Urinary tract infections are a very common cause for stranuria and hematuria seen in the general veterinary practice. Usually, a urinalysis is obtained and appropriate therapy is provided with limited imaging and the hope is that the patient’s symptoms will resolve due to a self-limiting problem. This lecture will focus on all the modalities available to help the clinician assess the urinary tract with examples of specific diseases to help illustrate key points.

Radiographs are considered the first line of diagnostic imaging obtained in a urinary patient. This is to look for urinary calculi since struvite and calcium oxalate crystals are radiopaque. The problem is that soft tissue and fluid have the same opacity so cystitis and a thick wall of the urinary bladder. Ectopic ureters cannot be seen, hydronephrosis secondary to obstruction, pyelonephritis and even a renal mass or perinephric pseudocyst cannot be seen because of similar opacities. For this reason intravenous contrast medium can be used to create contrast between the urine and the soft tissues of the organs, bearing in mind that the contrast medium can even a renal mass or perinephric pseudocyst cannot be seen because of similar opacities. For this reason intravenous contrast medium can be used to create contrast between the urine and the soft tissues of the organs, bearing in mind that the contrast medium can damage the kidneys and cause renal failure.

Despite the inherent risk of contrast medium, the benefits of excretory urography (also called intravenous pyelogram or IVP) and the ease of the procedure still make it a viable modality in patients with urogenital disorders. The basic types of contrast medium procedures that will be discussed are retrograde urethograms, positive contrast cystograms, double contrast cystograms and excretory urograms. Generally, procedures are performed in the order listed above of a complete evaluation of the urinary system.

The contrast medium of choice for all urinary procedures is iodinated contrast medium. Ionic (hypertonic) or nonionic (closer to isotonic) contrast medium is less important for urethograms or cystograms, but the choice may come into play with intravenous administration. Ionic contrast medium, such as MD-76 and Conray, are very hypertonic and as such can cause a tachycardia and reflex bradycardia due to the increased blood volume by pulling fluid from the periphery into the vascular space, much like hypertonic saline. Non-ionic contrast medium, such as Omnipaque and Isovue, is generally closer to isotonic saline and so the vascular changes are minimal. The other complication with contrast medium is the simulation of the chemoreceptor trigger zone in the brain, which can cause vomiting. This is believed to be the direct result of the high level of iodine within the blood when contrast medium is administered. This response is avoided by administering the contrast as a slow bolus over 30 seconds to 1 minute or having the patient under general anesthesia. Due to the potential damage to the nephrons and the multiple images obtained for the contrast medium procedures, all animals should be heavily sedated or under general anesthesia and placed on at least twice maintenance intravenous fluids during the procedure. The risk of an anaphylaxis event is considered equally likely between ionic and non-ionic contrast medium.

Retrograde urethograms can be performed in males by placing a catheter directly into the penile urethra and infusing contrast medium. Generally a small volume of contrast medium diluted with sterile saline is used. In the author’s experience, 2 mL of contrast medium diluted with 8 mL of saline is sufficient to infuse the urethra with contrast medium. In females, a vaginourethrogram is usually performed using a Foley catheter within the vestibule and 30 mL of contrast medium and saline in a 1:5 dilution. A tissue clamp may be needed on the labia to keep the contrast medium within the vestibule. A lateral and ventrodorsal radiographic projection is then obtained at the end of the infusion of contrast medium so that the pressure of the contrast medium administration dilates the urethra.

Positive contrast cystograms are generally used to evaluate for urinary bladder ruptures whereas double contrast cystograms help evaluate the wall of the urinary bladder, evaluate for calculi and help identify ectopic ureters. A positive contrast cystogram is performed with a patient in left lateral recumbency and a Foley catheter is placed in the urinary bladder. The catheter balloon can be filled with air or saline and the urine removed from the urinary bladder. Then approximately 60 mL contrast medium is infused into the urinary bladder diluted with saline in a 1:5 ratio. A lateral and ventrodorsal radiographic projection is obtained while infusing the contrast medium to look for leakage in the urinary bladder wall. If the urinary bladder is insufficiently dilated with 60 mL of dilute contrast medium, another 60 mL is administered and radiographs are repeated. Fluoroscopy, when available, will aid in evaluating the volume of contrast medium administered as well as watching the distention of the urinary bladder.

After the positive contrast cystogram is performed, the contrast medium and urine are removed and carbon dioxide or room air is administered into the urinary bladder. Carbon dioxide is recommended if available as the risk of air emboli, especially in cats, is greatly reduced since carbon dioxide is more soluble in blood compared to room air. If room air is used, maintaining the patient in left lateral recumbency and monitoring the heart for “gurgling” sounds is necessary. If air emboli occur, you should elevate the pelvis of the patient to allow the right ventricle to be higher than the pulmonary outflow tract. This will trap the gas in the right ventricle and allow time for it to dissolve before entering the pulmonary system as an emboli. It generally takes approximately 20 minutes for the air to dissolve; however, a radiograph of the thorax can be used to identify the air within the ventricle.
After infusion of the negative contrast medium (air or gas), a small volume of positive contrast medium is administered. Generally 1-3 mL is sufficient to create a small pool of contrast medium. Right and left lateral as well as ventrodorsal and dorsoventral radiographs are obtained to evaluate the urinary bladder wall.

