Thoracic and Abdominal Radiography
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Introduction
Thoracic and abdominal radiography are integral diagnostic tools in general small animal practice. With proper technique and good image quality control practices, radiography can be an exceptional tool. All too often though, radiography is underutilized due to difficulties with image acquisition and degraded image quality.

A background knowledge of the principles of image acquisition, basic patient positioning and what views should make up a standard study are important components that are needed to produce good quality diagnostic images that add value to a clinical workup. As veterinarians, we typically delegate the task of image acquisition to the hospital staff and are usually busy with other tasks making oversight and quality control sometimes difficult.

Knowledge of the normal anatomy is highly important, and having anatomy resources available for reference will be extremely useful. Radiology is largely applied anatomy, and one of the difficulties with traditional radiographs is imagining the relationship of three dimensional structures in a two dimensional image.

The purpose of these sessions is to refresh some of that background information, discuss the different views of a thoracic or abdominal radiographic examination, and provide the information that can help you and your technicians provide excellent radiographic images.

Basics of Image Acquisition
We are well into the digital age and in a SVMA survey performed several years ago, over 50% of private practice respondents in Saskatchewan had already begun using digital radiography. Digital radiography does provide improved exposure tolerance compared to traditional film screen radiography. This means that the digital system is more forgiving of an imperfect exposure setting on the x-ray machine. The downside of this is that it has allowed many users to become less stringent when selecting the exposure settings, sometimes leads to a “one setting fits all” mentality, and tends to lead to exposure creep where a higher radiographic technique is used than necessary. The higher settings do often improve the image quality, but there is increased radiation exposure which is especially important in veterinary medicine where our staff often tend to be in the room with the patient being x-rayed.

Many digital systems may have pre-sets that can be programmed based on body part thickness with a predetermined setting for kVp and mAs. It is also important that there be multiple sets of settings which are tailored to the body part being imaged. Given the same body thickness, the kVp and mAs settings for thorax, abdomen or musculoskeletal body parts will still be different. This is an important distinction that is often lost, and not typically promoted by vendors selling digital radiography systems. There has been an increase in “dog-o-gram” and “cat-o-gram” type studies with digital radiography, and it seems this may even be promoted as a selling feature by the radiography system vendors. While you can
certainly get an adequate exposure of both regions in one view, the image quality is still not optimized and important diagnostic information may be lost.

**DICOM**

What is DICOM? Digital Imaging and Communications in Medicine is the standard for acquiring, storing and transmitting information in medical imaging. It is its own file format with the patient information embedded and is the preferred format for viewing or sending images for a referral. This format preserves the image quality whereas sending images as a jpeg causes the image files to be compressed and some of the image quality is lost along with some ability to zoom and change brightness/contrast of the images.

All image modalities, whether x-ray, ultrasound, CT, etc. output the images in DICOM format in order to facilitate communication and storage. Your x-ray or ultrasound machine can be configured to send images directly over the internet to another hospital or radiologist. To set up a DICOM connection you need:

- AE (application entity) title
- Device/computer name
- IP address
- Port number

These will be set up on both ends of the connection and then image studies can be sent back and forth with the click of a button, and along with them the attached patient information. Setting up the connection is not very difficult (literally can be done in a few minutes) and there are many internet or technical support resources to guide you. The benefits are much greater ease of sending images in one step without having to download to a disc or USB drive, and the images you send will be of the same quality as what you acquired with no degradation due to conversion to jpeg format.

**Radiographic settings: Thorax vs. Abdomen**

Standard x-ray imaging is based on attenuation of the x-ray beam and differential absorption of the x-rays by the various tissues in the body which then “cast a shadow” on the film or digital detector. We can use the machine settings to change the quality or makeup of the x-ray beam and this can help us improve contrast in the resulting images.

The basic settings we change on the x-ray machine are kVp and mAs. Changing these settings changes the characteristics of the x-ray beam. We can change both the energy and number of x-ray photons that make up the x-ray beam – and depending on what body region we are interested in, this can greatly change the appearance of the resulting image. An understanding of this principle can go a long way to improving the contrast in thoracic and abdominal radiographs.

