Proudly Presents:

**Diagnostic Imaging**

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Thoracic Radiographs: How to Read the ENTIRE Chest

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1. Thoracic Radiographs: Old techniques reinvented

Introduction

The goals of this lecture are to provide you with techniques of radiography and radiology of the dog and cat thorax. Thoracic radiology remains the main imaging modality in the interpretation of pulmonary and other intra-thoracic diseases. These techniques should provide the basis for production of diagnostic images and ability to derive a reasonable set of differential diagnoses.

A few key points to remember:

- Radiographs provide information NOT answers
- answers are derived from proper interpretation of the radiographic signs in concert with other clinical aspects of the case
- radiographs may lead you to ask more or different types of clinical questions
- if poor quality, radiographs are a waste of personnel time and client money
- without a systematic approach to film interpretation, the information may be on the radiograph, but goes unseen
- without a good knowledge of clinical medicine, the changes are noted on the radiographs but incorrect conclusions are reached

What is a radiograph?

Radiographs are images on photographic film by x-rays that have passed through tissue. The interaction of x-ray photons with the intensifying screen in the cassette produces photons of visible light. The light interacts with silver in the film to produce a latent image. The latent image is converted into the blacks and whites by the developing process.

The whiteness of the film is termed “opacity”. There are five radiographic opacities:

- metal
- mineral (bone)
- soft tissue
- fat
- air

The resultant opacity of the image is a function of both the object density and the thickness of the structure (which is why some end-on blood vessels can appear as opaque as a rib). The film has characteristics that allow us to image structures as varied as air-filled to metallic objects on the same radiograph. We are very dependent on proper technique, positioning, and developing for production of diagnostic images.

A radiograph is a medical legal document and needs to be diagnostic, identify the patient, date, clinic name and properly marked with patient positioning (lateral views are marked by the side closest to the cassette) and anatomical sidedness (left versus right).
2. **Thoracic Radiography**

Any “weak link in the chain” of positioning, technique or developing can lead to a nondiagnostic image. If hand developing, then the chemicals need regular maintenance. Remember to use time-temperature developing (not guesswork or “experience”). If you want consistent high quality radiographs with minimal maintenance, purchase an automatic processor. Use rare earth screens and a grid with bigger patients (> 10 cm thick) for optimal film quality.

**Positioning**
The diagnostic value of a radiograph is more dependent on positioning than any other single factor. Remove all foreign objects: collars, leashes, bandages, dirt, water or blood. Restrain the patient either chemically, physically, or both. Restraint techniques are limited by clinical concerns and patient compliance. Clever use of sand bags, rope, tape and straps minimize the radiation dose to holders. The front legs need to be pulled forward so that they are not superimposed on the chest. On VD/DV views, the spine MUST be superimposed on the sternum. On lateral projections, elevation of the sternum is often necessary so that the sternum and spine are the same distance above the cassette.

Features of the properly positioned lateral projection include:
- ribs extent equally and are parallel
- costal arches do not extend more ventral than the sternum
- ribs do not extend more dorsal than the spine (unless symmetrically)

Features of the properly positioned VD/DV include:
- sternum superimposed on the spine throughout the entire length of the thorax
- symmetrical shape to ribs
- spine is in a straight line

**Views**
Enough should be taken to provide the complete set of information. Typical studies include three views; left and right lateral and VD views. Opposite laterals provide better detection for focal diseases (lobar pneumonia and nodules). The VD view “opens” the chest providing better lung disease detection. The VD view is indicated with suspected pleural effusion.

Exceptions to the above listed recommendations are important to remember. The DV view provides a “better” view of the heart base and caudal lobar vessels. The DV view may be better tolerated by dysneic patients, especially cats. Patients should not die while we attempt a diagnostic procedure.

With severely dysneic patients:
- be judicious and efficient
- premeasure the patient before transport to radiology
- set the machine technique and gown up before bringing the patient
- position the cassette and collimate the beam before the patient arrives
- MAYBE take only one view: a lateral view is the least stressful
- MAYBE wait until tomorrow!
**Technique**

Technique refers to the balance of KvP and mAs. We want a high KvP-low mAs technique because the thorax has inherent very high contrast. A low mAs means a very short exposure time will stop the breathing motion. Remember that interpreting a film that is a little too grey is easier than one that is too black and white. A technique chart should be derived for all species and body parts imaged. The technique chart is based on the maximum dimension, usually at the level of the last rib. Inaccurate measurements invalidate the technique chart insuring improperly exposed radiographs. Technique charts can be constructed from standing or recumbent patient positioning. Be consistent. If the technique chart was made assuming recumbent positioning, then measure your patients in the appropriate recumbency.

3. **Thoracic Radiology**

**Film Reading technique**

Learn a system then use it! Make sure to look at the ENTIRE film. My system is listed below, but any system used consistently, is a good system:

Peripheral structures in a clockwise direction starting cranially:
- forelimb
- neck (soft tissues, spine and trachea)
- thoracic spine (spinous processes, canal and bodies)
- diaphragm
- stomach
- liver (and any other intra-abdominal structure)
- falciform fat pad and other intra-abdominal fat
- sternum

Mediastinum and pleural spaces

Ribs for symmetry

Heart

Lungs

Inevitable some portion of the films will be “dark” (overexposed). To best view these areas use a bright light. Alternatively use a “bob-o-scope” (two lightly clenched hands arranged in series or an empty paper towel roll!). Either of these devices limit the extraneous light, size of the portion evaluated and thereby, increase acuity of detecting lesions in the darker areas of the film. Bright lights are more expensive but fewer people laugh at you!

4. **Radiographic Anatomy of the Thorax**

**Introduction**

Knowledge of “what is normal” is essential for detection of lesions. “Normal” includes all the variations by age, breed, sex, and body condition. Radiographic variations are as clinically important as, and more difficult to learn than, normal radiographic anatomy. Remember that cats are not little dogs.
Radiological Variations
Expiration causes increased lung opacity. Decreased amount of air in the lung results in proportional increased interstitial pattern. Overlap of the diaphragm and caudal cardiac silhouette should alert you to this variation. (See comments below on obese patients)

Underexposure causes increased lung opacity. Poor penetration of the spine, especially superimposed on the scapula, should alert you to this variation. This is especially a problem with obese patients if the technique is not adjusted accordingly.

