DIAGNOSTIC IMAGING FOR TECHNICIANS: POSITIONING AND TECHNIQUE FOR THORACIC AND ABDOMINAL RADIOGRAPHS

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The goal of veterinary radiology is to safely and efficiently produce diagnostic images.[1] Therefore, it is essential that veterinary technicians think critically about patient anatomy and positioning, radiological standards, and proper radiographic technique in order to effectively and consistently produce diagnostic radiographs.

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Learning Objective

Readers will gain an understanding of the veterinary technician's role in producing diagnostic thoracic and abdominal radiographs, be able to accurately position patients and critically evaluate radiographs of the abdomen and thorax.

Figure 1: Two technicians position a patient for a VD (image A) and right lateral (image B) thoracic radiograph. One technician restrains the head of the patient and pulls the forelimbs cranially towards the head. The second technician centers the beam on the heart and palpates the xiphoid process and the thoracic inlet to collimate the beam appropriately. Note that this a large dog and additional images may be necessary to include the entire lung field.

Radiological Standards

There are several radiological standards that should always be followed to produce anatomically accurate images. These standards are: obtain a minimum of two orthogonal views in a study, center the beam on the anatomy of interest, collimate appropriately, include a directional marker, and adhere to ALARA.[1,2,3] Orthogonal images (two two-dimensional images taken at right angles to each other) allow visualization of three-dimensional anatomy. For example, a fracture may be displaced in only one plane, meaning that it may not be visible in a lateral view, but can be easily appreciated in a craniocaudal view or vice versa.[2,3] In an abdominal study, an abnormally dilated small intestinal loop may be misinterpreted as the colon if only one image is available for evaluation. The colon can more often be differentiated from the small intestines when two orthogonal images of the abdomen are viewed concurrently.

In accordance with the other radiological standards, technicians should center the x-ray beam, use directional markers, and collimate appropriately. Centering the beam over the anatomy of interest minimizes distortion of anatomy that occurs when objects are outside the central part of the x-ray beam.[4] Directional markers should always be placed in the field of view to ensure accurate identification of patient position and anatomy.

Collimation ensures adequate image quality and personnel safety by reducing scatter radiation.[1] The patient does not absorb all of the x-rays produced during imaging. Some x-rays pass through the patient, and others are scattered in different directions, rebounding off objects in their path. Scattered x-rays may strike the image receptor and cause loss of image contrast which degrades radiographic quality.[2] Some x-rays will travel toward personnel in the room where they may be absorbed (and cause biological damage) if proper personal protective equipment such as lead aprons, thyroid shields, and gloves are not worn.

The radiological safety standard established by the United States Nuclear Regulatory Commission is known as ALARA, or As Low As Reasonably Achievable. ALARA has three tenets: reduce time, increase distance, and use proper shielding. If ALARA is followed, patient and personnel exposure to ionizing radiation is kept to the achievable minimum.[1,2,5] Following all of the standards listed above and wearing personal protective equipment adheres to the ALARA principle.

In addition to following the aforementioned standards, personnel should always remove patient collars and other accessories before any radiographic study. Removing accessories decreases image artifacts, improves visualization of anatomy, and decreases misinterpretation of accessories as anatomy or pathology. If possible, fur should be clean and dry to decrease the appearance of wet hair and dirt artifacts on the image.

Thorax Positioning

The goal of positioning the patient for any radiograph is to place the animal so that the anatomy is accurately represented. Sedation or anesthesia can be used when appropriate. The patient should not be rotated unless the intention is to produce an oblique image. Palpating normal anatomical features and recognizing normal anatomical landmarks on the x-ray image is necessary to correctly position the patient and evaluate the image. The ventrodorsal (VD) or dorsoventral (DV) and right and left lateral thoracic radiographs should be centered on the heart and include the entire lung field and surrounding ribs. The crosshairs of the collimator should be positioned in the middle of the thorax, which is approximately at the level of the heart base and the 5th intercostal space. The technician can determine the location of the heart by palpating the heartbeat or by flexing the forelimb and positioning the crosshairs at the point where the elbow touches the thorax. The patient is positioned by pulling the forelimbs forward and fully extending the elbows away from the chest. This prevents the soft tissues and bones of the forelimbs from being superimposed over the cranial thorax.[6] The sternum and spine should be placed in a parallel plane to ensure that the patient is straight. The cranial margin of the collimator light is placed at the level of the thoracic inlet and the caudal margin extends 1.5 to 2 inches (two to three finger-widths) past the xiphoid process. Collimation should include the cranial and caudal margins and the complete thoracic body wall (Fig 1).

