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Ultrasound as a Diagnostic Tool in Equine and Small Animal Medicine

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Since the early eighties, ultrasound has become increasingly popular in all aspects of veterinary medicine. As more practitioners become experienced in the application of ultrasound and as the cost of units becomes increasingly affordable, its use in the average large or small animal practice may become more common. As the demand for more advanced medicine in the veterinary field increases, it becomes especially important for the veterinary student as well as the practitioner, to become proficient in the various diagnostic applications of ultrasound.

Physics

Ultrasound uses very short wavelengths to produce frequencies of greater than 20,000 cycles per second, which are above the detection limits of the human ear. The same physics which apply to x-rays apply to sound waves. A wavelength is one cycle, or the distance between two peaks or two troughs in an oscillation. Frequency is the number of cycles per unit time, or Frequency = Hertz (cycles/second), and velocity is the speed of sound through the medium it passes. The distance between the peaks, or the wavelength, can be changed by increasing or decreasing the frequency or the velocity. The type of tissue being examined with ultrasound and the depth of penetration desired, determines the velocity and frequency used.

Ultrasound Units

The unit or “scanner” has a computer terminal connected to a cathode ray tube or a video screen, and a probe attached to the terminal by a flexible cable. The probe, also called a scanning unit or transducer, is a handheld piece which is placed against the animal to scan the tissue of interest. The transducer is actually housed inside the probe and acts as both a transmitter and receiver of sound waves. The unit has two main controls, depth, measured in centimeters (cm), and sensitivity, measured in decibels (dB). These settings are used to adjust the unit for different tissue depths and to get the best clarity of the image.

Transducers

A transducer is a device which translates one form of energy into another. In ultrasonics, sound waves are produced by electrical charges causing vibrations in a piezo-electric disc within the transducer. Piezo is derived from Greek, meaning ‘to press’. Piezo-electric materials are pressure electric materials such as quartz which will change shape and size under an electric field. Piezo-electric crystals are generally cylindrical in shape, 1-2 cm wide, and 1 mm thick. Electric current expands and contracts the crystal according to the polarity of the current and this vibration generates the sound waves. The crystals also act as receivers converting reflected sound waves into electricity, which in turn is converted into modified radiowaves which produce the image on the screen. Other piezo-electric substances include barium titarate, lithium sulfate, and lead zirconate. Barium titarate is most commonly used.

Transducers of various frequencies produce different penetrating power. Frequencies range from 1-25 MHz; frequencies of 3.5, 5.0, and 7.5 MHz are most common. High frequency transducers produce short, high frequency wavelengths (i.e. 7.5 MHz) and scan shorter distances with clearer resolution. Lower frequency transducers produce longer wavelengths with greater beam penetration. Although these transducers can scan at greater depths, resolution is reduced.
**Echo**

Ultrasound waves are produced by the transducer and directed toward the region of interest by holding the transducer above the area. Part of the sound waves will be absorbed by the tissue, and part will be reflected. The reflected portion produces the "echo" which is received by the transducer. Homogenous media produce many echoes, which are echogenic areas, or no echoes, which are echo free or anechoic areas. Echo poor tissues, such as edematous tissues, have scattered echoes. Solid tumors are echo rich tissues and produce many echoes at medium sensitivity. Fluid is an echo free media and appears black on the screen, while bone is echogenic and appears white. Tissues distant to a cystic region (fluid filled) will appear hyperechogenic due to large numbers of sound waves passing through the fluid.

**Imaging**

Gray scale imaging converts echoes into dots of varying shades of gray. High intensity echoes are light gray and low intensity echoes are dark gray. Echo free or anechoic areas appear black. The old units produced only four shades of gray and the image was then exposed to photographic film. This method was less accurate and more time consuming than the current units. Presently, units exist which produce up to sixty-four shades of gray. The image is then projected onto a screen, close circuit TV, or videotape and may be recorded on photographic film.

