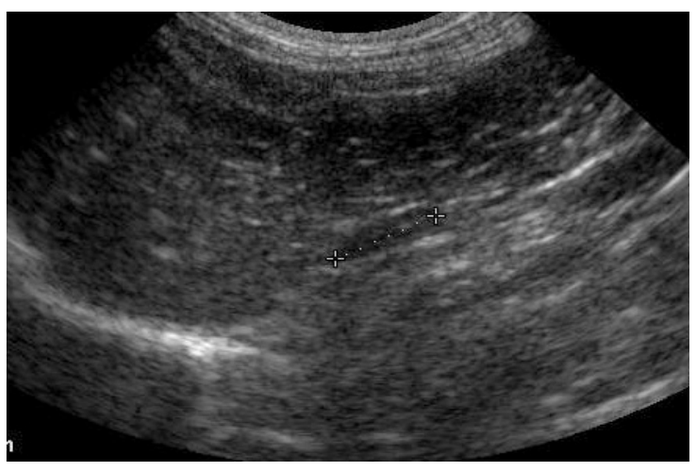


Figure 32. **The right adrenal gland in a cat. The shape is oval and the echogenicity is hypoechoic relative to the surround retroperitoneal fat. The adrenal is located between the right kidney and the diaphragm along the caudal vena cava.**



corticomedullary development or multiple renal and hepatic cystic disorders as seen in some breeds of cat (Himalayan, Persian).

From the kidney, the focus turns to the area just cranial to the kidney. The most obvious structure in this region is the spleen, (**Figure 34**). The spleen will be located in the near field, will be triangular in shape when imaged in the dorsal plane, and will have a homogeneous parenchyma with the exception of the splenic portal vessels that collect centrally along the mesenteric border of the spleen (far field). The spleen should be evaluated for changes in echogenicity. Common changes seen in the spleen include hyperechoic fibrotic or fat nodules noted along the mesenteric border of the spleen at the hilus where the vessels enter and exit the spleen. The field of view should be decreased to evaluate the spleen optimally. The spleen should be traced from a dorsal (head of the spleen) to a ventral location (tail of the spleen) using distance motion of the transducer. Once the spleen has been evaluated, reposition the transducer along the left paralumbar fossa just caudal to the last rib. The head of the spleen should be in the near field, the stomach is in the cranial aspect of the mid to far field and the colon is in the caudal aspect of the dorsal plane of the mid to far field. This area is called the splenic triangle and encompasses an initial search for the left limb of the pancreas, (**Figure 35**). Once in this position, evaluate the fat in the central portion of the image for the pancreas. If you rotate the transducer so that the splenic portal vein is in long axis, the pancreas will be located just above or below this vessel position depending upon the exact plane the transducer is located. More often than not the pancreas is located above the portal vessel. One way to identify the pancreas, which is normally isoechoic with the surrounding peritoneal and mesenteric fat is to look for two parallel hyperechoic lines that are normally only 1 to 2 mm apart. This structure is the pancreatic duct and appears within the center of the left limb of the pancreas. When evaluating structures deep within this region, it is sometimes possible to see right adrenal masses and/or caudate lobe of the liver, liver masses or perihepatic, pancreatic or splenic lymphadenopathy. Before assuming the mass to be pancreatic in origin, be sure to evaluate the right side of the patient's abdomen. Also, if evaluating a dog for a portosystemic shunt, the most common extra-hepatic shunt vessel is a left gastric. Sometimes from this position, the shunt vessel can be identified as it goes deeper toward the caudal vena cava.

The next major organ is the liver. Place the transducer in a sub-xiphoid position and angle cranial. Then sweep in a rightward and leftward direction to evaluate the various hepatic lobes. Using distance and angular motions of the transducer, increase the depth and appropriate multifrequency transducer shifts/focal zone shifts to image deeper within the abdomen. In larger dogs you may need to evaluate the near, mid and far field aspects of the liver with each area being optimized for the particular distance from the probe. Angling cranial, one should start to image normal hepatic parenchyma. Most of the liver can be imaged with the transducer placed caudal and ventral to the xiphoid process or along the ventral caudal margins of the costal cartilages. In dogs or cats with microhepatia, an intercostal approach may be necessary. For evaluating the left side of the liver, the ventral intercostal approach provides the access for evaluation of most of the liver without lung interference. The liver should be evaluated for its size, margins, overall echogenicity and major intrahepatic struc-