It may not be possible to obtain all margins in a single image on larger patients. The initial image should be centered on the heart and include the thoracic inlet. Additional images may be necessary to include the caudal lung field and the thoracic body wall. Note that the collimator light should only be moved laterally enough to include a small amount of empty space beyond the chest wall. The objective is to maintain an image field that contains the most anatomy appropriate to the study.

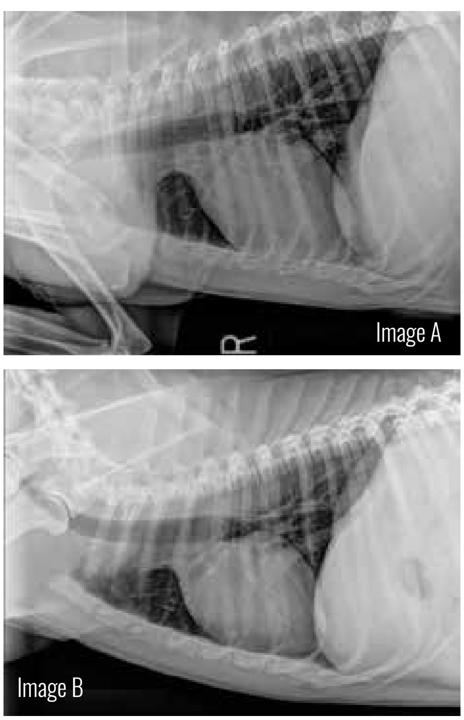


Figure 3: In image A, the patient is rotated. Note the space between the rib heads. Also, the cranial portion of the lungs are obscured by the elbows. In image B, the rotation of the thorax is reduced, the rib heads are nearly superimposed. Also, not that the forelimbs are extended away from the thorax, so that the cranial thorax is not obscured by bone or musculature.

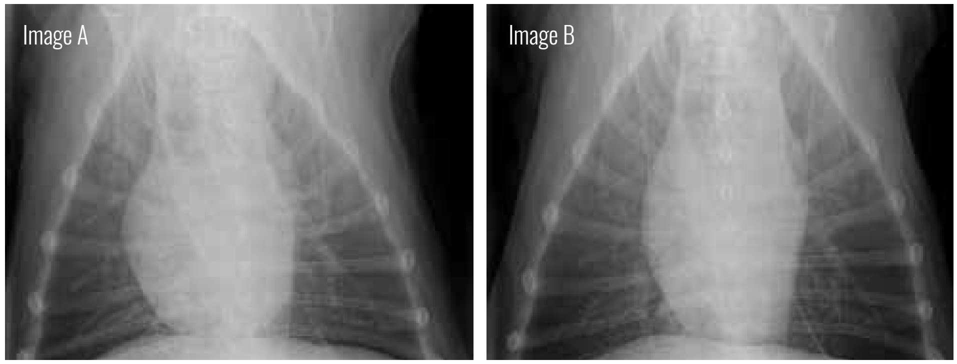


Figure 2: In image A, the patient is rotated, distorting the shape of the heart. Rotation is noted by the elongation of the dorsal spinous processes of the thoracic vertebrae. Image B is straight, showing the true appearance of the heart.

Alternate thoracic images that can be obtained in addition to the VD and right/left laterals include the DV, the VD with the arms pulled caudally, and oblique images. The canine heart is less affected by chest conformation when the patient is placed in the DV position.[8] The vessels in the caudal lung lobes, which are important in evaluating heart disease, are better magnified in the DV position in both dogs and cats.[2,9,10] The forelimbs can be pulled caudally on the VD view to eliminate summation of the scapulae over the thorax and improve visualization of abnormalities in the cranial thorax.[6] Oblique images are appropriate when it is necessary to improve visualization of questionable pathology.