Flexion of the neck causes bending of the trachea in the lateral projection. Undulation of the trachea should not be mistaken for “dorsal deviation” secondary to a cranial mediastinal mass. Repeating the radiograph with the neck hyperextended tests the validity of the tracheal positioning due to head position.

Rotation of the chest in the lateral projection makes the heart base appear larger. Without foam support beneath the ventrum, an increased opacity in the heart base mimics left atrium enlargement and hilar lymphadenopathy.

Oblique positioning on VD/DV projections distorts the cardiac silhouette mimicking chamber enlargements.

Geriatric patients
With increased age we see a large number of changes to the appearance of the thorax. The most common change in cats and dogs is increased lung opacity. This is mostly due to combined increased bronchial and interstitial patterns. The bronchial pattern is due to dystrophic mineralization in the walls. The interstitial component is thought to be due to pulmonary fibrosis. Mineralized costal cartilages and costochondral junctions are seen in the ventral thorax. Spondylosis deformans is a radiographic change (more common in dogs than cats) associated with smooth bone formation extending (= originating) from the vertebral end plates towards the adjacent vertebral end plate. This change thought to be a degenerative of the annulus fibrosis part of the intervertebral disk and, as an isolated finding, is an incidental finding. Heart orientation often changes in older patients. The heart in older animals (more common in cats) tends to be less upright (= “falls forward”, “leans over”) than in young animals. This exaggerates the appearance of the aortic arch on both the lateral and VD/DV views.

Obesity
With increased obesity, increased lung opacity. This is mostly due to an increased interstitial pattern. This is due to relative expiration. The weight of the thoracic wall fat limits chest wall excursions and intra-abdominal fat decreases caudal movement of the diaphragm. Increase the KvP 10 to 15% compared to a normal conformation patient of the same measurements.

The heart size is apparent increased in obese patients. The smaller lung volume makes the heart appear larger (= out of proportion). This is a challenge with both the subjective
interpretation and when using cardiac measuring schemes that utilize intercostal spaces or percent of chest width.

In obese patients increased width of the mediastinum is seen. Fat infiltration in the cranial mediastinum can mimic a mass (cats and dogs). This increased width usually has parallel sides, as seen on the VD/DV view, unlike an enlarged lymph node or thymoma. In the middle mediastinum the fat adjacent to the heart may silhouette with the cardiac outline mimicking heart enlargement. Caudal mediastinal widening, between the accessory and caudal left lung lobes can be mistaken for pleural effusion.

Finally, increased distance between lung lobes or between lung and inner body wall is often noted. Fat can accumulate in pleural fissures or on the inner aspect of the chest wall mimicking pleural effusion.

**Breed variations**

Brachycephalic dogs often have smaller diameter to trachea (normal > other brachycephalic breeds > bulldogs). Additionally, they have apparently larger heart size (result of wide, shallow conformation). A bulldog is not a bulldog without a caudal thoracic hemivertebra. Dachshund and greyhound hearts measures big using the vertebral heart scale. Collies commonly have heterotopic bone formation in the lungs (mimic nodules).

**5. Some old techniques reinvented**

**How many views**

Whilst the norm may seem to be 2-views we have discovered that the 3rd view is requested so frequently that is was more efficient to always take 30 views. The reason to take both laterals was because middle lung field disease is hidden when that disease is in the dependent lung. For example, right middle lung pneumonia is NOT seen in a right lateral projection.

Similarly, in dogs with suspected dynamic large airway disease, the ability to detect collapse of the intra-thoracic portions is greatly reduced on inspiratory-phase images. So, an expiratory-phase radiograph is indicated to demonstrate collapse, or at least the propensity to collapse, of the intra-thoracic trachea and larger bronchi. This is so common that it has become our traditional 4-view thorax.

In our most dyspneic patients we either add an additional view (“5-view”) or replace the expiratory view with a lateral projection of the neck, including the nasopharynx to the level of the thoracic inlet. This view provides information on the extra-thoracic trachea, larynx, pharynx and soft palate. Seeing air-filled lateral laryngeal ventricles supports normal or laryngeal paralysis. Opaque lateral ventricles support laryngeal collapse (everted saccules) and mass-lesion diagnoses. Laryngeal inflammation and mass lesions are common in cats. In these cases the thoracic portion of the series may be normal or indicate a global thoracic wall conformation change associated with upper airway obstruction. This conformation will be discussed in the lecture.
Other views?
The reason to take other views depends on the clinical history, clinical exam findings and concurrent radiographic findings.

1. Placing barium on suspected cutaneous lesion is very helpful to evaluate possible nodules seen on routine images. Ticks, nipples, skin tags and other skin lesions can show up when located in the nondependent portion of the patient, making interpretation of nodules difficult.

2. Horizontal beam radiographs are indicated to more accurately determine the presence or absence, more accurately characterize the volume, and to diagnose the concurrent fluid component of a patient with pneumothorax. The VD view is the worst at detecting pneumothorax. Horizontal beam view is more accurate than other projections at providing volume of the pneumothorax in the nondependent hemithorax and detecting the fluid component in the dependent hemithorax. This technique requires the use of thick open cell foam pads (8-12 inches thick) to elevate the patient off of the radiology table and ability to: 1) lower, and 2) rotate the x-ray tube to a horizontal position. Both horizontal VD views are taken with the dog in right and left lateral u

3. e the cranial lung regions bilaterally. On standard VD views the scapulae are superimposed upon the left and right cranial lobes obscuring the lungs. By pulling the arms caudally, alongside the chest wall (similar to a person standing with their arms at their sides) on the VD projection, the scapulae are rotated and are no longer superimposed on the lungs. This positioning will be discussed in greater detail during the lecture.