Figure 33. **The left kidney from a dog in long axis with the renal pelvis noted in the middle of the image of the kidney. The renal cortex is hyperechoic and the medulla is hypoechoic.**

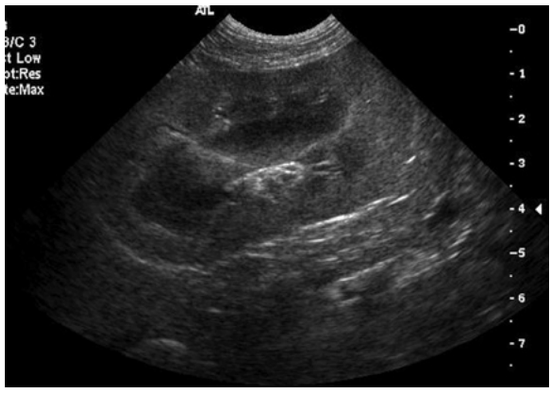


Figure 34. **A normal transverse section through the spleen in a dog.**

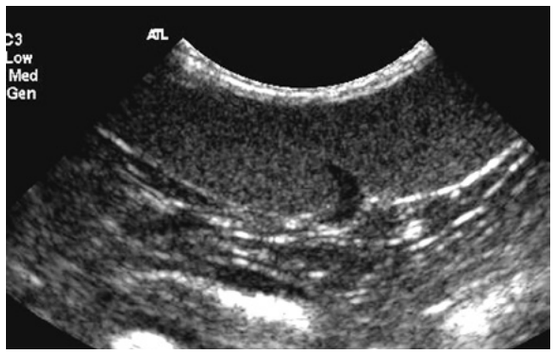
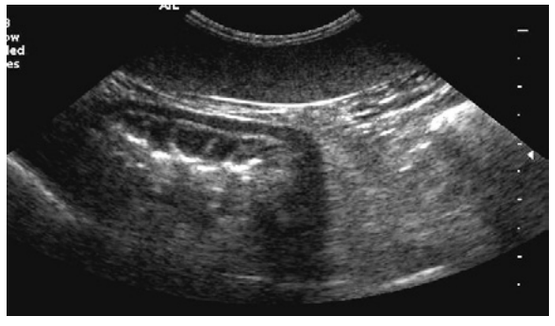


Figure 35. **The splenic triangle is the area that is formed between the spleen (superficial), the stomach (cranial) and the colon (caudally). This is the region where the left limb of the pancreas can be found.**



tures. The liver lobes are not easily differentiated unless there is a peritoneal effusion that separates the different hepatic lobes. The liver echogenicity should be slightly hyperechoic or isoechoic to the renal cortex and hypoechoic relative to the spleen. The major intrahepatic structures include the medium and large sized portal veins and hepatic veins, the porta hepatis (hepatic hilus) and the gall bladder. Portal veins can be distinguished from the surrounding hepatic veins by their origin from the central portal vessel at the porta hepatis and the brighter hyperechoic walls when compared with the walls of the hepatic veins, (**Figure 36**). The hepatic veins also can be connected to the caudal vena cava deep and dorsal within the liver. Changes in the size, shape, margin and echogenicity of the liver are indicators of hepatic parenchymal disease. Diffuse changes in hepatic echogenicity may be difficult to recognize and are subjective in nature. A diffuse increase in echogenicity can be caused by lipidosis, fibrosis or cirrhosis, lymphoma and steroid hepatopathy. Decreases in echogenicity can be seen with lymphoma, leukemia, passive venous congestion secondary to right heart failure, chronic-active hepatitis and steroid hepatopathy. In the early stages of hepatic lipidosis, a decrease in overall hepatic echogenicity may also result. Ultrasound has not realized the original intent of tissue characterization for specific hepatic disease and due to overlap in disease appearances within the liver; the final diagnosis is dependent upon hepatic biopsy. However, ultrasound is good for evaluating parenchymal changes and monitoring response of a disease process to treatment.