The exposure should be obtained at peak inspiration when the lungs are fully inflated. This ensures the best visualization of vessels and lung parenchyma and provides maximum contrast between air and soft tissue. Peak inspiration is noted on the image by the movement of the cardiac apex away from the diaphragm, expansion of the left lung cranially to the level of the first rib, and caudal lung lobe expansion past the twelfth thoracic vertebra. Images obtained on expiration show an artefactual interstitial pattern and can be misinterpreted as evidence of lower airway disease.[2]

Radiographic Evaluation

In a properly positioned VD radiograph of normal anatomy, the sternum will be superimposed over the spine, the dorsal processes of the thoracic vertebrae will appear centered over the vertebral bodies with a “tear drop” shape, and the heart will appear evenly divided by the spinal column with the apex pointing to the left side of the patient. Visualization of the sternum to either side of the spine, the appearance of the dorsal spinous processes outside the center of the vertebral bodies, and/or the apparent elongation of the spinous processes indicates that the patient is rotated.[7] (Fig. 2).

Holmes et al note that images in which the dorsal spinous processes extend outside the bounds of the vertebral bodies are not suitable for evaluating cardiac changes. Rotation causes the right heart to appear larger and the left heart smaller, possibly leading to inaccurate cardiac measurements. Rotation on the VD can also misrepresent the shape of the heart and its association with other structures by allowing visualization of cardiac anatomy not normally appreciated.[8]

A properly positioned lateral radiograph is indicated by superimposition of the rib heads.[7] Rotational malposition will result in separation of the rib heads and space between the arches of the ribs (Fig 3). The amount of space between the arches of the ribs directly relates to the extent of patient obliquity. The rib heads may not align in some barrel-chested dogs. In those instances, proper positioning may be judged by the superimposition of the costochondral junctions.

Critical evaluation of the radiograph requires knowledge of soft tissue anatomy. The trachea, heart, great vessels, lungs, and diaphragm can all be visualized on the lateral and VD thoracic radiographs (Fig. 4). Identifying these structures and

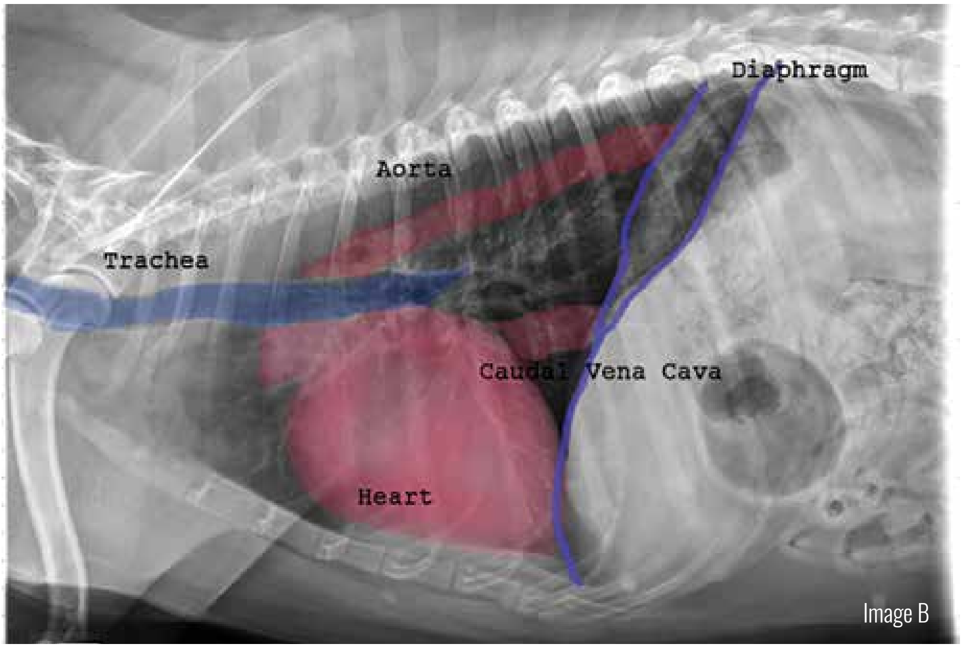


Figure 4: Image A and B are identical. The trachea, heart, aorta, caudal vena cava, and diaphragm are labeled on image B.

appreciating their normal appearance strengthens the ability to evaluate patient positioning and recognize radiographic pathology.