6. Summary
Thoracic radiographs are powerful tools for the detection and characterization of lung, heart, mediastinal, pleural and body wall lesions. Through knowledge of normal variants (according to age, breed, species, and body conformation) differentiation of disease from a normal variant is possible. Through utilization of additional creative radiographic views, lesions are seen better or better differentiated from normal anatomy.
Lung Patterns Made Easy
Robert O'Brien, MS, DVM, DACVR

Lung Disease
The most important question to ask yourself is: Is the lung too opaque or too lucent? If the lung is diffusely or focally too opaque then use the pattern system (below).

1. Pattern Method
The pattern approach to interpreting lung lesions simplifies your life. For reasons of simplicity we will not discuss mixed patterns. Clinically when faced with a mixed pattern, identify the most severe (i.e. alveolar or nodular).

   a. Normal variants causing increased lung opacity
      • Expiration: mild interstitial pattern
      • Underexposure: mild interstitial pattern
      • Geriatric patients: mild bronchial and interstitial patterns
      • Obesity: mild interstitial pattern
      • Collies: heterotopic bone mimic nodules
      • Nipples, ticks, dirt, and costochondral junctions: mimic pulmonary nodules.

   b. Alveolar
      This is the most underdiagnosed pattern. The silhouette sign (=border effacement) is the hallmark radiographic sign of an alveolar disease. This manifests as the inability to see margins of the heart, vessels or diaphragm. A particular form of the silhouette sign is the air bronchogram. This is the ability to see air in bronchial lumen surrounded by opaque lung. The analogy is “black tree branching in a snow storm”. The lobar sign indicates that the disease margins are limited precisely by the lung lobe margin and the disease seems to completely fill one lobe.
      i. Causes: (HELP ME acronym)
        • Blood (Hemorrhage)
        • Water (Edema)
        • Cells (neoplasia; Lymphoma in dogs, primary pulmonary neoplasia in cats)
        • Pus (pneumonia; viral, bacterial or fungal)
        • Atelectasis (detected by the Mediastinal shift when the alveoli are Empty)

   c. Bronchial
      The hallmark of this pattern is thickened bronchi. This may be due to infiltration with inflammatory cells or edema.
      i. Causes include:
        • bronchitis
        • dogs: bacterial > allergic (eosinophilic)
        • cats: allergic > bacterial (Mycoplasma)

   d. Vascular
      Enlarged vessels the sole cause of increased opacity (see heart notes)

   e. Nodular Interstitial
      These are soft tissue nodules or masses in the lung
      i. Causes
        • Metastatic neoplasia
        • mycotic pneumonia
• granuloma
• abscess
• hematoma, hematocoele

f. Unstructured Interstitial
This pattern is the most commonly over diagnosed pattern. It is very common as a normal variant due to expiration or underexposure, and seen in geriatric or obese patients. It requires a high degree of skill to differentiate variants from true disease.

i. Causes
• Lymphoma
• nonalveolarized edema (edema in transition: forming or resolving)
• Left-side heart failure (see above)
• Vasculitis (see above)
• atypical allergic/infectious pneumonitis

So a flow diagram for decision-making regarding pulmonary patterns is:

Is there evidence of border effacement? 
No? ❯
Are the bronchial walls more opaque or thickened? 
No? ❯
Are there nodules or masses? 
No? ❯
Then... 

If yes, ➔ Alveolar
If yes, ➔ Bronchial
If yes, ➔ Structured interstitial
➔ Unstructured interstitial
Coughing Dog with a Murmur...What to Do Next?

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A dog presents with a cough and on auscultation a murmur is detected. This can be a clinical challenge: is the murmur due to heart disease, lung disease or both? Add to this puzzle is the dog with the above problems presenting in respiratory distress. By following some basic guidelines the mystery of the coughing dog can be sorted out. Age, breed and respiratory patterns can help sort out cardiac from pulmonary disease.

Clinical considerations
Dogs presenting in respiratory distress can be a challenge and be very stressful for all involved. Unfortunately they will not tell you why they are in distress. Stabilization is often necessary before a diagnosis can be determined; the patient is too fragile to be put through diagnostic tests. It is important to recognize respiratory patterns to help sort out differentials. Rapid shallow breathing patterns (i.e. low tidal volume) are usually found with pleural space disease. Dysynchronous pattern or paradoxical breathing pattern is characterized by opposing motions of the chest and abdominal wall during inspiration and expiration. During inspiration, the caudal ribcage collapses inward while the abdomen expands outward. This can occur with a variety of respiratory disorders but in the dog typically implies pleural space disease.

Pulmonary parenchymal disease can have normal to increased respiratory rate but increased respiratory effort is noted (often described as dyspnea or labored breathing). These respiratory patterns are often accompanied by specific postures. Dogs in respiratory distress often adopt an orthopneic posture--elbows abducted and neck extended. Reluctance to lie down is often seen. Also note dogs in respiratory distress are not interested in the surrounding environment or the owners; all effort is concentrated on breathing.

History is very important to sorting out the cause of the cough and labored breathing. Congestive heart failure in the dog is preceded by several days of progressive coughing and exercise intolerance. If a small breed dog, the presence of a murmur before presentation is helpful. The cough is described as a wet cough and often the pet may be seen swallowing shortly after coughing. Coughing due to non-cardiogenic causes is often chronic and described as a dry or hacking cough. Surprisingly, many pneumonia cases do not have coughing as a primary complaint. A history of vomiting or regurgitation accompanies most aspiration pneumonia cases.

Most of our patients with murmurs are middle to older age. A young patient presenting with a murmur should prompt the consideration of a congenital or developmental condition. Finding a murmur in a juvenile pet should enable the practitioner to narrow down the possibilities based on the intensity and location of the murmur, breed and age of the pet. Remember that congenital does not necessarily imply genetic or inherited.

Once a murmur has been detected, diagnostic work up, regardless of age, should include radiography and an ECG, which can be done in most clinics. Ideally an echocardiogram
completes the picture. Older dogs presenting with acquired murmurs tend to fall into two basic categories: small breed dogs and large breed dogs. For the most part, small breed dogs with a murmur have endocardiosis leading to mitral +/- tricuspid insufficiency. Large breed dogs with a murmur tend to suffer from dilated cardiomyopathy (DCM) although they, too, can have chronic mitral valve disease (CMVD). Cocker spaniels tend to be the middle breed: they can have either CMVD or DCM. Here is a general rule for small dogs: a small dog with a cough who you suspect is suffering from congestive heart failure SHOULD HAVE A MURMUR. No murmur, no heart failure. Frustratingly, some dogs with DCM do not have a murmur, even when presenting in heart failure (Doberman Pinscher is a classic example of this).