Excretory urography is performed by administering 1 mL of contrast medium per pound of patient body weight intravenously up to 50 mL. The toxic dose of contrast medium is 4 mL per pound and the 50 mL cut off is more for convenience and cost rather than safety as most bottles of contrast medium are 50 mL. Generally the patient is in lateral recumbency for the injection in case vomiting occurs and then immediately placed in ventrodorsal recumbency to obtain the first radiograph. This will provide a vascular phase of the kidneys. After 3 min, repeat radiographs, both ventrodorsal and lateral radiographs are obtained to evaluate the kidneys, called the nephrogram phase. After 5 minutes, both ventrodorsal and lateral are obtained and contrast medium should be seen within the renal pelves (called the pyelogram phase) and within the ureters. Oblique radiographs and subsequent images can be obtained until you seen the ureters enter the urinary bladder. Having negative contrast (air or gas) within the urinary bladder will aid in this contrast and help to identify the ureteral papilla and any ectopic ureters that are present. During this procedure, if contrast medium is present within the urethra, an ectopic ureter is strongly suspected.

Contrast procedures of the urinary bladder can be labor intensive, but with digital radiographic equipment, it requires less technical skill than ultrasound and can provide a large amount of diagnostic information in a patient with a urinary tract disorder.
The evaluation of the musculoskeletal system is difficult due to the numerous soft tissues as well as the bone structures involved. Rapid assessment of the bone structure is routinely performed using radiographs; however, the subtlety of disease and joint compared to bone pathology can be confusing. The purpose of this lecture is to cover the identification of aggressive compared to non-aggressive bone lesions as well as erosive compared to non-erosive joint pathology.

When evaluating the skeletal system, the first thing to determine is if the lesion is aggressive or non-aggressive. A non-aggressive lesion diagnoses include callous, malunion fractures, bone cysts, osteomas, osteochondritis dessicans, panosteitis, fragmented medial coronoid process, osteoarthritits or metabolic disorders. Aggressive lesions are due to neoplasia or osteomyelitis.

When deciding about aggressive lesions, there are 6 radiographic signs that are used: bone lysis, periosteal reaction, rate of progression, zone of transition, cortical lysis. Bone lysis has three different appearances, geographic (focal) moth-eaten and permeative. The difference between the degree of lysis is mainly on the rate of progression. It requires approximately 50% of the bone per unit area to be destroyed before it is visible on radiographs. This is because the bone is a three dimensional object viewed from two dimensions. Because of this, bone is superimposed on itself, making subtle lesions hard to detect. The more lysis that is present, the easier it is to see on radiographs. Also, by the time lysis is seen on a radiograph, the lesion is quite severe.

Periosteal reaction can either be smooth (continuous) or interrupted. The easiest way to determine this is if you could trace the outline of the periosteal reaction with a pencil and never have to lift the pencil from the radiograph. Smooth periosteal reactions are generally associated with trauma whereas interrupted periosteal reactions are due to an aggressive process.

Rate of progression is probably the most overlooked method to assess an aggressive lesion. By the time a questionable aggressive lesion is seen on a radiograph, the lysis is quite substantial. Therefore, the rate of progression in 2-4 weeks will also be dramatic. If a question exists between an aggressive and non-aggressive lesions, supportive medical management for 2-4 weeks then repeat radiographs to look for progression can aid in determining if the lesion is aggressive.

Zone of transition is a more nebulous sign, but the idea is that if a clear-cut demarcation between normal and abnormal bone is seen, then the lesion is more likely non-aggressive. If there is a long zone of transition, the difference between normal and abnormal bone is blurred and the lesion is more likely to be aggressive. In addition, cortical lysis as opposed to overall bone lysis can be used to determine aggressive bone lesions. If the cortex is thin, but no lysis is present, then it is more likely that the lesion is non-aggressive.

After determining these radiographic signs, the next clue is based on the location of the lesion. If the lesion is generalize in that it effects all bones equally, then the primary differential diagnosis is a metabolic or nutritional abnormality. If only one bone is involved, this is a focal or monostotic lesion and a primary bone tumor or soft tissue tumor with secondary bone involvement is considered most likely. If multiple bones in the same region (locally extensive), different bones that are not in close proximity or multiple areas in the same bone are involved, this generally indicates a hematogenous spread disease as bacterial osteomyelitis or metastatic neoplasia. A soft tissue tumor with secondary bone involvement is possible with locally extensive lesions, such as aggressive lesions that cross a joint.

Anatomic location is also a key into the differential diagnoses. If the lesion is epiphyseal or physeal in origin, then it is likely secondary to infection, trauma or potentially a nutritional abnormality. These lesions are generally in juvenile dogs and cats. If the lesion is in the metaphyseal region, then a primary bone tumor or hematogenous infection is most likely due to the proximity of the nutrient foramen. If the lesion is diaphyseal, then the lesion is likely metastatic neoplasia, a soft tissue mass with secondary bone involvement or a focal infection related to a penetrating trauma.