Three-view vs. Two-view

As stated above, the radiological standard is a minimum of two orthogonal views in a study, but a complete evaluation for pathology in a thoracic study can only be achieved by obtaining a VD or DV image, right lateral image, and left lateral image. In lateral recumbency, air is pushed out of the dependent lung by body weight, compression from the heart, cranial displacement of the dependent crus of the diaphragm, and restricted movement of the dependent hemithorax due to compression of the chest.[2] Collapse or atelectasis of the dependent lung occurs quickly in lateral recumbency.

Compression causes decreased aeration of the dependent lung which can obscure the visualization of lung disease, such as nodules and subtle pneumonia. Prolonged recumbency can cause an overall increase in tissue density in the dependent lung (recumbent atelectasis) which may be misinterpreted as lung disease.[2,6,11] Lesions in the non-dependent lungs are better visualized because structures with a soft tissue opacity are more readily detected when surrounded by well aerated lung tissue. This is due to the radiographic contrast between air and soft tissue.[2,12] Conversely, air-filled bullae are better visualized in the dependent lungs due to the radiographic contrast of the air-filled structures against the soft-tissue appearance of the compressed lung.[6] Simply stated, the effects of recumbent atelectasis are such that the left lung is more completely evaluated on the right lateral image, and the right lung is more completely evaluated on the left lateral image.

Anesthesia and sedation can worsen atelectasis.[2] Optimally, patients should not be sedated for thoracic imaging. If anesthesia is necessary for thoracic imaging, the patient should be kept sternal during induction and as much as possible while under anesthesia. Positive pressure ventilation should be used during the image exposure to maintain lung inflation. The technician should maintain an inspiratory pressure between 15-20 mm Hg, monitoring carefully that this limit is never exceeded and that pressure is immediately released following the image exposure.[13] In a study comparing 300 three-view and two-view thoracic studies of 100 dogs, Ober and Barber reported that there were 29 instances in which the reviewer found the two-view study negative for a lesion, but made a positive diagnosis after reviewing the three-view study. There were thirteen instances in which a nodule was diagnosed on the two-view thoracic study, but not on the corresponding three-view thoracic study of the same patient.[11] Although the researchers did not evaluate the reviewers diagnoses for accuracy, the disagreement between the two-view and three-view studies indicates that there is a discrepancy of information gained. Thus,

Figure 5: Position the cranial portion of the coxofemoral joint/femoral head in the radiograph to ensure assessment of the entire caudal abdomen

the authors reasoned that diagnostic information is maximized by obtaining a three-view thoracic study.[11]

Abdomen Positioning

The abdominal study is usually comprised of two views: the VD and the right lateral. Similar to the thoracic study, there are anatomical markers that can be palpated on the patient or appreciated on the radiograph that act as positioning guides. Familiarity with these landmarks is essential to producing a diagnostic image.
The cranial margin for the VD and right lateral abdominal image is 1.5 to 2 inches (2-3 finger widths) cranial to the xiphoid process, and the caudal margin is the femoral heads. The xiphoid process is palpated in the same manner as in the thoracic study, but the cranial margin of the collimator light is placed 1.5 to 2 inches cranially to the xiphoid process rather than caudally. Radiographically, the entire diaphragm should be visualized. The approximate location of the coxofemoral joint can be found by moving the hindlimb and palpating for movement of the greater trochanter of the femur. The cranial portion of the coxofemoral joint/femoral head must be included in the radiograph in order to ensure assessment of the entire caudal abdomen (Fig. 5.)