Initial physical exam may be brief if the patient is in severe respiratory distress. In addition to the observation of respiratory patterns, mucous membrane color, capillary refill time, thoracic auscultation, femoral pulse quality and rectal temperature can all be evaluated quickly. Then the patient needs oxygen therapy +/- anxiolytics.

**Initial empirical therapy**
Oxygen can be provided by a variety of means. Flow-by, face mask, nasal prongs, oxygen collar and oxygen cage are all options. Oxygen concentrators can be used instead of depleting the hospital’s supply of tank oxygen. Human infant incubators with flow-by oxygen into them, fish tanks or plastic bins can also be used for short term oxygen supplementation. Issues with these for long term use include carbon dioxide build up and hyperthermia.

Anxiolytics come in many forms. It is important to use those that have minimal cardiovascular effects. Butorphanol (0.2-0.4mg/kg) is an excellent mild sedative for respiratory distress cases. Diazepam or midazolam is also another anxiolytic medication that may help the pet to settle down and allow for more diagnostic testing. Acepromazine is not an appropriate anxiolytic in an emergency setting as it is not reversible, can last 6-8 hours and may cause issues if cardiopulmonary arrest occurs.

**Radiology of the Heart**
The assessment of heart enlargement is both subjective and objective. True to form most radiologists depend on their experience for a subjective interpretation. More objective criteria include intercostal spaces and % width of the chest. These depend on a normal full inspiratory effort, which is often inhibited by underlying pulmonary, pleural or chest wall diseases, pain and obesity. The vertebral heart scale is a useful objective system of assessing dog and cat hearts. For cats I measure the maximum width on the VD, which should not exceed 4 vertebra. For dogs the combined length and width on the lateral view should not exceed 11 vertebrae. These criteria are most useful for overall cardiomegaly. For specific chamber or side of enlargement the heart face analogy is very useful. Some misused criteria include “reverse D” shape, which is normal (gentle almond?) and sternal contact, which again is a normal finding.

In dogs, unlike cats, the pulmonary veins often become enlarged with moderate to severe pulmonary congestion. This is evidenced by disparity between veins and arteries or when
the veins exceed the width of the proximal 4th rib measured at the level where they cross this rib on the lateral projection or the 9th rib on the VD/DV view.

Radiology of the lungs
The most important premise to the conclusion that the enlarged heart is causing the lung opacity associated with cardiogenic pulmonary edema, is the interpretation of an alveolar lung pattern in the perihilar region. Often more opaque on the right than left side, this is often easily seen on the DV or VD projection. This pattern begins, often subclinically, as an interstitial pattern. The capillaries that weep with excessive hydrostatic pressure associated with pulmonary venous congestion live in the interstitial space. With increased time or severity the fluid weeps out of the interstitial space and into the adjacent alveoli. The fluid-filled alveoli and terminal bronchi illicit a cough response.

How do we interpret an alveolar pattern? The most encompassing sign is border effacement. Lobar sign, air bronchograms and loss of distinctness of borders of the adjacent heart, pulmonary vessels, and diaphragm are all examples of this effect. The regional distribution of perihilar edema seems highly specific for heart failure.

Alveolar disease in other regions is much less commonly associated with heart failure in dogs, although quite common in cats. Ventral, middle and cranial distributions are seen with bronchopneumonia. Patchy widespread alveolar disease can be due to bleeding nodules or inflamed granulomatous diseases. Blood can accumulate either dependently (like bronchopneumonia) or locally in the case of contusions. Noncardiogenic causes of edema, including cerebral edema, may be caused by head trauma, seizure or neck injury and have a specific very dorsal and caudal distribution. Other causes, including vasculitis, DIC, ARDS and toxicities are more widespread and variable.

Conclusions
Left-sided cardiomegaly causes cough by two mechanisms; 1) static compression of the left mainstem bronchus caused by left atrial dilation and/or 2) pulmonary edema associated with a perihilar alveolar pattern caused by excessive pulmonary congestion. These are both associated with left-sided heart enlargement. Noting this enlargement and the concurrent effects are important aspects of associating a heart murmur with a patient's cough. If the association seems weak, the pattern of heart enlargement or lung opacity does not fit these causes, then strongly consider a second, unrelated disease and treat appropriately.
Imaging the Dyspneic Cats: What to Do and When to Do It

Robert O’Brien, MS, DVM, DACVR

...With help from: Mauria A. O’Brien, DVM, ACVECC

The adage “cats are not small dogs” is especially pertinent when dealing with the dyspneic cat. This is a creature who is teetering on the edge of Darwin’s “survival of the fittest” cliff. Decisions regarding treatment and handling need to be made judiciously and quickly. The car ride (in a cat carrier) alone is enough to stress even a healthy cat.

**Clinical considerations**

The most common reasons for cats to present in respiratory distress are congestive heart failure, asthmatic crisis, pleural effusion/pneumothorax and neoplasia. Effusions can include transudates and modified transudates, pus and blood. Chyle is the most common modified transudate. In the cat, chylous effusion is due to heart failure, neoplasia or idiopathic. Cats in left sided heart failure can present with pulmonary edema, pleural effusion or a combination.

History is very helpful when it comes to determining the cause of the respiratory distress. Cats do not cough with heart disease; they cough with asthmatic or inflammatory airway disease. Owners will often describe seeing the cat “trying to cough up a fur ball” more frequently before presentation. Asthmatic cats can have flare ups with the changes in season (furnace being turned on) or construction in the house (dry wall dust). Cats in heart failure often have no warning signs and may present in failure with an aortic thromboembolism or saddle thrombus. Asynchronous or paradoxical breathing can be seen with any form of respiratory distress in cats whereas it usually points to pleural space disease in dogs.