In simple terms, kVp changes the energy or power (kVp: p = power) of the x-ray photons in the beam. Higher energy photons pass through the body more readily and fewer are absorbed by the tissues. mAs changes the number of x-ray photons in the beam (mAs: m = more). A higher mAs setting creates more photons in the beam, but also increases the length of the exposure time which can increase motion artifacts.
If we think about what tissues make up the body part we are interested in, it helps to know how we want our x-ray beam to be. The thorax is made up of mainly air-filled lung, a little soft tissue (heart and blood vessels mainly), and some bone so there is a lot of inherent contrast in the tissues – air vs. soft tissue vs. bone. Plus, there is a lot of respiratory motion in the thorax so we are going to want a short exposure time to minimize the chances of a blurry image. Therefore a high kVp and low mAs setting gives us the best of both worlds – we don’t need to worry much about the energy of the x-rays being absorbed so we can have a higher kVp setting, and we want a short exposure time so a low mAs makes sense.

Looking at the abdomen though, there is mainly a lot of soft tissue, some mesenteric fat, maybe some gas in the gastrointestinal tract and some bone. The soft tissues and fat are going to have fairly similar ability to absorb the x-rays, so low inherent contrast, and we are need to make the settings maximize the amount of contrast in the resulting image so we can see the margins of the various organs. Because the organs have a similar degree of x-ray absorption, we are going to want lower energy x-rays so that more of them do get absorbed by the different tissues, and we also then need more x-rays overall to make sure we have enough that pass through to create the image. Therefore, a low kVp and high mAs setting is needed so that we end up with a higher contrast image.

Collimation

Collimation remains important both from an image quality standpoint and a radiation safety aspect. Scatter radiation is generated largely within the patient, so the larger the area exposed to radiation, the more scatter you will have. Scatter can also go in any direction, so it has a direct impact on increased radiation exposure to personnel who may be in the room at the time of exposure. Scatter also degrades the quality of the images by adding exposure to the film or detector that causes generalized decrease in contrast in the images (generally hazy grey appearance).

The cranial abdomen is a very thick body part and generates a lot of scatter which is particularly bad in thoracic radiographs. Not collimating on the thorax can create the appearance of an interstitial pattern or general hazy appearance of the caudal lung fields in a ventrodorsal projection.

The other important consideration with collimation is to make sure that the desired body region is included within the image. In large breed dogs and other animals, you may need to take multiple images such as a cranial thorax and a caudal thorax in order to image the whole region. In practice we see many studies where some regions were “sacrificed” and just not included, which obviously limits the scope of the examination. It is much better to take more images and ensure the region is adequately imaged.

Many radiography technique errors arise from the region of the body which was intended to be radiographed not being fully included in the image. For example, the lateral thorax which is centered at the thoracolumbar junction and cuts off the cranial lung lobes, or the lateral abdomen which is too far caudal and cuts off the cranial part of the liver. The light from the collimator on the x-ray machine shows you where the primary x-ray beam will be directed – assuming the x-ray machine itself is calibrated properly...
So, for the thorax, make sure the box of light covers from just cranial to the thoracic inlet and extends just caudal to the last rib, and dorsal to the spine so that the spinous processes are included, and ventral to the sternum. In larger patients you may have to take more than one image – up to four even, to cover the whole thorax.

For the abdomen, with the patient in lateral recumbency and the front legs pulled forward, the cranial edge of the box of light should be at the back edge of the scapula. This will put the cranial portion of the image over the ribs, and should ensure that the cranial portion of the liver is included. The caudal margin of the box of light should be at least to the hip joints or ischium if possible. Similar to the thorax, the dorsal margin of the box should include the spinous processes, and the ventral margin should be below the xyphoid to ensure that the ventral abdominal wall is included.

**Takeaway tips:**

1. **Tailor the machine settings to be appropriate for the body part** – thorax: high kVp, low mAs; abdomen: low kVp, high mAs
2. **Collimate on the body region to decrease scatter and preserve good image contrast.**

**Appropriate views**

Traditionally, two views was the standard for both thoracic and abdominal studies, perhaps due to increased costs for film and developing time. This likely led to the current pricing structure which often has a “per view” fee. This has persisted, and many places still routinely do two views and charge extra for more. In both thoracic and abdominal radiography, three views has become the standard. I recommend a single fee per study so you aren’t constraining yourself, or your clients don’t limit you saying they will just pay for two views rather than the added expense of three views. Obtaining a complete study is important, and changing this pricing structure may help do that.