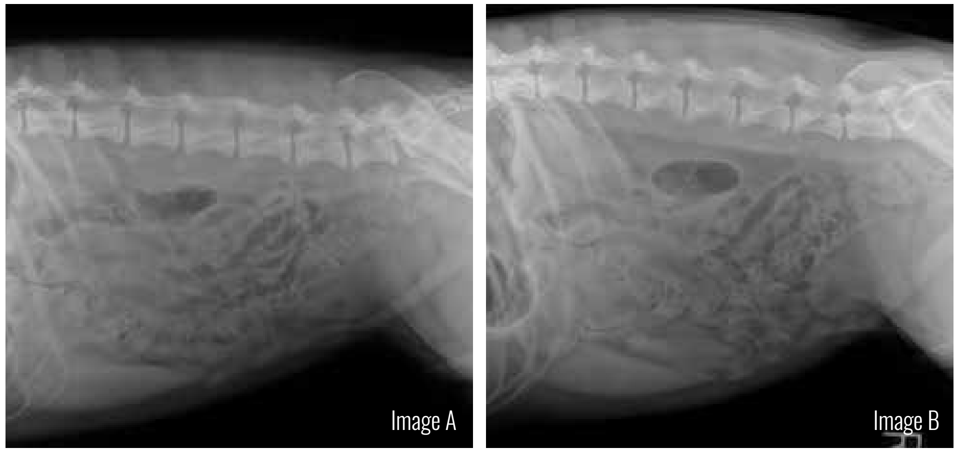
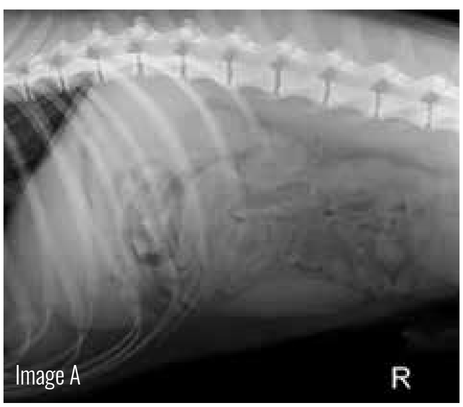


Figure 6: In image A, the patient is rotated and the transverse processes of the lumbar vertebrae are distinct and elongated in appearance. In image B, the patient has been repositioned by aligning the spine and sternum. The transverse processes of the lumbar vertebrae are superimposed. Note the improved visualization of the retroperitoneal space. Another image including the diaphragm is necessary for a complete evaluation of the lateral abdomen.

The exposure should be taken on complete expiration. The diaphragm moves caudally on inspiration, crowding the abdominal organs. Although not as critical as obtaining the thoracic image on inspiration, obtaining the abdominal image on expiration will increase the diagnostic quality of the radiograph.[2]



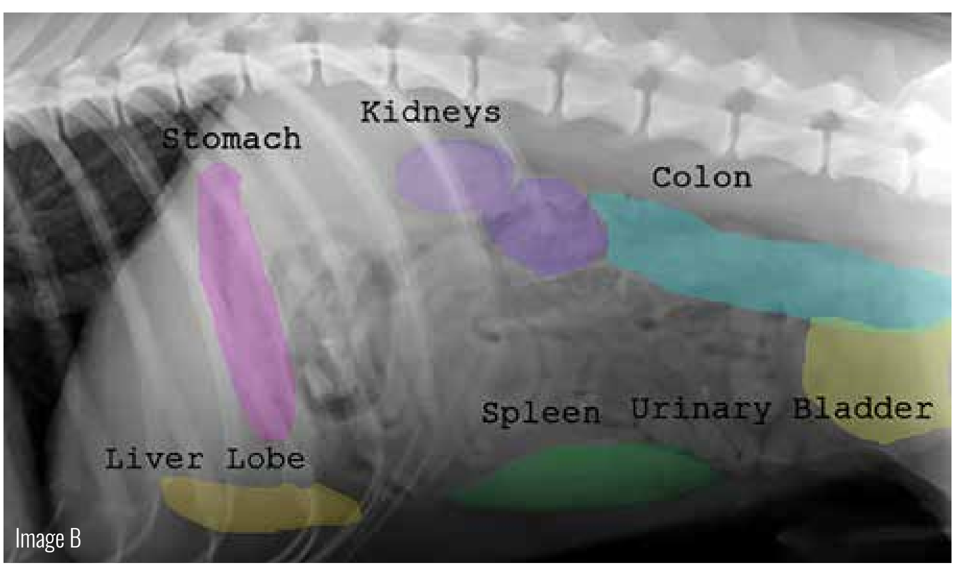


Figure 7: Image A and B are identical. The stomach, liver lobe, kidney, tail of spleen, colon, and urinary bladder are labeled on image B.