The gall bladder is easily identified within the right hepatic parenchyma as an anechoic ovoid structure with a neck that extends caudally. Distal acoustic enhancement is a common feature of the liver parenchyma deep to the gall bladder. The bile duct and intrahepatic biliary ducts are normally not seen in the dog. The cystic and bile duct in the cat can be traced and is usually ≤ 2 to 3 mm in diameter, (**Figure 37**). It is common to identify echogenic debris within the gall bladder that is gravity dependent. The overall size of the gall bladder can be difficult to assess and can be enlarged after fasting. Feeding a fatty meal or administering cholecystokinin and monitoring the size of the gall bladder can be used as a method for determining the presence of an extrahepatic obstruction. The most common cause of an extrahepatic obstruction is secondary to a pancreatitis with inflammatory obstruction of the bile duct and pancreatic duct as they course through the pancreas.

Now it is time to flip the patient over to the left lateral recumbent position (**Figure 38**). Starting in the right paralumbar fossa, we are going to repeat the same procedure for the caudal abdomen evaluating the caudal abdominal great vessels and the urogenital tract. Once this has been accomplished place the transducer in the right paralumbar fossa and longitudinalize the caudal vena cava. Excessive pressure can collapse this vessel so be careful that you do not mistake the aorta for the caudal vena cava. Using a cranial distance motion, move the transducer cranial along the paralumbar fossa to a position just caudal to the 13th rib. Angle the transducer cranially and identify the right kidney and the caudal lobe of the liver (**Figure 39**). By sweeping the transducer in a dorsal to ventral plane evaluate for the caudal vena cava. Just beside or cranial to the level of the kidney (but not worrying about keeping the kidney in the imaging plane, just like on the left side), gently sweep the transducer dorsally and ventrally and back again.

The right adrenal gland (**Figure 40**) is a hypoechoic structure that is more oval in smaller

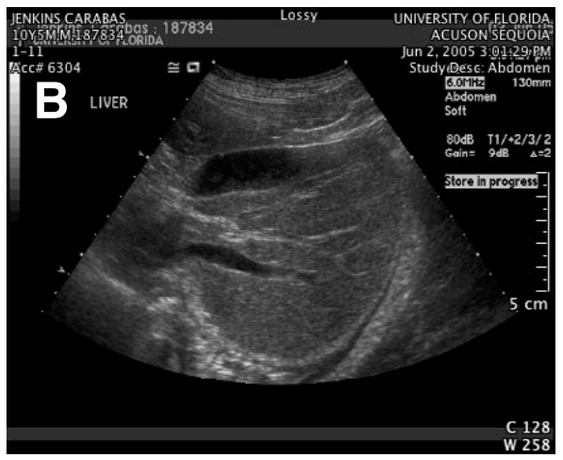


Figure 36. **Sagittal sections of the liver. In A, the linear vascular structure seen coursing through the middle of the liver with the hyperechoic walls are portal veins. In B, the tubular vascular structure at the lower left aspect of the liver image is a hepatic vein. These veins do not have the hyperechoic walls.**

Figure 37. **Sagittal section of a liver from a cat. Extending from the neck of the gall bladder is the cystic duct which measures 2.6 mm in diameter and is considered a normal finding in cats. The cystic duct and bile duct will not be seen routinely in a normal dog.**

dogs and cats and elongated in medium and large dogs just adjacent to the caudal vena cava (anechoic). Once part of the right adrenal gland is visualized, rotate the transducer 5 to 15 degrees so as to longitudinalize it, (Figure). The right adrenal gland may parallel the caudal vena cava or may extend in a craniodorsal to caudoventral direction adjacent to the caudal vena cava. Adrenal gland tumors (adenomas, adenocarcinomas and pheochromocytomas) usually distort the right or left adrenal gland anatomy and form a circular mass lesion. These lesions usually are hypoechoic. Adrenal cortical tumors may mineralize (can NOT be used to differentiate an adenoma vs. adenocarcinoma), while pheochromocytomas tend to be locally invasive with tumor thrombus invading the caudal vena cava via the phrenicoabdominal vein **(Figure 41)**. If the right adrenal gland is not visualized angle the transducer caudally, realign with the caudal vena cava and move cranial again. You may have to use a dorsal intercostal approach to visualize this area. Another possible angle that can be used to identify the right adrenal is to place your transducer along the caudal aspect of the costal cartilages around the middle of the abdomen and pointing the transducer dorsally, again looking to longitudinalize the caudal vena cava. Gently moving the transducer in a medial and lateral direction will place the right adrenal gland lateral to the caudal vena cava. The right dorsal intercostal approach is a great window for evaluating the aorta, caudal vena cava and the portal vein. In cats, the right adrenal gland will not be found at the level of the right kidney but between the diaphragm and the right kidney, still adjacent to the caudal vena cava.