Brightness mode, or B-mode, systems display the echoes as dots using gray scale imaging and displays two dimensional cross sections of tissues. A second type of recording system, the M-mode, or motion mode, produces dots on the screen which are seen as lines. The lines represent the distance of the reflected organ from the transducer. The lines are often recorded on a strip of paper moving at a given speed. This tracing is the same as the image on the screen and demonstrates motion, such as contractions of the heart. The moving lines show the different position of the valves, and the changes in heart chamber size as the heart beats.

Current ultrasound systems use either a sector scanner, or a linear array transducer. These "real time" scanners permit viewing of motion by projecting sequential two dimensional images. Sector scanners use one crystal of a given frequency mounted on a shaft which rotates in a circle. Only a portion of the circle is open to send and receive signals in an arc. The image seen is, therefore, a sector of pie-shaped section of tissue. Continuous rotation and pulsing allows for repeated imaging, display of the area on the screen, and permits the observation of motion. Linear array transducers use several crystals mounted in a line along the length of the probe. Crystals are pulsed individually in sequence to produce a continuous scan to allow the observation of motion.

**Artifacts**

Imaging quality is best if the sound beam is perpendicular to the organ being imaged. Tilting of the probe decreases echo intensity and may cause loss of the signal. Poor contact will produce an unclear image. This can be prevented by shaving thick hair and using an adequate quantity of conducting gel to prevent any air from getting between the probe and the skin. If the sound beam is not perpendicular to the target organ, the reflected sound beam will appear wider than it is and will cause distorted images. Reverberation artifacts occur when sound hits a highly reflective surface such as air or bone. A loud echo artifact is produced distal to the bone surface and appears as an echo free area immediately following the strong echo. This is due to crystal reverberations. Lowering the sensitivity will remove the artifacts. Distortions may occur if the scanning systems are in need of adjustments, however, regular maintenance should prevent this problem.

**Thorax & Skull**

Ultrasound is less popular than radiology for examination of the skull, however, it can be useful and is frequently used in human medicine. For example, in dentistry, the depth of boundary layers and homogenicity of tissues is examined. Cerebral scanning can detect space-occupying lesions, i.e. tumors, cysts, subdural hematomas, vascular deformities, and their positions in the brain. This is achieved by locating reference structures such as the midline (falx cerebri, third ventricles, pineal gland, the lateral ventricles, and the sylvian fissure, and then recognizing their displacement by some space occupying lesions. Tumors can also be located with sector scanners by typical echo patterns, compact echo masses, or...
multiple echoes in areas with dot-like echoes. An added advantage over x-ray is that during ultrasound examination the animal does not have to be perfectly still.

Echocardiography is a useful non-invasive diagnostic technique when ECG or auscultation abnormalities are found. A window is shaved between the ribs to increase contact between the probe and the skin. Reference structures, such as the mitral valve are located for orientation. The horse is evaluated in the standing position, while small animals are often evaluated in lateral recumbency.

In the equine, the cardiovascular system is evaluated for performance characteristics as well as disease. In small animals, examinations concentrate on pathology. In both small animals and horses, ultrasound allows visualization of valves, cardiac chamber size, myocardial changes (hypertrophy), calcification, and pericardial thickening or fluid accumulation. Cardiac ultrasound can diagnose valvular thickening, vegetative endocarditis, valvular prolapse, ruptured chordae tendineae, decreased contractility, septal defects, and pericarditis.