Radiographic Evaluation

As stated above, the cranial margin of the abdominal radiograph is the cranial border of the diaphragm, and the caudal margin is the femoral heads. On the VD image, the body wall should be fully visible on both sides of the abdomen. On the lateral image, the ventral body wall and the dorsal aspect of the spine should be included. The hind limbs should be placed in a natural anatomical position perpendicular to the abdomen.[2]

The position of the dorsal processes of the lumbar vertebrae are evaluated to determine if the patient is positioned correctly on the VD image. The spinous process will be centered over the vertebral body and have a “tear drop” shape in a correctly aligned image of normal anatomy. Rotation will distort the spinous process and shift it off the center of the lumbar vertebral body.

On the lateral abdominal image, the positioning of the lumbar vertebral transverse processes are evaluated to determine an accurately positioned lateral image. The two transverse processes of each vertebrae will be superimposed (appearing as one process) when the patient is correctly positioned. The transverse processes will appear as two distinct separate processes in an oblique (rotated) patient (Fig. 6).

The ability to identify normal organ appearance on an abdominal radiograph will aid in positioning. Additionally, knowledge of anatomy is critical to evaluating the radiograph for pathology. The stomach, liver, spleen, kidneys, intestines, and urinary bladder are all visible in the lateral and VD radiographs of a normal abdomen (Fig. 7).

Additional Views

The VD and right lateral images are sufficient for most abdominal studies. Urinary studies and cases of suspected gastric foreign body may require additional views for complete evaluation of the abdomen and to increase accuracy of interpretation. In right lateral recumbency, the pylorus of the stomach is dependent. Gravity will pull fluid and ingesta from the fundus into the pylorus, causing it to have a soft tissue opacity, which can be misinterpreted as a mass.[2] Alternately, the stomach contents may obscure a foreign object of similar radiographic density in the pylorus. Left lateral recumbency has the opposite effect, allowing fluid and ingesta to settle in the fundus and gas to rise up into the pylorus. A left lateral image will allow for a more thorough evaluation of the pylorus as radiographically contrasting gas (air) will fill the lumen of the pylorus (soft tissue). Air in the pylorus can help distinguish it from a mass or can enhance visualization of foreign content within the stomach. (Fig 8). An additional right lateral view of the caudal abdomen should be obtained in male canine patients with lower urinary tract symptoms. This image is critical because portions of the penile urethra are obscured by the pelvic limbs on a standard right lateral image. The hind limbs should be pulled cranially towards the body until the penis is ventral to the femurs.[2] This view will allow a more complete evaluation of the urethra and visualization of urethral calculi. Decreasing the x-ray technique may be necessary to prevent overexposure of the soft tissues (Fig 9). A right lateral image including the entire pelvis and soft tissues may be beneficial for evaluation of urethral obstruction in female dogs and male and female cats. The hind limbs may remain in a natural anatomical position, but the image should be collimated to include the complete hind end of the patient.

A compression image may be taken in cases when urinary bladder stones are suspected, and the urinary bladder is obscured by the colon or small intestines on the right lateral image.[2] A wooden spoon or a specialized radiolucent paddle can be used to compress the abdomen and displace the colon or small intestine away from the urinary bladder to improve visualization. (Fig10). Finally, oblique images may be taken if necessary to evaluate pathology not appreciated on the VD or lateral views.

Radiographic Contrast and Density: Thorax and Abdomen

Correct radiographic technique is also important in creating diagnostic images. A perfectly positioned patient will not yield diagnostic data if the image is overexposed or underexposed. Although technique settings are different for each x-ray machine, it is important to understand how image contrast (kVp) and image density (mAs) play a role in radiography, and how contrast varies between the thorax and abdomen. The kVp and mAs should be adjusted appropriately to create a balanced radiographic image with the appropriate density and contrast. Kilovoltage peak (kVp) and milliamperage-seconds (mAs) are the two technique settings which affect the power and the quantity of the x-rays produced. The mAs setting affects the quantity of electrons that are available to create x-rays, therefore affecting radiographic density or the overall blackness of the image. The kVp setting changes the penetrating power of electrons and is the most important factor that affects radiographic contrast. Radiographic contrast refers to the varying shades of grey between adjacent areas on the radiograph and is inversely related to kVp.[1] Bone appears white, soft tissues and fluid appear as various shades of grey, and air appears black on a radiographic image. A high contrast image has more blacks and whites and less grey. A low contrast image has mostly shades of grey. The thorax has inherently high contrast because the air-filled lungs appear black against the white of the thoracic skeleton and the grey soft tissues of the heart and