Cats in respiratory distress may not have the same clinical signs as the dog will. Many present in a sphinx position with their sternum held off the cage bottom to allow for maximal chest excursion. Abdominal effort is common and flaring of the nostrils is a subtle sign of trying to “open up their airway”. Non-cardiac causes of pleural effusion are usually due to a chronic condition and the cat will adapt and show a minimum of signs until very late in the disease process.

**Empirical therapy**

Most feline respiratory distress patients need treatment before imaging can be performed. Do not try to take radiographs on a dyspneic cat; they may die on you if you do. To quickly assess for pleural fluid a FLASH ultrasound can be performed (see next lecture on “FLASH” ultrasound). In the case of pleural space disease, evacuation of fluid or air is vital to stabilization. Do not rely on pharmacotherapy (i.e. furosemide) to remove the fluid; it must be removed manually. Thoracocentesis is relatively simple and does not require a tremendous amount of supplies. If sedation is needed to perform this procedure, butorphanol (0.2-0.4mg/kg) works well.

Trying to distinguish heart failure from asthma can be difficult in the cat. Some clues may help to differentiate the two. Pulmonary crackles can be heard with both conditions but
more commonly with heart failure. With asthma there is typically an end-inspiratory wheeze and expiratory push to the respiratory pattern. Body temperature is usually lower (<99°F) in heart failure whereas it is normal to elevated with asthma. Coughing up pink, frothy fluid is heart failure until proven otherwise.

Because we wish to do no harm and sometimes the answer may not be that easy to determine initially, we often need to treat empirically. Try and use medications that will cause the least amount of harm if your suspected diagnosis is wrong. One reasonable dose of furosemide (~2mg/kg) is not likely to harm the asthmatic. Parenteral furosemide administration can initially cause bronchodilation and pulmonary vasodilation giving some relief before the diuretic effect kicks in. Recall that a patient in heart failure has poor perfusion so intravenous administration is preferred but may not be possible in the most fragile patients. The next best option would be intramuscular over subcutaneous injection. If the patient is suspected to be asthmatic, bronchodilation will lead to immediate relief. This can usually be accomplished with the use of an albuterol inhaler with a specially designed face mask to deliver the “puffs”. Albuterol, a β adrenergic agonist, has mostly β2 effects at the typical lower dose. There is the danger of β1 effects that could be deleterious for patients with heart disease but again, one dose will not likely be that harmful if the diagnosis is incorrect. Corticosteroids are the long term treatment for asthma and should not be used until the diagnosis has been confirmed radiographically. Although poorly supported in the literature, there are anecdotal reports of corticosteroids being harmful in cats with heart disease. Theories claim that it has an aldosterone, fluid-retaining effect or that they lead to hyperglycemia and increases in intravascular volume.

Although daunting, sometimes a decision must be made to take a cat’s airway, ideally before the patient arrests on its own. Having a crash cart with a variety of endotracheal tubes and laryngoscopes nearby is important. Quick induction drugs are ideal in this situation; although propofol can have serious cardiovascular depressive effects it is fast acting but short lived. Etomidate is ideal but not very practical for the general practice setting. Ketamine/valium is also another alternative although ketamine may increase myocardial oxygen demands and may not be ideal in the cardiac patient. For cats in fulminant heart failure who are coughing up the pink, frothy fluid rapid intubation and emptying the larger airways is very helpful. I find that holding the cat up by its rear end and “tea potting” it empties the airways much faster than a suction unit can. Be very careful in protecting the airway when doing this procedure and make sure the endotracheal tube does not twist around in the cat’s trachea. Know that by choosing this option you will need to be committed to ventilating for this animal until they can do so on their own.

Once a patient is stable enough, radiographs or imaging can be performed. If the patient is not stabilizing with empirical therapy, I start to worry about the “untreatable” conditions such as neoplasia or fungal disease.

**Summary**

Often our most delicate patients, dyspneic cats demand the utmost efficiency with the minimal stress during imaging. While most radiologists would appreciate 2 or 3 view imaging, the practical clinician will attempt to minimize the stress inherent in radiography
by obtaining a single view. This session will discuss radiographic views, differential diagnoses and "clinical pearls" of radiology, and advanced thoracic imaging of dyspneic cats.

**Principles of localization**
Reading radiographs accurately requires a method. One method is to quickly review the entire image looking for a recognizable lesion. This "Aunt Minnie" technique serves us so well in so many cases; we are apt to err in using this method to the exclusion of a more complete method. Any method that provides a complete evaluation of all structures is OK with me. I may start with an Aunt Minnie approach but invariably complete the interpretation with a systematic approach.

**Emergency radiography**
Don't kill the cat! Make it quick and as stress free as absolutely possible. Along these lines make sure to measure the cat in its cage. Place the cassette on the tabletop (if you are still analog!), set the technique on you machine and put on your lead all before removing the stressed patient from their little temporary home. Limit your views to those that the cat will temporarily allow, starting with a lateral, up to a lateral of the neck region as clinically indicated. A four-view series is often necessary to sort through all potential underlying regions.

**Where is the problem?**
The most important interpretation may be to isolate the primary lesion site. Is the disease pleural? Pneumothorax and pleural free fluid must be diagnosed early and confidently to speed definitive therapy. The next most important decision tree branch is; heart or lung? This can often be quite difficult. Concurrent lesions may prevent complete assessment of the cardiac silhouette and therefore our ability to assess cardiomegaly. Often I would perform a quick echocardiogram rather than perform an elaborate radiographic series or consider post-therapy radiographs just for speed of reaching the final diagnosis (see next lecture on "FLASH" ultrasound). Similarly, primary mediastinal diseases warrant an ultrasound examination early in the process for concurrent fine needle aspiration of the causative mass lesion.

**Lung lesions**
Let's say that the cat has no pleural or mediastinal disease and obvious increased lung opacity. This is where we use the pattern approach for lung lesion characterization. The twist is that the rules differ from basic dog rules. Most important is the rule of cardiogenic pulmonary edema being predominantly perihilar. In cats it may be perihilar or just as likely ventral, multifocal or solitary. In other words, it is a difficult diagnosis to confidently rule-out until echocardiography is supportive. However concurrent clinical signs, such as a murmur, hypothermia, thrombosis, and radiographic cardiomegaly (next section) are very supportive.