**Thorax**

In the thorax, the “up” lung is the aerated one that you visualize best in a lateral projection. Right lateral images let you well visualize the left lung lobes. Left lateral images let us see the right lung lobes best. Still, typically a right lateral and a ventrodorsal projection are included in a standard study of the thorax and abdomen. If we think about aspiration pneumonia for example though, and our knowledge that this is most commonly seen in the right middle lung lobe, then we should at the very least be taking a left lateral projection to see the right lung lobes rather than a right lateral projection.

Either a ventrodorsal (VD) or a dorsoventral (DV) view will work for the thorax. The VD view tends to be the one most commonly performed, and is better for visualizing smaller volumes of pleural fluid as the fluid seeps between the lung lobes rather than in a DV view where the fluid will pool around the mediastinum. A DV view can be better for cardiac patients as many with respiratory distress will be more comfortable in sternal recumbency rather than dorsal recumbency. The DV view is also better for visualizing the caudodorsal lung fields and caudal lobar pulmonary vasculature. Increased aeration of the caudal lung lobes in the DV view makes it more sensitive for detecting subtle pathology in the caudal lung lobes. Additionally, the heart is closer to the table and detector so there is less possibility for magnification or rotation of the heart as can be seen with the ventrodorsal projection.
A four-view thoracic study (LL, RL, VD, DV) may also be of benefit for checking for metastasis as you get maximum aeration in the caudal lung lobes in the DV projection, better visualization of the ventral aspect of the lungs in the VD, and both lateral projections to aid in assessing the right and left lungs. However, this is not routinely done outside an oncology setting.

**Pulmonary Patterns**

We generally speak of pulmonary patterns as being one of three major categories: interstitial, bronchial or alveolar. Along with this we can also certainly have pulmonary patterns which are a mixture of these broader categories. It is also important when describing and categorizing the pulmonary pattern to try and quantify it as well – mild, moderate or severe – though this is somewhat subjective. Pulmonary patterns tend to be frustrating to us as veterinarians, certainly when we first were learning about them in veterinary school, and unfortunately can remain so throughout our careers. The goal is to categorize the radiographic changes we are seeing, apply a list of differential diagnoses, and correlate these with our clinical suspicions in order to rank the most likely differentials first.

Proper radiographic technique is particularly important for evaluation of the lungs as exposure factors, positioning, and aeration of the lungs can have a dramatic impact on our ability to identify pathology and differentiate pathology from artifact.

**Normal:** In normal lung the pulmonary parenchyma should be well aerated and thus mainly radiolucent resulting and darker areas in the image, generally a homogenous light grey. In a well-exposed image there should be clear visibility of blood vessel margins with sharp delineation of the larger vessel walls, and also clear visibility of thin walled bronchi. Numerous resources exist which describe normal radiographic pulmonary and cardiovascular anatomy, and these atlases are an excellent tool when assessing thoracic radiographs.

**Interstitial pattern:** Interstitial patterns are divided into structured and unstructured patterns.

  Structured interstitial pattern: nodules or masses in the lungs. Generally, these are fairly easy to identify. Remembering which lateral recumbency will facilitate better viewing of lung lesions is of benefit here – a nodule in the right caudal lung lobe will typically be better visualized in a left lateral projection. More aerated lung will help visualize nodules, so a dorsoventral projection may be preferred to a ventrodorsal projection to see nodules in the caudal lung lobes. Nodules must reach a certain size in order to be visible radiographically – if they are too small, then they do not absorb enough x-rays to be visible in the resultant image. Nodules as small as 4 mm can be seen, though typically a threshold of 7-9 mm improves detection rate. Thus, it is clear that metastatic nodules can be present in radiographically normal lungs. End on blood vessels can have the appearance of nodules, so if you are seeing a small, opaque round structure which is 4 mm or less and more opaque than expected, consider an end on blood vessel. Differentiation between a nodule and a mass is generally based on size, with nodules being less than 2 cm in diameter, and masses being greater than 2 cm in diameter.