After all these signs and locations are taken into account, then the differential diagnoses are prioritized based on the signalment and history of the patient. A 2 year old hunting dog with an aggressive bone lesion in the proximal metaphysis of the humerus is more likely to have a fungal infection; however an 8 year old Rottweiler with the exact same radiographic findings is more likely to have osteosarcoma. These considerations should be made when assessing aggressive lesions. Since osteosarcoma is a common tumor type, it is not uncommon for clinicians to see an aggressive lesion, even if it is locally extensive and crosses a joint, and consider a primary bone tumor like osteosarcoma. However, other tumors such as malignant histiocytosis, synovial cell (histiocytic) sarcoma, or even fibrosarcoma, chondrosarcoma and metastatic neoplasia can all be considered possible. Biopsy (excisional or incisional), thoracic radiographs and history may aid in further prioritizing the lesion.

Lesions centered on joints are similar to those in bone. These lesions are centered on the epiphysis of both sides of the joint. Just as aggressive and non-aggressive lesions exist in bone, erosive and non-erosive lesions are in joints. A non-erosive lesion is osteoarthritis. Everything else is considered erosive. Osteoarthritis is a degenerative condition due to joint instability or trauma. It is characterized by the presence of osteophytes and enthesiophytes. An osteophyte is smooth bone production within the joint capsule.
that serves as a buttress to tighten ligaments and stabilize the joint. Enthesiophytes are bone production at the attachment of the joint capsule and ligaments due to abnormal tension that is present on the soft tissues from joint instability.

Erosive lesions in small animals are usually infectious and mostly autoimmune in origin. Causes of erosive arthropathy also include chronic hemarthrosis or neoplasia, but these are less likely in small animals. Just as with bones, joint lesions are characterized by the number involved. A monoarthrosis (one joint) is usually osteoarthritis or a traumatic infection, such as a puncture wound. A polyarthropathy (multiple joints involved) usually indicates a hematogenous infection or immune mediated disease.

The radiographic signs for an erosive arthropathy include subchondral bone lysis, presence of osteoarthritis, decreased joint space (especially when weightbearing), luxation or subluxation of the joint and fragmentation of adjacent bone. Based on these signs, and the presence of one or multiple joints involved, a arthrocentesis can be performed to determine the cause for the erosive arthropathy.

Radiographic findings of joint bone lesions can be confusing if one does not consider the vast number of differential diagnoses possible and then makes an educated decision to prioritize the lesion. This is generally done by the clinician automatically due to the geographic location and the likelihood of disease in a given area. If a dog in southern Michigan presents to Michigan State University for an aggressive bone lesion, neoplasia is more likely. However, if the patient is from northern Michigan, then fungal osteomyelitis should be considered possible. At the end of this lecture the hope is that the veterinarian will have numerous examples and a better overall appreciation of how to evaluate a radiograph for aggressive and erosive lesions.
Neonatal imaging is riddled with problems, not the least of which is that it is not performed routinely. When you have an acutely lame puppy, the growth plates and the lack of ossification of the bones can cause confusion. The purpose of this lecture is to show various congenital disorders including osteochondritis dissecans, panostitis, elbow dysplasia, hip dysplasia and nutritional abnormalities.

Osteochondritis dissecans is likely the most commonly diagnosed congenital disorder. This disorder is a failure of endochondral ossification that occurs in young growing animals. The key to this disorder is that to have failure of endochondral ossification, it must finish and therefore the diagnosis should only be made after the dog is 5-6 months of age. This disorder can occur in the tarsus, elbow, shoulder and stifle. For the tarsus, since it can occur in the talus, a flexed dorsoplantar projection of the tarsus and a flexed lateral can help to remove the superimposition of the distal tibia to identify the lesion.

Panostitis is a self-limiting disorder that is hard to diagnosis because of the subtlety of the radiographic changes. It ranges from increased opacity of the medullary cavity to a decreased opacity or smooth periosteal proliferation. The ulna, radius and distal humerus are the most commonly affected areas and the contra-lateral limb should be obtained for comparison. Generally, lateral radiographs are all that is needed to make the diagnosis.

Elbow dysplasia is a current hot-topic in the breeding world with the Orthopedic Foundation for Animals (OFA) creating a 0-3 grading scale as part of the routine screening test for dogs. Small ridges on the anconeal process causes an elbow to go from a grade 0 to a grade 1, but when evaluated with CT, this irregularity is a normal variant in most cases and not associated with osteophyte formation. In fact, a current study at Michigan State University being performed by Dr. Chelsea Kunst is finding that grade 0 elbows can sometimes have osteoarthritic changes on CT whereas grade 1 elbows sometimes do not. The bottom line is that radiographic assessment of the elbow is mainly to determine the severity of disease rather than the presence. Such is the case with an united anconeal process. This is a normal finding in dogs < 5 months of age, but the apophysis should be fused by the age of 6 months. It is the cut point when an anconeal process is considered united. Fragmented medial coronoid processes are the most commonly suspected elbow disorder, but with the superimposition of the radius, are difficult to evaluate on standard radiographs. Computed tomography is the modality of choice for evaluating the elbow to minimize the superimposition and detect small fragments or luencies within the bone.