This window can also be used for identifying the presence of single, extrahepatic portosystemic shunts that may be entering this location. Localization of portosystemic shunts is beyond the scope of this text; however, several caveats should be kept in mind. Typically without color Doppler the azygous vein may not be seen. If this is readily apparent, then the diagnosis of a porto-azygous shunt should be considered. Second, portocaval shunts or any shunt that enters the caudal vena cava will do so at or around the level of the diaphragm. This results in turbulence in this region and should not be mistaken for normal hepatic venous flow entering the caudal vena cava from the liver. Intrahepatic shunts are more common in large dogs and positioning has been shown to potentially collapse these shunts. Remember to make sure that you image the liver for an intrahepatic shunt in dorsal, right lateral and left lateral recumbencies, **(Figure 42)**. The porta hepatis can also be evaluated from this window. Lymphadenopathy of the perigastric or perihepatic lymph nodes can be seen.

Once the adrenal gland has been identified and measured, the right kidney and the right side of the liver should be evaluated in a similar manner as described for the left side. Once this is accomplished, place the transducer in the right paralumbar fossa and get the major vessels in the long axis again. This time move the transducer in a distance motion using a ventral direction until there is a small intestinal loop that is located in the near field that extends from the cranial aspect of the image to the caudal aspect of the image. This small intestinal loop most likely is the duodenum. The duodenum is typically located about 1/3 of the distance from the back to the ventral aspect of the abdomen **(Figure 43)**. You should be able to trace

Figure 38. **The dog or cat is now placed in left lateral recumbency with the head noted to be in the opposite direction. This is so that the holder can still maintain a good grip on the patient without you having to help. However, this means that you are driving backwards with the probe. The marker of the US image remains to the left so that cranial is till to your left as you are looking at the image. Therefore, the probe has to be rotated 180 degrees in your hand to maintain the long axis image.**

Figure 39. **Sagittal section of the caudate lobe of the liver and the renal fossa adjacent (cranial) to the cranial pole of the right kidney (caudal). In this case, the renal cortex is hyperechoic relative to the liver. A high resolution transducer was used and this is a normal finding.**

this bowel loop cranially and connect it with the stomach. Move back to the gastroduodenal angle and look for any mass lesions in the region of the body of the pancreas and then down along the duodenum evaluating for the right limb of the pancreas. The pancreas can be identified by similar features noted for the left limb of the pancreas. Although a vessel paralleling the pancreatic duct can also be identified. This vessel is the pancreaticoduodenal vein. Features of pancreatitis include: hypoehoic pancreas, duodenal hypomotility or ileus, peritoneal focal effusion, pseudocyst or abscess formation, hyperechoic mesenteric fat consistent with saponification.

The final area to evaluate is the gastrointestinal tract, and the mid abdomen. We have already evaluated the stomach, colon and duodenum. Sweeping in a cranial and caudal distance motion as well as in a dorsal and ventral distance motion is used to evaluate the entire middle abdomen. Evaluation of the mid abdomen for lymphadenopathy and focal peritoneal effusion should be the final stages of the abdominal evaluation. The mesenteric lymph nodes, (Figure) are located surrounding the cranial mesenteric portal vein (readily seen) and the cranial mesenteric artery (seen on color Doppler evaluation). Mesenteric lymph node enlargement and a small amount of peritoneal effusion can be common findings in pediatric abdomens up to the age of 10 to 12 months.

Summary

Abdominal ultrasound is a complex imaging tool for evaluation of the abdomen. It is not necessarily a good survey imaging tool and should not be used as a first choice for evaluation of the abdomen. Ultrasound is not a good diagnostic tool for ruling out disease. The abdominal ultrasound examination should be considered complimentary to abdominal radiographs just as thoracic radiographs are a critical part of the cardiac patient work up along with an echocardiogram. Abdominal ultrasound requires time and patience and proper understanding of the equipment and the physics. One should us this handout only as introductory material. The dedicated sonographer should have several textbooks of small animal abdominal ultrasound that have plenty of pictures. Differential lists can be obtained from these textbooks as can descriptions for the various types of disease processes, recognizing that the final diagnosis for tissue characterization will require cytology and/or histology.