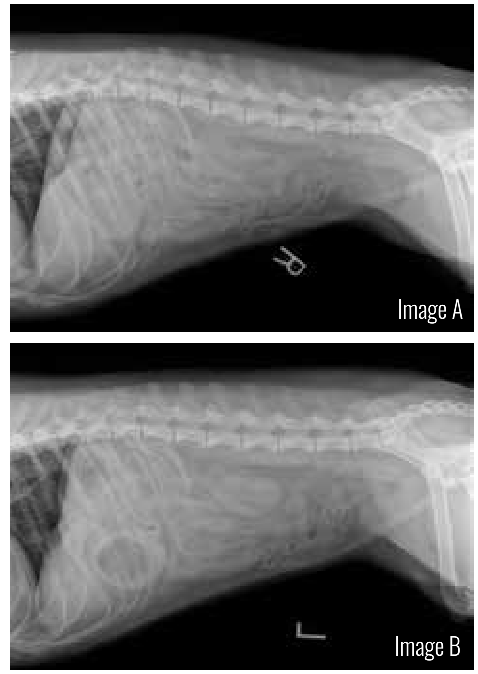


Figure 8: Image A is a right lateral abdominal image. The pylorus is fluid-filled causing a mass effect in the abdomen. Image B is an abdominal left lateral image of the same patient showing the lumen of the anatomically normal pylorus filled with gastric gas.

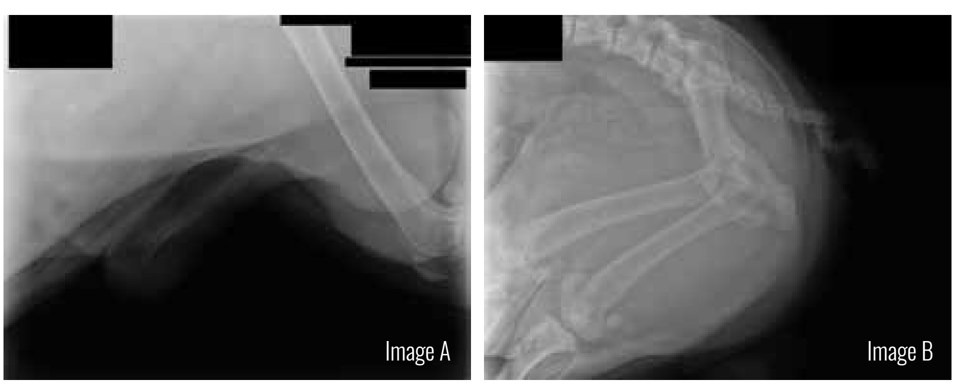


Figure 9

Image A is a right lateral abdominal radiograph with the hind limbs placed in a natural anatomical position. The femurs are obscuring calculi present in the urethra. Image B shows the same patient with the legs pulled forward so that the urethral calculi is more easily visualized.