Canine hip dysplasia is an orthopedic disorder that causes widespread confusion among breeders mainly due to the difficulty of predicting the likelihood of young animals developing osteoarthritis later in life due to hip laxity. Currently, two methods to evaluate the hips are used. The first is a standard ventrodorsal projection. This view is accepted by OFA in animals greater than 2 years old as a good predictor of hip health. The idea that is osteoarthritis or incongruity is present, the degree of the laxity can be assessed and a grade of Excellent, Good, Fair, Borderline and Dysplastic can be made. Three board certified radiologists score the radiographs independently and then the assessment is average. The main limitation to this is that it is a subjective measure and does not take into account the breed of the animal. The other method is PennHip, which uses a distractor to assess the amount of passive joint laxity. This measure is then compared to all the dogs in the database of the same breed and a percentile is given. Greater than 50% is considered a pass and hips with a distraction index of < 0.3 are considered unlikely to develop osteoarthritis later in life. The benefits of this method is that it is an objective measure that is breed specific and that all evaluations must be submitted to PennHip to provide a general database of the breeds. In addition, this method can be used to accurately predict hip laxity after 6 months of age.

Nutrition in animals is also something that in these economic times can manifest as growth plate disorders or delayed ossification. Understanding the timelines when growth plates close and having normal radiographs or textbooks that show bone development of puppies helps with this assessment. Careful history and physical examination as well as thorough blood work can also aid in making this determination.

Neonatal radiographs can be difficult, but due to more concerned owners and the better resolution of radiographic examinations, care must be taken to adequately obtain and evaluate these images. Although not routinely performed, radiographs of the immature skeleton can show far more than just a fracture, but also can show growth plate disorders, nutritional deficiencies as well as developmental disorders. If detected early enough, these developmental disorders can be corrected and treated appropriately prior to irreparable damage.
Thoracic radiography generally focuses on the lung and pulmonary patterns; however, the presence of the pleural fluid, the esophagus, thymus, heart and lymph nodes within the mediastinal and pleural space, there is a lot more to evaluating the thorax besides the lungs. The goal of this lecture is to provide anatomic review of the mediastinal space, the use of positional radiography on the pleural space and cardiac silhouette and common diseases that affects these regions.

The pleural space is a potential space that surrounds the lungs and contacts the ribs. The primary abnormality that occurs with the pleural space is the accumulation of fluid. This fluid accumulation causes havoc with evaluating the lungs and heart since the fluid opacity and soft tissue opacity are the same. This causes silhouetting with the other organs making it impossible to see inside the thoracic cavity. The best way to work around this issue is to use gravity by taking upright images allowing the evaluation of cranial mediastinum or lateral horizontal beam radiographs to look at the lungs. This would keep fluid separate from the underlying organs.

When pleural fluid is present, the most overlooked cause is a rib lesion. Care should be taken to evaluate each rib individually and compared to the contralateral rib as well as the rib cranial and caudal to look for lysis and periosteal reaction. Other causes for fluid includes a mediastinal mass, such as a thymoma, heart failure (primarily in cats), foreign bodies, and in rare cases secondary to pulmonary neoplasia and pneumonia.

The mediastinum contains the heart, esophagus, lymph nodes including sternal, cranial mediastinal, and tracheobronchial as well as the thymus and trachea. The mediastinum also directly communicates with the cervical soft tissues and the retroperitoneal space. This is important since a pneumomediastinum may lead to pneumothorax but a pneumothorax will not lead to pneumomediastinum.

In addition to determining the location of pneumomediastinum, the enlargement of the lymph nodes can help localize lesions. The sternal lymph node drains the cranial three pairs of mammary glands and the peritoneal space. The cranial mediastinal lymph node drains the head, thoracic limbs and the sternal lymph node and the tracheobronchial lymph nodes drain the trachea and bronchus. An important point of this is that generally these lymph nodes are not seen during reactive hyperplasia and therefore if present neoplasia or severe fungal infection are the primary differential diagnosis.

The esophagus has a large number of disorders that range from congenital abnormalities causing compression such as persistent right aortic arch, foreign bodies or neurologic disorders causing megaesophagus. Fluoroscopy is useful for evaluation of the esophagus but with the quick cycling of digital radiographs, some information can be gained from serial images after administration of contrast medium.

The pleural space and mediastinum are overlooked regions that have a large number of abnormalities that are generally overlooked and usually considered idiopathic, but a large amount of information can be gained by evaluating these spaces on radiographs. After this lecture, you should have a better understanding of the use of positional radiographs as well as the various diseases that occur in the pleural and mediastinal space.
Thoracic radiographs are the mainstay of diagnostic imaging. The debate between two view and three view thoracic radiographs may continue, but no one argues that imaging the thoracic is the most complicated and more informative radiographic procedure available. With the contrast provided by the lungs, soft tissue opacities and radiographic changes within the lungs are easy to see, but hard to interpret. By far, a normal thoracic radiograph is still the most difficult to interpret.