  Unstructured interstitial pattern: results from fluid or cellular infiltration into the interstitium of the lungs, and is not organized into discrete lesions, but causes a patchy or diffuse increase in opacity of the lungs. Typically this is seen as decreased ability to discern margins of structures such as the blood vessels or margins of the heart. Low grade inflammation, pneumonia, cardiogenic or non-cardiogenic edema, pulmonary contusions from trauma, and infiltrative neoplasia such as lymphoma can all be
causes of an interstitial pattern. This is probably the most misdiagnosed lung pattern due to the fact that other factors can cause the appearance of an interstitial pattern. Increased extrathoracic body fat can superimpose with the lungs and cause generalized increased opacity of the pulmonary parenchyma. Images acquired in the expiratory phase of respiration will have an interstitial pattern due to atelectasis.

**Bronchial pattern:** Created when the bronchial wall is thickened by cellular or fluid infiltration or when cells or fluid infiltrate the immediate peribronchial space (bronchial cuffing). Radiographically with a bronchial pattern there are distinct rings of end-on bronchi or parallel lines (tram lines, train tracks) when viewed in a longitudinal orientation. A mild bronchial pattern can commonly be seen in older dogs with age-related fibrosis. Bronchitis of allergic or inflammatory causes, infectious or parasitic causes can cause a bronchial pattern. Early pulmonary edema in cats can start in the peribronchial interstitial space giving the appearance of a bronchial pattern.

**Alveolar pattern:** An alveolar pattern is caused by filling of the alveoli with fluid, mucous, pus or blood and thus increases the opacity of the lung. This lung consolidation causes several features that help to define an alveolar pattern:

- Air bronchograms – the opaque surrounding lung tissue highlights the still air-filled larger bronchi and makes these bronchi easily visible against the white background of the alveolar pattern.
- Lobar sign – the opaque, consolidated lung tissue forms sharp margins when seen at the edge of the lung lobe and is adjacent to normal aerated lung. The alveolar pattern in the right middle lung lobe commonly seen with aspiration pneumonia is a good example of a lobar sign.
- Area of intense opacity which does not have clear margins – this is one feature which can help distinguish an alveolar pattern from a heavy interstitial pattern. As stated previously, with an interstitial pattern the margins of blood vessels and other structures are visible, but are blurred or less distinct. With an alveolar pattern, you lose the ability to distinguish underlying structures – vessel margins and the margins of the heart may not be visible.

**Mixed patterns:** As we know with living creatures, it is difficult to tidily put things in little boxes. We very commonly have mixed patterns – interstitial to alveolar and bronchointerstitial are typical combinations due to disease in transition, or one disease process that can cause more than one radiographic abnormality. With congestive heart failure we typically think of an interstitial pattern representing cardiogenic edema, but with the effects of gravity and progressive buildup of edema, this can coalesce into patches of alveolar pattern and then even to a more ventrally distributed alveolar pattern. Bronchopneumonia, as another example, can even have all three lung patterns – a bronchial pattern due to thickened bronchi, peribronchial inflammation causing an interstitial pattern, and regions of consolidated lung and alveolar pattern.

**Abdomen**

A three view study has become the standard for evaluation of the abdomen as well. The different views aid in moving gas around within the gastrointestinal structures which aids in assessing the anatomy. Generally in a right lateral projection there will be gas in the fundus of the stomach, and fluid in the pylorus. The fluid filled pylorus often looks like a round ball and is sometimes mistaken for a foreign body or mass. The left lateral projection moves the fluid into the fundus of the stomach and gas into the pylorus and often the proximal duodenum. The left lateral projection is often not performed, but is one
that can be very helpful in looking for pyloric or proximal duodenal foreign bodies! A ventrodorsal projection is standard, but sometimes a dorsoventral projection can also be useful in evaluating the stomach or to reposition gas within the intestines.