Pneumonia looks like pneumonia, except when we consider atypical locally prevalent causes, such as mycoplasmosis, toxoplasmosis, histoplasmosis, and blastomycosis amongst others. Primary lung neoplasia may be a large solitary mass, a la dog, but more commonly
appears as a nonconsolidating alveolar pattern. These lesions can be focal or multifocal, unilateral or bilateral, and can overlap quite readily for the patterns seen with cardiogenic edema an atypical pneumonia.

Finally, how can a discussion of the dyspneic cat be complete without a review of asthma? The two classic manifestations are the hyperlucent, hyperinflated appearance associated with the acute phase and the bronchial pattern seen in the more chronic phase. However, a normal appearing thorax is still a viable manifestation of a severely asthmatic cat. In fact asthma (or the latest “in vogue” term/acronym) is the primary rule-out for a severely dyspneic cat with a normal-appearing thorax. As a consideration, remember that infections, such as mycoplasmosis, can have a substantial immune component to the chronic bronchitis. Mineralization is seen with primary lung neoplasia and atypical pneumonia, but not with edema.

**Cardiomegaly**

Cat hearts are much more difficult to interpret than dogs. The rules of “% of the width of the chest” or “# of intercostal spaces” are extremely dependent on body condition, phase of respiration, ability to deeply inspire and concurrent medical conditions. With obesity so very common in our feline patients, a heart filling the chest may be more a manifestation of obesity than cardiomegaly. Two tools seem relevant after we discount other more variable criteria: 1) shape of the caudal heart base on the lateral projection and, 2) vertebral heart scale on the VD view. On both projections the normal cat heart is “almond” shaped. With left atrial enlargement, the caudal heart base becomes concave, instead of convex. This appearance is likened to a cashew or the normal curved contour of the kidney. Almond good, cashew bad! On the VD view the normal heart is less than 4 vertebrae wide. While this is not very sensitive, it is highly specific. Cats deposit fat adjacent to the heart, which widens the heart on the VD view and, while of a disparate physical density, often causes border effacement with the heart.

**Conclusions**

Be gentle, quick and efficient. Where is the lesion? How big is the heart? Primary lung or secondary to heart? Don’t forget asthma.

**References**

FLASH Ultrasound: Partial Scans of the Chest and Abdomen  
Robert O’Brien, MS, DVM, DACVR

We see something on a thoracic radiograph. Now what? Or the patient has pleural free fluid. Why? The dog has a murmur... how bad is the heart disease? The dog was hit by a car or has a pendulous abdomen. Do we obtain radiographs or FLASH ultrasound? This session will describe techniques, normal anatomy, and appearance of limited ultrasound scans in the thorax and abdomen.

Techniques
A limited ultrasound can be everything from a quick peak for pregnancy or free fluid to a rigorous evaluation of more complex diseases. Most commonly it serves as an adjunct to a more complete ultrasound evaluation or thoracic radiographs.

Many emergency clinicians will be aware of some of the newer “FAST” or “FLASH” scan protocols. These are limited sonographic evaluations with a particular diagnosis in mind; e.g. peritoneal or pleural free fluid. Often this is a component of a search for manifestations of a traumatized; “FAST” stands for Focuses Assessment with Sonography in Trauma. Additions to this acronym indicate the body part being scanned, hence the “t” of “tFAST” in thoracic imaging and “a” of “aFAST” in the abdomen. But, in my opinion, limited these sonographic techniques for assessment of only trauma both oversimplifies and greatly limits the utility of these types of scans. The veterinary literature is extensive with descriptive studies, but weak for prospective evaluation of the accuracy of these types of scan protocols and void of studies evaluating the same protocols for nontraumatic patients.

Abdomen
Trauma
The discussion of the first limited ultrasound scan began in the mid-90’s in the human ER in cases of blunt trauma. Ultrasound was quickly adopted as a tool to identify free fluid and guide the subsequent abdominocentesis. Peritoneal free fluid (hemoabdomen) is common, often under diagnosed by physical examination and conventional imaging, and a common cause of early death in patients with blunt trauma. The aFAST can be performed in less than 10 minutes and have high sensitivity (99-100%) and specificity (86-100%) for hemoabdomen.

Veterinary studies soon followed. Studies published in 2004 and 2009 both indicated the high sensitivity and specificity of ultrasound for the detection of free fluid in the abdominal cavity. Regardless of laterality, the greatest accumulation of fluid was in the dependent aspect of the abdomen. Ultrasound was useful as an early test of hemorrhage, prior to changes in the packed cell volume.

However, it should be noted, none of the dogs in either study went to surgery based on the ultrasound examination and therapy was based on the PCV, not ultrasound findings. It would appear that although useful for detecting fluid, the aFAST did not affect prognosis nor alter therapy.
Other diseases in the abdomen
Ultrasound is the best test for detection of free fluid. There is no doubt! It is a fast and accurate test. I can train a student to perform an ultrasound scan looking for free fluid in 10 minutes and they will be very accurate performing a limited 30-60 second exam, regardless of the cause of free fluid. And detection of free fluid is really, really important. This finding is the essence for the following surgical diseases (“BUSH”):

- **Bile peritonitis** compare fluid to serum bilirubin
- **Uroabdomen** compare fluid to serum creatinine or potassium
- **Septic peritonitis** cytology for intra- or extra-cellular bacteria
- **Hemoabdomen** compare fluid to serum PCV

Restricting the discussion of limited ultrasound in the abdomen to a discussion of the traumatized patient would be analogous to limiting the use of thoracic radiographs to only detection of pulmonary metastases. There are so many other diseases to look for! In the emergency patient there are so many other diagnoses to make with a limited scan: Fluid from any underlying disease. Pregnancy is often again a simple search. Pyometra is a very common disease requiring a limited study. Masses can be very easy. Bladder masses and stones require a quite limited scan.