Radiographic technique and positioning is the most important thing to thoracic radiographic interpretation. The first priority is the proper radiographic technique. Due to respiratory motion, the kVp setting is set high (generally 100 or 120) and the mA is also maximized to keep a small exposure time to minimize motion artifacts. Recumbency is also a major factor in radiographic interpretation. The lung needs to be aerated in order to see radiographic changes since the soft tissue opacity of the lesion needs to contrast with the aerated lung. Therefore if a lesion is in the right cranial lung lobe, then a left lateral radiograph is needed. Alternatively if the lesion is in the left caudal lung lobe, especially in the dorsal aspect, a dorsoventral projection should be performed.

Once the radiograph is obtained, the next step is to determine if the lungs are too white, too dark or normal. The second question is if this change is secondary to technique or pathology. To determine if the increased opacity is secondary to technique, one should evaluate the degree that the first and second thoracic spinous process can be seen, also the degree of contact between the diaphragm and the heart as well as the the ability to see the pulmonary vasculature and the superimposed triceps musculature on the thoracic inlet.

Once you decide a lesion is present, the next debate that is currently going on is the importance of pulmonary patterns versus location. Pulmonary patterns are divided into alveolar, interstitial and bronchial lung patterns. These patterns were based on air bronchograms, increased opacity to the lung fields or increased thickness of the bronchial wall creating increased lines and rings, respectively. That said, generally, it is easier to consider the radiographic pattern as a degree of severity with alveolar being the most severe, interstitial is moderate and bronchial being mild pulmonary disease. The alternative way to evaluate the lungs is to decide on the location and the distribution of the pathology identified.

For location, you can divide pulmonary disease into cranioventral, caudodorsal or diffuse disease. Cranioventral disease has 3 differential diagnoses: bronchopneumonia, hemorrhage or neoplasia. If it is caudodorsal there are 2 differential diagnoses: cardiogenic and non-cardiogenic pulmonary edema. Diffuse can be any of the five diagnoses. If the lesion is not occupying a lung lobe and is more structured, it can have a focal or multifocal distribution. A focal pulmonary lesion can be a tumor, granuloma, abscess or bulla (if radiolucent), whereas multifocal lesions tend to be neoplasia, fungal granulomas or pulmonary osteomas (which are < 5 mm soft tissue to mineral opacities throughout the lungs, generally seen in Collies).

If pleural fluid is present, retraction of the lung lobes away from the body wall can be seen. In cats, if this retraction remains after the fluid is removed, restrictive cardiomyopathy is considered most likely. If a cranial mediastinal mass is suspected, a standing horizontal beam radiograph can be obtained with the dog or cat standing on their hindlimbs and a ventrodorsal projection obtained to cause the fluid to be caudal to the heart. If pleural fluid is seen, the first thing to evaluate is the ribs, as rib tumors are a frequent, overlooked cause for pleural fluid. Also, radiographs can help identify a site to obtain a sample of the fluid, which can provide insight to the cause.

The cardiovascular structures of the lungs can also be evaluated to provide further information if a cardiogenic pulmonary edema is suspected. The cardiac silhouette is comprised of the heart and the blood within the heart as well as the surrounding pericardium. Since fluid and soft tissue have the same opacity, a difference between these structures cannot be identified. If the heart is enlarged, generally chamber enlargement is seen such as the left atrium or right atrium. Cardiac changes are generally vague and only occur when the changes are severe. When the heart hypertrophies, it undergoes concentric or eccentric hypertrophy. Concentric hypertrophy is secondary to a pressure overload. If the heart can compress hard enough, it can push the blood out of the chamber. The heart then hypertrophies the muscle to create a smaller lumen. The heart shape remains the same and therefore cats with hypertrophic cardiomyopathy and dogs with pulmonic or subaortic stenosis will not have radiographic signs of cardiomegaly until the disease is very advanced. Alternatively, eccentric hypertrophy is secondary to a volume overload. No matter how strong the contraction, the fluid cannot clear the chamber so the hypertrophic muscle is formed on the outside of the lumen. This change can be seen radiographically, but is a rare condition, mainly occurring with dilated cardiomyopathy.

Pulmonary vasculature can also be evaluated to help to determine the cause for a caudodorsal lung pattern. If the pulmonary artery is dilated, the primary cause is pulmonary hypertension from any cause. In adult dogs, the main cause is secondary to heartworm disease or pulmonary thromboembolic disease. If the pulmonary vein is enlarged, then generally it is a sign of left-sided heart failure. This vein enlargement is first seen in the right caudal lung lobe and then progresses to the remaining lung lobes with time. If both the
arteries and veins are enlarged, then that is caused by over circulation, such as a patent ductus arteriosus or ventricular septal defect. Small vasculature is a rare finding, but may be secondary to hypovolemia, hypoadrenocorticism or severe pulmonic stenosis. Radiographic interpretation of cardiac disease is considered difficult and numerous studies have tried to identify the easiest methods to simplify the interpretation. Using vertebral heart score, inverting the image so that black is white and white is black, even rotating the image to look for rib lesions. All these methods have found that nothing is better than experience at image interpretation and practice. In addition, with the rapid expansion of digital imaging, bronchial lung patterns are being over diagnosed due to the increased image resolution. Having normal radiographs and evaluating the entire image, included the surrounding musculature and skeletal structures is essential to make accurate diagnoses.