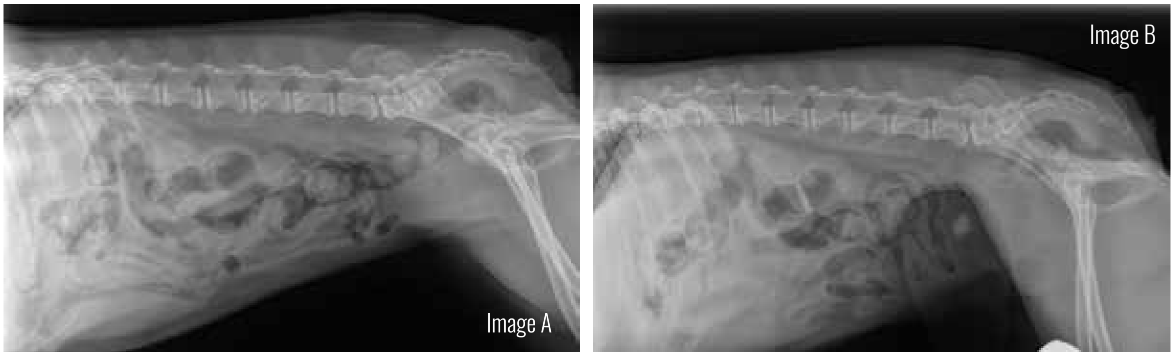


Figure 10: Image A shows an abdominal radiograph in which the colon is superimposed over the urinary bladder. In image B, the colon is compressed and moved dorsally with a wooden spoon, revealing urinary bladder calculi that was obscured by the colon.

vessels. The abdomen has inherently low contrast because it contains predominately soft tissue structures of similar, but varying radiographic densities, creating an image with many shades of grey.

A low kVp creates less energetic x-rays. The low energy x-rays are able to penetrate air and some soft tissues, exposing the film and causing it to appear grey or black. These x-rays are less able to penetrate bone (which is denser than soft tissue and air), and less x-rays expose the film, causing the film to appear white. Thus a low kVp setting will create high radiographic contrast between bone and soft tissue or air and should be used when imaging parts of the body with inherently low contrast (such as the abdomen.)[1] A low kVp (in conjunction with a high mAs) setting increases contrast and enhances the subtle differences in the many grey shades of an abdominal radiograph.[2]

A high kVp setting creates more energetic x-rays. Higher energy x-rays are able to penetrate bone and denser soft tissues. Therefore, more x-rays expose the film, enhancing shades of grey, rather than black and white contrasts. Thus, a high kVp creates low radiographic contrast and should be used when imaging parts of the body with inherently high contrast (such as the thorax.)[1,2] A high kVp (in conjunction with a low mAs) decreases contrast and allows for better visualization of small vessels in the lungs and other subtle anatomy in the thorax.

Conclusion

Radiography is an essential diagnostic tool in veterinary medicine. The diagnostic value of a radiograph is largely reliant on the technical skill with which it is produced. Knowledge of positioning and anatomy is crucial to producing a radiograph that will afford the clinician the greatest chance of making an accurate diagnosis.[14] Technique settings with proper radiographic density and radiographic contrast are also crucial. Without contrast, it would not be possible to view discrete anatomical structures.[2] Accordingly, technicians must think critically about anatomy, patient positioning, and radiographic technique in order to produce diagnostic images safely and efficiently.

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Article Questions

1. Which of the following statements are standards that should be followed for any radiographic study?

a. obtain a minimum of two orthogonal views

b. collimate to include as much of the patient's body as possible

c. center the x-ray beam on the center of the patient

d. only follow ALARA when you are not in a rush

2. Which of the following statements apply to the safety standard known as ALARA?

a. ALARA stands for As Long As Reasonably Attainable

b. there are three tenets of ALARA; reduce time, increase distance, use proper shielding

c. ALARA is necessary only for patient safety

d. ALARA is important to people who work with plutonium, not veterinary technicians

3. If a thoracic lateral radiograph is correctly positioned, what features are present?

a. the image is centered on the diaphragm

b. the majority of the apex of the heart is superimposed over the diaphragm

c. the forelimbs are pulled cranially, so that there are no soft tissues or bones overlapping the cranial thorax

d. the caudal lung tips are not included in the image

4. A three-view thoracic study is recommended because:

a. laterally recumbent atelectasis may cause an apparent increase in opacity of the dependent lungs, leading to misdiagnoses of pathology

b. soft-tissue density pathology may be difficult to visualize if present in the dependent lungs

c. air-filled structures such as bullae may be difficult to visualize if present in the inflated lungs

d. all of the above

5. Which of the following views may be necessary when radiographing a patient with lower urinary tract disease?

a. a DV with the forelimbs pulled caudally

b. a right lateral with the hind limbs pulled cranially and dorsally

c. a VD with the hind limbs pulled cranially and dorsally

d. a left lateral