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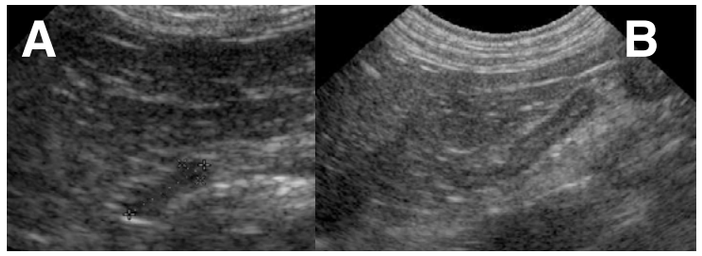

Figure 40. In the cat (A), the right adrenal gland is located along the caudal vena cava between the right kidney and the diaphragm. In the dog (B), the right adrenal gland is located immediately adjacent to the caudal vena cava at the level of the right kidney.

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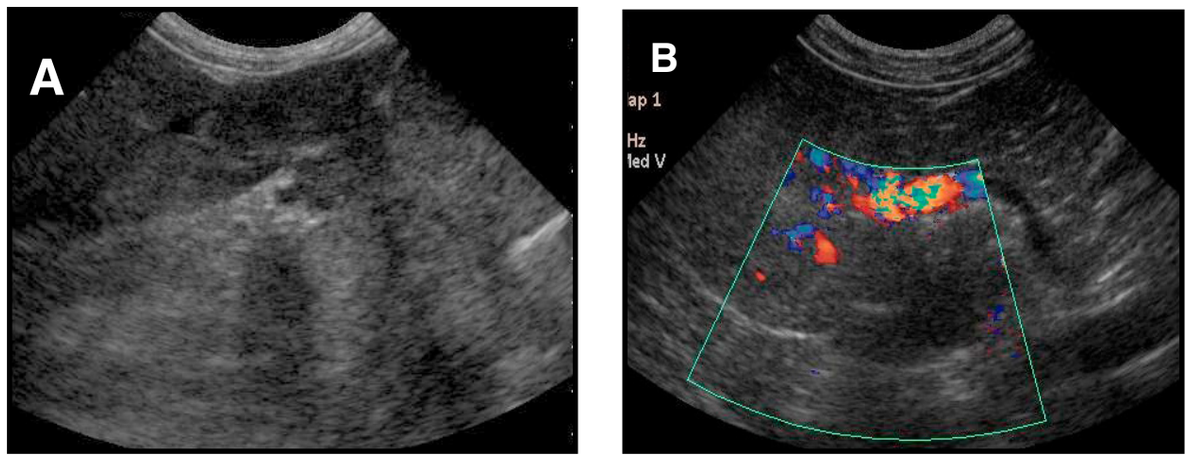

Figure 41. Sagittal images of a right adrenal tumor with caudal vena caval tumor thrombus (A) and color Doppler evaluation of a left adrenal tumor displacing the renal artery caudally (B).

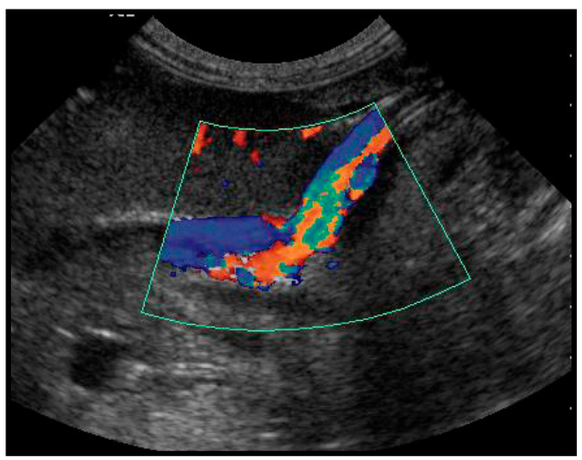

Figure 42. Extrahepatic portosystemic shunt vessel extending across the mid abdomen prior to entering the caudal vena cava (out of imaging plane).

Figure 43. The duodenum extends in a craniocaudal direction and is the most superficial small intestinal segment imaged (near field structure) in the dog. In this image, the cranial duodenal flexure is seen with the head of the pancreas being noted just deep to the duodenum at this level.