Thoracic radiography is considered a challenging region to interpret not because the lesions are difficult to see, but rather because the lesions identified are generally non-specific and are difficult to interpret. Generally, most practitioners see a cranioventral alveolar lung pattern and diagnose aspiration pneumonia and a caudodorsal lung pattern as pulmonary edema. In truth, the thoracic radiographs should be evaluated as a whole, is there a megaesophagus or history of vomiting? Is there a heart murmur, enlarged pulmonary veins or enlargement of the left atrium of the heart? These questions should be asked prior to starting therapy with the hope the diagnosis is correct. Thoracic radiographs are not obtained to determine if a disease is present, but rather to identify the extent of disease and determine the progression or regression. Bearing in mind that radiographic improvement may lag behind clinical improvement by several days.

Although thoracic radiography is challenging, this lecture will provide an overview of normal anatomy as well as case examples of common disease processes to help provide the participant with an increase knowledge and level of comfort interpreting pulmonary and cardiac changes.
Fractures in the small animal patient are very common occurrences that are repaired with external bandages, splints or fixators or internal fixation with a large choice of bone plates, intramedullary pins, wires or screws. Although the repair is challenging, a further challenge is evaluating these lesions post-operatively to determine if the fracture is healing, infected or if the lesion is a tumor. This lecture will review the types of fractures, locations and the ways to determine if the fracture is pathologic. Time will be spent talking about fracture repair, healing and implant failure.

When a fracture occurs, the type of torque will determine the type of fractures. A transverse fracture is a linear fracture that is bicortical and is perpendicular to the long axis of the bone. A segmental fracture is two transverse fractures that do not communicate with each other. A short oblique fracture is a bicortical fracture that is angled, but is shorter than twice the width of the bone. A long oblique fracture is longer than twice the width of the bone. A spiral fracture is a long oblique fracture that extends around the cortex of the bone. Finally, a comminuted fracture is when multiple fracture lines are present that communicate with each other to create multiple fragments.

The location of the fracture helps to determine the possible pathology. Generally, long oblique fractures are low-impact, twisting fractures. These usually occur due to getting a limb caught in a fence and subsequently pulling and breaking the bone. When a long oblique fracture occurs in a thick bone like the femur or humerus, a pathologic fracture should be considered highly likely. If periosteal reaction is present, this is pathognomonic for a pathologic fracture since it will take 3-5 days in puppies to form periosteal new bone and can take 2-3 weeks in adult dogs. Therefore, if at initial presentation a periosteal reaction is present, then microfractures have likely occurred previously.

With fracture healing the type of repair and the age of the patient are two important factors for bone healing. With primary, ridged fixation, such as bone plates, there is generally little motion of the fracture so healing is generally primary with little callus formation. When external fixation is used or a bone plate with minimal screws, micromotion is present. This motion causes a mild instability of the fracture and a small amount of callus formation. The degree of callus will relate to the degree of motion. If infection occurs, then the fracture gap generally widens. This usually occurs within 3-5 days post surgery and therefore, radiographs in 2-4 weeks should be done to avoid mis-diagnosing the remodeling phase of bone healing with infection. If infection of the surgery site is a concern, soft tissue swelling and pain are usually more useful findings than radiographic change. This is because radiographs usually lag behind clinical signs by a week or two.

In young animals, bones tend to heal quite rapidly. The table is provided to give you rough guide of the time for healing based on the age of the animal. Note that the less stable the repair, the faster the healing due to the larger amount of callus that is formed.

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<tr>
<th>Age of Animal</th>
<th>Pins (External or internal)</th>
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<td>&lt; 3 mo</td>
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<td>&gt; 1 yr</td>
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In animals with an open growth plate, Salter-Harris fractures are classified. These fractures indicate a growth plate is involved in the fracture. Although there are 14 classifications, veterinary medicine generally recognizes 5. The types increase with severity with Salter I extending through the physiis, Salter II through the physis and metaphysis, Salter III through the epiphysis and physis. Salter IV fractures extend through the epiphysis, physis and metaphysis and Salter V is a crushing injury to the physis. Mal-union and non-union fractures can look like cancer, but the smooth periosteal reaction and lack of progression are key features to the fact that these are fractures that are healing in an abnormal way. Periosteal reaction is useful to determine if infection is present as exuberant periosteal reaction is usually secondary to cellulitis and inflammation rather than stabilization of the fracture.