The lungs can be viewed through the ribs in a manner similar to cardiac ultrasound. Air reflects 100% of the sound such that penetration beyond air-filled lung does not occur.8 The lungs can be seen moving next to the static chest wall. The diaphragm can be seen medial-ventrally, with intestines and liver located deep to the diaphragm.8 Normal visceral pleura is echogenic and easily seen. Lesions of the chest wall, pleural effusions, thoracic empyema, and superficial infiltrative lung lesions such as abscessation, consolidation, or infiltrative masses and necrosis of the visceral pleural lining can be evaluated.8

**Ophthalmology**

The eye can be examined with ultrasound for foreign objects, cataracts, stephylomas, retinal detachments, tumors, glaucoma, anterior chamber pathology such as hypopyon, and many other vision-related problems. Several ultrasound methods can be used in ophthalmology depending on the area being examined. Using the corneal contact method, gel is placed on the anesthetized eye and the probe is placed on the cornea.9 This produces a high quality image when examining the vitreous chamber, choroid, sclera, retina, and retrobulbar structure. The water balloon method places a small water balloon between the cornea and the probe to distance the transducer 1-2 cm from the eye which allows observation of the anterior chamber and lens. Other methods produce a number of artifacts, hence, the two previously described methods are used most often. As with other ultrasonic examinations, knowledge of anatomy is important for proper interpretation.

**The Abdomen**

Internal medicine utilizes ultrasound to evaluate many abdominal organs and cavities. Presence of fluid (ascites), organ size, organ shape, peritonitis, and internal masses can be evaluated. Peristalsis can be evaluated by looking for changes in the size of the lumen during contractions. Two other areas where ultrasound is being used more frequently is in evaluation of the liver and the urogenital system.

Because the liver is cranial in the abdomen, the lungs may obscure portions as they move back and forth over the liver. This happens because air reflects 100% of the sound waves and no sound waves can pass through to the liver. This should not be mistaken for a pathological process. White masses in the liver may be calculi or choleliths, while nodular or diffuse mottled areas indicate either neoplasia or inflammation.8 Abnormal fluid-filled structures are cysts, hematomas, or abscesses. The best biopsy sites for these structures can be determined from a frozen ultrasound picture.

Ultrasound can be used to gain valuable information about the urogenital system. The bladder, ureters, and urethra can be examined for stones, thickening of the lumen walls, or mural lesions of the bladder.8 The renal tissue changes density at the cortico-medullary junction, and the renal pelvis is seen as a dark area located in the center of the kidney. An increased central dark area with decreased renal parenchyma suggests hydronephrosis, while increased white areas suggest mineralization, such as urinary sediment or nephroliths.

Normal adrenal glands are not visible because of their small size and overlying tissues. However, adrenal enlargement, secondary to neoplasia or pituitary dependent hyperplasia, can be visualized in dogs.10 Scanning should be focused cranial to the kidneys. Downward pressure on the transducer as it rests on the abdomen can help displace any overlying gas-filled gut loops. Enlarged adrenals appear spherical or oblong and have similar or slightly increased echogenicity when compared to the renal cortex.10 In larger dogs, the adrenals are harder to find because of reduced ultrasound penetration and because of the difficulty in dis-
placing overlying bowel loops. In small dogs, higher frequency transducers may improve resolution and help when locating the gland.

Differentiation of prostatic enlargement in dogs is another area where ultrasound has proven useful. Dogs with benign hyperplasia will generally have bilateral enlargement and will produce a single echogenicity or echo density. Cysts and abscesses will appear as echo free areas and may be unilateral or bilateral. Enlargement due to malignancy may also be unilateral or bilateral but often there is more than one echo density seen.\(^7\)

**Reproductive Tract**

In both small animal and equine medicine, ultrasound is useful in evaluating normal and pathological reproductive anatomy. For equine work, the linear array scanner is useful as 95% of reproductive work involves rectal scanning. Linear array scanners are less expensive and smaller, making them easier to use rectally. Small animals are usually scanned by placing the transducer externally against the abdomen. No specific type of transducer is recommended for small animal work.