However, if there is a limitation to all these limited scans it is that they are, by definition, “limited”. They are quick and often accurate, but often do not tell the complete story. Secondly they often require sophisticated sonographic skills. The better the sonographer, the better the limited scan. A 2 min scan of the abdomen performed by me is more accurate than performed by my first year residents. The better you are able to scan, the faster you can scan. Is it better to perform a limited scan in 2-3 minutes or a complete scan in 5 minutes? Of course, this question is often answered by the resources available in your practice setting. If you decide to purchase an ultrasound system, please consider intensive training to maximize that investment.

**Thorax**

**Pericardial disease**
This is a very important and very easy diagnosis that can be made with a limited ultrasound scan. Most practitioners can be taught to scan for pericardial free fluid within a few minutes. However, characterization of the disease as “tamponade” and determining the cause are often quite demanding echocardiographic examinations.

**Trauma- Pneumothorax**
Similar to the abdomen, human patient imaging led the field for developing techniques of the limited scan in thoracic trauma. In both penetrating and blunt trauma, ultrasound is an important point of care procedure for the detection of pleural free fluid (hemothorax) and pneumothorax. The discussion of hemothorax is similar to that already addressed in the abdomen; ultrasound is great for the detection of fluid. However, the discussion of the detection of pneumothorax has a few wrinkles worthy of discussion. In human patients up to 20% of patients with blunt polytrauma suffer from pneumothorax. Clinical finding may be nonspecific. Radiographs are quite insensitive, only detecting 50% of patients with pneumothorax (!). I do not find that we in veterinarian medicine are quite that insensitive
for pneumothorax. Admittedly computed tomography may be the gold standard, but, in my opinion, radiographs are very sensitive for “clinically relevant” levels of pneumothorax.

The basis for detecting pneumothorax during the limited scan of the human traumatized patient involves the “slide” or “glide” sign. This is the normal appearance of pleural irregularities (including comet tail artifacts) and pleural sliding. Lack of these findings supports pneumothorax. In one study ultrasound improved sensitivity from 62% (clinical exam) and 79% (chest radiographs) to 95% (tFAST).

Unfortunately, although there is a very nice manuscript depicting these techniques in the Journal of Veterinary Emergency and Critical Care, there is no study indicating any scientific assessment of the tFAST technique in veterinary medicine. And, even after extensive use in our clinical setting, all of our boarded faculty and trainees in emergency have rejected the tFAST as an accurate test for pneumothorax. It is neither sensitive nor specific.

Heart Failure
Perhaps even more disconcerting that with pneumothorax, are some assertions of the use of ultrasound for detection of pulmonary edema, therefore the diagnosis of left-sided congestive heart failure. A recent study indicated that a particular artifact was seen with most cases of pulmonary edema associated with heart failure in dogs. These “lung rockets” are reverberation artifacts caused by small areas of nonaerated lung. In human medicine they are caused by a large variety of primary and secondary lung diseases. Unfortunately there are no studies indicating the usefulness of these artifacts for the detection of heart failure in dogs or cats.

Are there limited scans that can be useful for the detection of congestive heart failure? In my opinion a limited scan of the left atrial region is both useful and practical. By obtaining an LA:Ao ratio in both dogs and cats, the presence of left atrial enlargement can be evaluated and factored into the entire clinical picture. This limited scan is of immense clinical utility, but can only be implemented by those with reasonably adept echocardiographic skills.

Conclusions
Limited ultrasound techniques definitely have a place in clinical veterinary medicine. They have been demonstrated as extremely useful point of care procedures in human emergency medicine. They are extremely important in the initial point-of-care workup of all emergency patients in out practice. However, the aura of descriptive ultrasound techniques has preceded good scientific evaluation. In the rush to adopt human medical techniques, we have forgotten that everything that works in human medicine does not always work in veterinary (and visa versa). Ultrasound is the definitive test for detection of abdominal, pericardial and pleural free fluid. Masses, bladder stones, and certain masses can be detected quickly with ultrasound. In trained hands, the characterization of heart disease can be performed quickly and safely. In our hands, ultrasound is neither a sensitive nor specific tool for the detection of pneumothorax or pulmonary edema.


Gastrointestinal Ultrasound: Fun and Faster than Radiographs?

Robert O’Brien, MS, DVM, DACVR

Ultrasound is becoming a widely available tool for diagnostic imaging in all small animal practices. Machines are reasonably inexpensive and training widely available. This session will discuss machine features and scan protocol considerations for abdominal ultrasonography for general small animal practices. The session will conclude with a demonstration.

Introduction

Ultrasound is a highly technical and very economically rewarding form of imaging available to all levels of veterinary practice. This presentation will cover the breadth and depth of veterinary ultrasound and discuss the economical aspects of introducing it into your practice.

Clinical Scenario

Although as vague as “ADR” or anorexia, clinical signs often point directly to an abdominal basis of disease. This can include abdominal pain or distension, icterus, vomiting or specific hepatobiliary, urinary, reproductive or gastrointestinal signs on physical exam, history or blood work. The most important decision may be, “Is this surgical or not”. More often than not, ultrasound provides the most important aspect of that answer in our clinical setting.

Normal Anatomy

Like any other form of imaging, knowledge the normal appearance of abdominal structures, including anatomical variations, is required for detection of, and differentiation of disease. There are many resources available for this, including anatomy and ultrasound textbooks. Beyond the anatomy, the sonographer must be able to acquire high quality images of the relevant abdominal structures. Errors of omission are most common that other error types, (i.e. not finding the organ or lesion is more common than misinterpretation of a particular sonographic appearance).

Surgical Gastrointestinal

Our most common emergency ultrasound procedures are to rule out a suspected gastrointestinal surgical condition. The most common diseases are as follows, in order of the ease of diagnosis (not prevalence or need for urgent surgery).

1. Intussusception

   The intussusception is a large mass lesion. It is always composed of the internal intussusceptum portion within the outer enveloping intussuscipiens. Interestingly, in 2nd and 3rd world nations, these are often not surgical, resolving merely with the induction of general anesthesia. In our caseload, these usually have an underlying cause of abnormal gastrointestinal motility, including other causes of surgical and nonsurgical conditions. The most common site is the ileocolic junction, but possible from the terminal esophagus through the descending colon. The sonographic appearance is classic, therefore relatively straightforward.
2. Foreign body
The mechanical obstruction caused by a foreign body, usually a “lucent” foreign is the most common cause of an emergency surgical abdomen in our practice. Foreign bodies run the gamut from balls, peach pits, and corn cobs to name just a few. In cats we add trichobezoar (hairballs). Sonographically these can be very easy or very, very challenging. The location often determines the difficulty, with the “high duodenal” foreign body being the most difficult. In any event the sonographic features are consistent.