Radiography is a fast and easy way to assess fracture healing and complications; however, time is needed for bone remodeling to be severe enough to see on radiographs. Sequential radiographic examinations and interpretation based on clinical findings such as disuse of the limb, swelling, pain or a draining track can help characterize aggressive lesions like neoplasia and osteomyelitis from normal healing.
Abdominal radiographs are a rapid, readily available method to give an overview of the abdomen. Though most people believe ultrasound is the new modality of choice for abdominal evaluation, the limitations of ultrasound not being able to penetrate gas as well as the technical ability and time to acquire images still make abdominal radiographs a great first modality in the patient with acute abdominal pain.

Ultimately, the question for the clinician with an abdominal patient is whether surgery is indicated or if medical management is the best course of action. With radiographs providing an overview of the entire abdomen, and the use of the gas within the bowel to provide contrast, abdominal radiographs can be useful as a triage tool that can be augmented and finding further characterized using abdominal ultrasound.

When evaluating the stomach, generally most abdominal radiographs include a right lateral and ventrodorsal projection. The question always arises on why this is performed. These two views have become the standard since a right lateral projection places gas in the fundus of the stomach and fluid in the pyloric antrum. To evaluate the pylorus, a ventrodorsal projection is used to put fluid in the fundus and gas in the pyloric antrum. At Michigan State University, we take 3 view radiographs of all abdomens to include a right lateral to seen the fundus, a left lateral to evaluate the pylorus and look for pyloric outflow obstructions and a ventrodorsal to provide more information about the pylorus and to better evaluate the colon.

With the availability of ultrasound, the use of contrast medium for upper gastrointestinal contrast medium procedures is not routinely performed. However, in clinics without the benefits of ultrasound, barium or iodinated contrast medium procedures still provide some use to evaluate if a luminal obstruction exists, if the bowel wall is think or infiltrated, look at overall motility or assess for a rupture. The main drawback to this procedure is that if any of those differential diagnoses are suspected, an exploratory laparotomy is indicated rather than a contrast procedure that could delay surgery by 3-6 hours.

Barium contrast medium is the most universally used for gastrointestinal imaging. It is safe, the dose is 6-10 milliters per pound and generally is administered through a gastric tube. If aspirated, barium causes physical obstruction of the airways with no inflammatory component, but may cause granulomas if it leaks into the peritoneal or pleural cavity. For this reason, barium is contra-indicated if a ruptured bowel or ruptured esophagus is suspected. Iodinated contrast medium is generally used intravenously but can be administered orally. The main limitation is that it has a bad taste, is hypertonic so it will draw fluid into the bowel and since it is hypertonic, will cause an inflammatory reaction if aspirated into the lungs.

Positional radiography can also be used to evaluate for free gas in the abdomen. Since an air/fluid interface is needed to help to see gas within the peritoneal space, a horizontal beam projection with the dog on its left side and obtaining a ventrodorsal projection will put the gas in the right lateral abdomen near the pyloric antrum. Since the pylorus is small, the gas accumulation will be identified caudal to the diaphragm.

For gastric dilation with volvulus, the main feature is to obtain a right lateral radiograph. No other projection is needed. If the pylorus is seen in the craniodorsal abdomen, a GDV is confirmed. Numerous times people have been fooled by the normal appearance of the ventrodorsal projection and decided the case was just gastric dilation. Nothing else can put the pylorus in the craniodorsal abdomen except for a GDV.

Small intestinal wall thickness is also something frequently evaluated on survey radiographs. This cannot be done. Since soft tissue and fluid are the same opacity, it is impossible to know if the structure observed is a thick wall or just a combination of fluid summating with the small intestinal wall.

The abdomen is divided into two spaces, peritoneal and retroperitoneal. The retroperitoneal space contains the adrenal glands, kidneys and sublumbar lymph nodes and the peritoneal space contains the remaining organs. This determination is important since it will aid in the differential diagnoses of a mass that is present or the cause for gas within the abdomen. The retroperitoneal space is dorsal to the colon. Therefore if a soft tissue mass displaces the colon ventrally, then the mass is likely retroperitoneal indicating it is either arising from the kidney or adrenal glands. If gas is present in the retroperitoneum, this is likely secondary to a pneumomediastinum rather than a rupture of the gastrointestinal tract.

Radiographs are useful to determine if a surgical obstruction or mass is present or at least provides a general overview of the abdomen. Though barium contrast medium can be used, this has largely been replaced with ultrasound or exploratory surgery. By the end of this lecture, the audience will seen numerous examples of radiographs for surgical and non-surgical lesions and how a better understanding of the limitations and benefits of abdominal radiography.
The use of radiography to examine the abdomen is full of complications. Radiographs are very good at determining the difference between bone and gas, but soft tissue and fluid are the same opacity. When dealing with intra-abdominal lesions, the main goal is to differentiate one soft tissue mass from a normal soft tissue structure from abdominal fluid. Ultrasound uses high frequency sound waves to accomplish what radiographs cannot. With ultrasound, fluid and soft tissue can be clearly distinguished from one another, where bone and gas cannot. The purpose of this proceeding is to describe the benefits and uses of abdominal ultrasound to the general practitioner.