Prior to rectal scanning in horses, the rectum should be emptied and thoroughly palpated to aid in interpretation of the results. The probe is held in the palm of the hand and the sound beam is projected downward. This gives a cross sectional view of the uterine horn. When scanning, the cervix, uterine body, both uterine horns, and both ovaries should be examined so that areas of pathology or early pregnancy are not missed. The 3.0 MHz linear probe is adequate for general reproductive work, but, a 5.0 MHz linear probe is better for early embryo (less than 14 days) detection or for looking at ovaries.\(^11\) Good contact is needed between the transducer, rectal wall, and uterine surface because air in the rectum or gas and/or fluid-filled bowel loops can disrupt imaging.

Pregnancy evaluation can be done as early as 15 days post ovulation with the best results after day 17.\(^11\) Early pregnancy diagnosis is especially helpful with twin pregnancy in thoroughbreds since a high percentage of twin conceptuses terminate in abortion or death of both embryos.\(^12\) With detection at day 15-17, one embryo can be eliminated earlier allowing increased chances that the remaining embryo will survive. Early detection examination should concentrate at the areas of uterine bifurcation. The early conceptus is primarily fluid and it appears as a dark non-echoic area. The embryo sac is spherical until day 16. The embryo becomes progressively more irregular in shape as it grows and pressure from the uterine wall distorts its shape. A conceptus that is smaller than expected during a given stage suggests either an error in the predicted ovulation day, or a defective conceptus. A larger than normal conceptus may be a unilateral twin pregnancy or an early ovulation.

In both small animals and horses, other abnormalities can be located in the reproductive tract. Endometrial cysts can be found ultrasonically. Single cysts may not be significant, however, generalized cysts may be associated with increased fibrosis and decreased fertility.\(^11\) When radiology is not sufficient, fetal viability may be determined with ultrasound which allows visualization of the fetal heart beat. Uterine fluid accumulation, such as pyometra, follicular cysts, luteal ovarian cysts and uterine stump granulomas are other types of pathology which can be diagnosed with ultrasound.

**Other Applications**

Recently, researchers have used ultrasound to assess leg injuries in horses. Diagnostic ultrasound can identify the extent and relative age of injuries to tendons and ligaments in the distal limbs of the equine.\(^13\) Observable changes in tendons, ligaments, and surrounding soft tissue include changes in echoic density, margination, thickness, and internal character.\(^13\) Advantages of ultrasound include more accurate prognosis of recovery time and improved accuracy in determining when an animal may safely return to training without risking re-injury.

Ultrasound has also been useful in detecting cases of aortic-iliac thrombosis which can be missed during rectal palpation. Clinical signs of aortic-iliac thrombosis include exercise induced hindlimb lameness and weak arterial pulses to the affected limbs. The thrombus may be identified by rectally palpating firm portions of the aorta or iliac arteries, or by palpating weak pulses in these arteries.\(^14\) However, some horses that palpate normally may show increased echogenic areas in the aorta or iliac artery. Use of ultrasound in horses with the clinical signs mentioned above, may lead to earlier diagnosis of problem areas and successful treatment before there is fibrosis of the thrombus and multiple vessel disease.\(^14\)

**Safety**

Diagnostic ultrasound levels do not appear to
have any physical or genetically deleterious effects, although no long term studies have been reported. Therapeutic levels are 1000 times the levels used in diagnostic ultrasound. High therapeutic levels and prolonged exposure can produce heat in the tissues. The heat causes increased membrane permeability and increased enzyme activity which may rupture cell membranes and cause cell death. Long periods of pulses of lower frequencies can cause pressure induced micro-bubbles which burst when the pressure increases. The bubbles may also resonate violently and cause destructive energy and cavitation. 3

Conclusion

Although ultrasound has been a tool in the medical field for many years, veterinary application has been restricted to larger hospitals where units are affordable. Ultrasound is becoming increasingly affordable as newer technology, such as acoustic holograms become available on a competitive level. Even “real-time” scanning is becoming old technology. There are many other uses for diagnostic ultrasound not discussed in this paper. As affordability and demand for units increase, it is important for veterinary graduates to be familiar with ultrasound usage as a diagnostic tool in veterinary medicine and surgery.

REFERENCES