The sonographic features of an obstructive intestinal foreign body form a triad. This triad is composed of a) fluid distended oral segment, b) empty aboral segment and c) the transition point. At the transition point you must see a space occupying luminal lesion with a hyperechoic near interface which has a shadow artifact. Missing any one of the triad is grounds for doubting your decision to perform surgery. Dogs eat foreign bodies all the time so just seeing one is not enough to perform surgery. Because they eat strange things, dogs commonly develop gastroenteritis with both fluid-filled and empty segment. You must find all three signs of the triad to be confident about the need for surgery.

3. Linear foreign body
Although not the most common foreign body, this is the most important surgical lesion. By failing to recognize a linear foreign body (LFB), the prognosis will greatly suffer as more time progresses for additional workup or empirical therapy. In dogs, approximately 50% will display similar signs as listed above for an obstructive foreign body; the “triad”. However, at least half of all dogs and most cats will not have a distended oral segment. This is very important to factor into your evaluation. You do not have to see a fluid distended portion of small intestine. Commonly the stomach will be fluid-distended for reasons listed below.

Linear foreign bodies are composed of two segments: head and tail. The fixed “head” portion prevents passage down the intestines. In cats we all know to look under the tongue. This also occurs in dogs. If not under the tongue, the most common site of fixation is at the pylorus. This causes two effects. First, as previously mentioned it prevents passage of the foreign body and secondly causes a gastric outflow obstruction. A fluid-distended stomach may be the most obvious part of the ultrasound (or radiographic) findings.

The second component of the LFB is the tail, which is the portion dangling downstream from the head. This portion causes plication of the affected segment, usually duodenum and proximal jejunum. The recognition of this plication is essential to the diagnosis of a LFB.

Most cats do quite well with this lesion. But, in my experience, approximately 25% of dogs will succumb to this disease. Time-to-presentation and time-to-diagnosis determines the prognosis. Perforation is common with this disease.

4. Obstructive neoplasia
Many tumors can cause obstructions. In the intestines they may have the form a similar triad as noted for foreign bodies with foreign material accumulating at the tumor site. Patients may have clinical signs (e.g. anorexia, vomiting) merely from growing a cancer as a
paraneoplastic effect. Or the tumor may cause obstruction due to impingement upon or growing into the gastrointestinal lumen. An important aspect of an ultrasound in these cases is to assess for mets and verify cytology, especially in dogs. In our practice, surgeons will not take a dog to surgery until a diagnosis of gastrointestinal lymphoma has been excluded. This usually requires an ultrasound-guided fine needle aspiration for a cytological sample.

5. Stricture
Ouch! These are extremely difficult cases because 1/3 of the classic triad is missing. The true stricture has no foreign body or mass at the transition site. However, the persistence of the transition site provides evidence of a stricture.

...versus a Medical Gastrointestinal cause of vomiting, anorexia or abdominal pain

6. Pancreatitis
Pancreatitis is a very, very common disease and, in dogs, a fairly straight forward ultrasound diagnosis. In cases of canine pancreatitis, the peripancreatic fat because very hyperechoic telling you, as the sonographer, “Hey! Look here! Something’s wrong here!” Although quite nonspecific, hyperechoic fat always alerts the sonographer to localized diseased. Next we interrogate the area of the hyperechoic fat to determine the cause. With pancreatitis, the pancreas becomes hypoechoic, enlarged, rounded and painful. Imaging this pancreas may be difficult because the patient does not appreciate you pushing a hard plastic object into their inflamed painful pancreas and tenses their abdomen or tries to move away (Murphy’s sign). Dogs most commonly get pancreatitis in the right limb and body regions.

Cats, always refusing to be “little dogs”, do not conform to this combination of signs and may not have inflamed peripancreatic fat nor a very enlarged, painful pancreas. Cats get pancreatitis equally prevalent in the left and right limbs.

To evaluate the entire pancreas is extremely difficult. It requires keen knowledge of anatomy and advanced sonographic skills. The pancreas extends from the descending duodenum to the gastric fundus in the dog. In the cats the pancreas extends from the ascending duodenum to the splenic head. This entire area, including the pyloro-duodenal junction for the body region, must be evaluated or a localized region of the pancreatitis can be missed.

**Gastroenteritis**

1. Infiltrative gastrointestinal disease
Inflammatory bowel disease (IBD) is a very common disease cats. The most common manifestation of IBD in cats is thickened muscularis layer. Often the overall bowel wall thickness is within normal limits. Mild adenoapthy accompanies both diseases. Severe adenoapthy is more common with lymphoma. Differentiation of IBD and lymphoma is a very controversial subject, beyond the scope of this presentation. Cytology, histology and PARR all have their merits and short comings. PARR (PCR for clonal antigen receptor gene
rearrangement) is thought to be approximately 90% specific and 65% sensitive for feline lymphoma (Colorado State University, Clinical Immunology Laboratory FAQ sheet)

In dogs the only “easily” identifiable form of inflammatory bowel disease is lymphangiectasia. With this disease large chyle filled spaces (lacteals or clumps of lacteals) accumulate in the mucosal layer leading to a protein-losing enteropathy. Often dog have concurrent peritoneal free fluid. This disease is common in Yorkshire terriers. Sonographically there are linear parallel striations in the mucosal layer of many, if not most, small intestinal loops. Usually there is not concurrent adenopathy. The overall bowel thickness is usually within normal limits.

Conclusions
Abdominal ultrasound should be a routine component of the workup of many patients with signs of gastrointestinal disease. This is also especially true when a biopsy is required for better characterization through cytology or histology. Surgical gastrointestinal lesions can often be quickly found and differentiated from medical conditions.