Abdominal ultrasound is a unique diagnostic test in veterinary imaging. Unlike blood work, radiographs, computed tomography or magnetic resonance imaging, ultrasound requires the sonographer to both acquire images as well as interpret them. This unique combination is why physicians have allowed technicians to acquire the ultrasound images and that leaves radiologists free to perform other studies and interpret the images acquired. This model has not been accepted in veterinary medicine as yet.

So the first stage to abdominal ultrasound is gaining the technical skill to acquire images. This requires patience and time, but is relatively easy with practice. Where ultrasound skill comes into play is with adaptation for disease processes. It is necessary to know that if you suspect portal hypertension, you need to look behind the left kidney for acquired portosystemic shunts. If you see a thrombus in the splenic vein, you need to evaluate the portal vein for thrombosis as well. This is the degree of medicine that keeps the ultrasound probe in the hands of the veterinarian.

Ultrasound examinations have nearly replaced abdominal radiographs at Michigan State University. As an example, on a given day, we performed up to 20 ultrasound examinations and only 3-5 abdominal radiographic series, generally performed during emergency hours. This replacement has occurred because ultrasound provides better detail and more information about the abdomen compared to plain radiographs. Although we have virtually replaced radiography, radiography is more rapid and gives a better overview of the abdomen compared to ultrasound. For example, a gastric dilation with volvulus can be diagnosed with ultrasound, but it would be easier and more accurate to use radiography to identify the gas filled pylorus displaced dorsally and to the right.

Once the images have been acquired, the next step is interpretation. When ultrasound was first used, it was the first non-invasive, cross-sectional imaging modality. This means that rather than just seeing the outline of an organ, you can now see the portal vein within the liver and the medulla within the kidney. Ultrasound images were compared to gross necropsy examination, but done in a much less invasive manner. Since the image generated can see into the organ, it is very sensitive to find morphologic changes such as masses, cysts, abscesses and tumors. However, unlike gross pathology, you no longer have color and smell to aid in your diagnosis. For this reason, an abscess can look just like a tumor, which can look just like a blood clot. This is why we considered ultrasound very sensitive for disease, but not very specific. The benefit of ultrasound is the ability to identify a lesion in an organ of interest as well as aid in obtaining a sample, either with fine needle aspiration or with a biopsy to help determine the true nature of the lesion.

Common lesions identified using ultrasound include: foreign body obstruction, mucocele formation, splenic hemangiosarcoma and urinary tract disease. Previously, a foreign body obstruction could only be identified if it was completely obstructive, was radiopaque or radiolucent and if there was marked dilation orad from the lesion. With the superimposition of other organ structures, sometimes barium was used to evaluate wall thickness and motility. Ultrasound has virtually eliminated the need for barium studies and allows the evaluation and identification of foreign material, whether completely or partially obstructed, within the gastrointestinal tract. This is because at any foreign material, whether it is made from wood, cloth or metal, will absorb sound and cast a dark shadow deep to the lesion. That coupled with the increased ability to identify small intestinal distension and wall layering, makes the determination between a foreign body obstruction and a neoplastic mass easily distinguished.

A mucocele is a chronic form of cholecystitis. Generally, a patient presents with a chronic history of intermittent vomiting followed by an acute onset of collapse or severe, unrelenting vomiting. Ultrasound is the only method available to non-invasively examine the gallbladder and bile duct for evidence of obstruction or mucocele formation. A mucocele has the unique appearance of linear striations that radiate from the center of the lumen. These radiations are thought to be bile salts trapped within a thick, hypoechoic (dark) mucosal wall. At this stage, the gallbladder is considered a nidus for infection and a surgical emergency since it has a high risk of rupture if left in place.
Large splenic masses are generally easily identified on radiographs or ultrasound (as well as physical examination). The difference is in the dog that presents with acute collapse and a hemoabdomen. It is true that with a hemoabdomen and no history of trauma, you can perform an exploratory surgery to find the source of the bleeding, but this is usually difficult to do. Instead, ultrasound evaluation of the abdomen to look for a mass as well as metastatic disease is considered the non-invasive method of choice to help with the surgical planning.

Lastly, urinary tract abnormalities such as hydronephrosis, perinephric pseudocysts, transitional cell carcinoma and cystitis can all be evaluated without the use for contrast medium or general anesthesia in a rapid non-invasive way using ultrasound. Examination of the kidneys will show if the renal pelvis is dilated or the kidney is surrounded by fluid. With radiographs, since fluid and soft tissue are the same opacity, it is not possible to make this determination without contrast medium, which is considered nephrotoxic. Instead, ultrasound can show the architecture of the kidney as well as help find a distended ureter if one is present. The wall of the urinary bladder is also a dilemma with ultrasound since the urine will obscure the luminal margin. With ultrasound, small areas of mineralization within the mass as well as proliferation of the wall seen with cystitis can be quickly and accurately identified, though differentiating tumor versus inflammation is difficult without obtaining a sample with traumatic catheterization.

Abdominal ultrasound in the general practice has the potential to provide a practitioner with rapid information to help facilitate referral or further diagnostic tests especially in the vague, chronically ill patient. With practice, guidance and perseverance, it is possible to use this modality as a triage tool as well as method to determine the progression and regression of disease.