In the normal abdomen, we should expect good serosal detail – that is, easy distinction of the margins of the liver, spleen, stomach, intestinal segments, kidneys and urinary bladder. In bigger dogs it there may not be great serosal detail, but usually some definition of structures is visible. Thin patients with little body fat can have poor serosal detail and not have peritoneal fluid.

In dogs and cats, the liver should generally end in the region of the costal arch, but in older animals can sag and extend more caudally. The caudoventral margin of the liver should taper to a point, with rounding of this margin seen as a sign of mild hepatomegaly. The gastric axis should be parallel to the ribs in the lateral projections and for dogs is generally perpendicular to the spine, and in cats can form more of a “J” in the left cranial quadrant.

The tail of the spleen can have variable positioning and with experience, one will learn normal variations in the appearance of the spleen. Splenic size is somewhat subjective, but in general in dogs the tail of the spleen is seen in the ventral abdomen in the lateral projection as a rounded, oblong structure adjacent to the ventral body wall, or as a thin linear structure along the ventral abdominal wall. The tail of the spleen is typically not visible in the lateral projection in cats.

The kidneys in normal dogs range between 2.5-3.5 times the length of L2, and in cats the range is 2.4-3 times the length of L2. The urinary bladder is of variable size depending on the volume of urine in the lumen.

The small intestine should be a uniform diameter throughout the abdomen and generally has gas and fluid in the lumen. Multiple schemes for measuring intestinal diameter have been developed, with small intestinal diameter in dogs typically being normal if less than twice the width of a rib, or less than 1.6 times the height of the L5 vertebral body. In cats, the small intestine is supposed to be less than 12 mm in diameter, or the intestinal diameter should have a maximal small intestinal diameter to L2 vertebral endplate height of 2.0 or less. The cecum can be seen as a tortuous gas filled structure which is often in the right cranial abdomen in the ventrodorsal projection, or in the mid to dorsal abdomen in the lateral projections. The colon is of variable distension depending on the quantity and consistency of feces in the lumen.

**When to make the exposure: Inspiratory vs. Expiratory**

For the thorax, the contrast and image detail is maximized if the images are acquired at **full inspiration** when the lungs are at maximal aeration. This provides the best visualization of the blood vessels and subtle pulmonary patterns. With expiratory lungs, increased opacity in the lungs due to lack of aeration can be mistaken for or can mask true lung pathology. In addition, the heart appears larger within the thorax and a misdiagnosis of cardiomegaly can occur. In anesthetized patients it is important to use positive pressure ventilation to achieve maximum inspiration. You have control of the airway, so use that to your advantage to make your exposures during breath holds at peak inspiration!
For the abdomen, the opposite is true and it is best to acquire the images at **full expiration** which helps to spread out the abdominal organs so there is less superimposition of structures and there will be improved visibility of the organ margins.

**This is another reason that whole body radiographs are not adequate -- there is no way to have an inspiratory thorax and expiratory abdomen in the same image!**

**Patient Positioning**

Ensuring good positioning of the patient is another important step in making a confident diagnosis. Light sedation can make a huge difference in the ability to get well positioned images and can be safer both for the animal and the staff rather than struggling with the dog or cat.

In the thorax, straight positioning is somewhat more important than for the abdomen, but is still important for both and makes our job of obtaining a diagnosis MUCH easier, purely from having well positioned images.

Why does it matter?

1. Normal anatomy looks normal.
2. Makes it easier to compare old images to new images.
3. You don’t have to decide whether an odd looking structure is due to poor positioning or is actually abnormal.
4. Helps you have a routine approach to evaluating the images.
5. Helps you to develop pattern recognition -- radiology is in some ways an art and repetition of patterns -- knowing normal and variations of normal, helps make abnormalities jump out at you.

**Conclusion**

Much of the mystery sometimes surrounding radiology can be removed by focusing more on some of the basics of quality control. With adequate views, proper exposure settings and timing, and good patient positioning, our job becomes much easier.

If we spend some time and energy in promoting these good practices in our institutions, it will help the staff to learn what is expected and what good quality is. They will get practiced at acquiring good quality radiographs, and the number of retakes needed to get them will decrease. Our degree of confidence in making a diagnosis increases, and our patient care improves even more.

Please feel free to contact me with further questions!

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