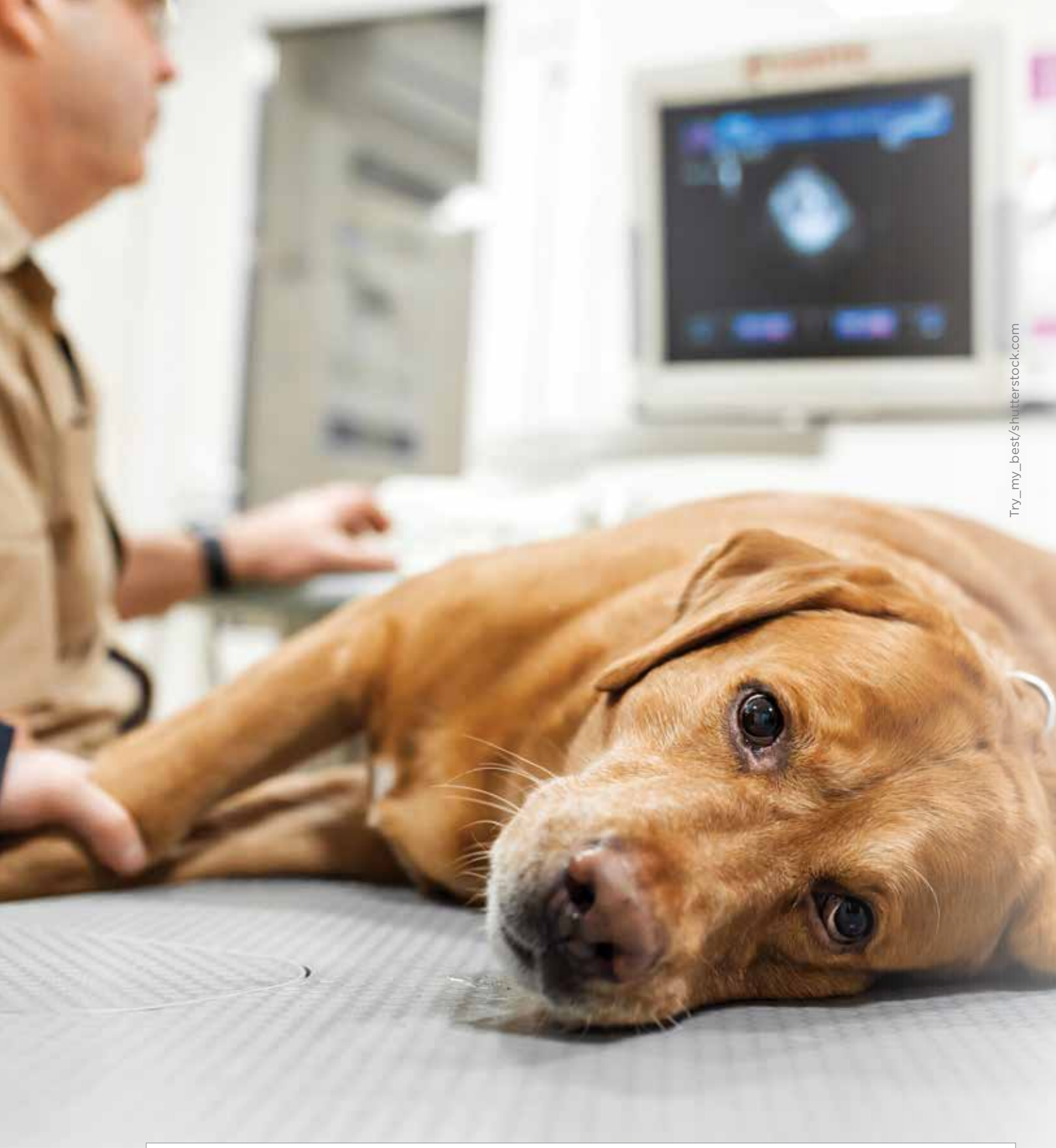




Abstract

This article compares the abilities of 3 imaging modalities—TFAST (thoracic focused assessment with sonography for trauma), radiography, and computed tomography—to facilitate the diagnosis of emergent thoracic injuries. Knowing the strengths and weaknesses of each modality enables the veterinary team to quickly identify life-threatening conditions, stabilize the patient, and implement life-saving therapies, all of which can improve the patient's prognosis.



RADIOLOGY/IMAGING

Evaluating TFAST, Radiography, and Computed Tomography in Emergent Thoracic Cases

Lydia Trott, BS, RVT, VTS (DI)

Purdue University College of Veterinary Medicine, West Lafayette, Indiana

This article explains how the veterinary team can effectively assess the extent and severity of thoracic injury with thoracic focused assessment with sonography for trauma (TFAST), radiography, and computed tomography (CT). This assessment promotes prompt implementation of targeted interventions to stabilize the patient's condition (**TABLE 1**). The veterinary team should strive to obtain optimal imaging studies, ensuring the veterinarian has the necessary information to make

an accurate imaging diagnosis. That diagnosis enables the veterinarian to make therapeutic decisions, which are paramount for reducing illness and death (**TABLE 2**). Common terms and definitions are found in **TABLE 3**.

TFAST

TFAST is a type of point-of-care, cost-effective, goal-directed ultrasonography. TFAST does not

Take-Home Points

- Following a cursory physical examination of a patient in respiratory distress, thoracic focused assessment with sonography for trauma (TFAST) can help quickly confirm or deny suspected diagnoses.
- The recommended emergent thoracic radiographic views are dorsoventral or ventrodorsal, left to right laterolateral, right to left laterolateral, and ventrodorsal horizontal beam in right or left lateral recumbency.
- Horizontal beam radiography may be more sensitive than a standard 3-view thoracic series for detecting mild to moderate pneumothorax and pleural effusion. Horizontal beam radiography is a useful addition when TFAST and/or computed tomography are unavailable.
- Computed tomography is more sensitive than TFAST and radiography for detecting most emergent thoracic injuries.



replace advanced imaging modalities, but it does offer a rapid, radiation-sparing, and noninvasive approach to assessing the thorax, which is essential for patients in respiratory distress. TFAST offers real-time information that is often undetectable by physical examination and laboratory values. Unlike comprehensive ultrasonography scans, TFAST scans provide concise answers with minimal waiting time for interpretation, which guide prompt treatment decisions. TFAST scans also require minimal patient restraint.

Veterinary nurses need training to successfully obtain TFAST images. TFAST is more technically challenging to perform than other imaging modalities, and the challenge may be compounded by a patient's respiratory rate and effort.¹ Regardless of who performs the scan, a foundational understanding of the information a TFAST exam provides is crucial for veterinary nurses, which allows for anticipation of the veterinarian's and patient's needs during and/or after the exam. A veterinary nurse may monitor vital signs, prepare for a subsequent procedure such as thoracocentesis, perform or assist with other advanced imaging procedures, and inform clients of results and the potential need for additional imaging.

Applications and Limitations

TFAST is most helpful for detecting emergent thoracic injuries, such as pneumothorax, hemothorax, pericardial effusion, pleural effusion, and pulmonary contusions. Lung ultrasonography focuses on visualizing fluid between the parietal and visceral pleura or analyzing artifacts on the lung's surface.

Ultrasonography waves emanate from the ultrasound probe and resonate off tissue; the density of tissue determines the intensity and speed with which the waves reflect back to the probe. The resistance encountered by the waves as they pass through a tissue is called acoustic impedance. The reflection of the wave is also determined by the difference in acoustic impedance between the interface of 2 different tissues. This difference is called impedance mismatch.

Ultrasound waves are not reflected by air but rather scattered back toward the probe. The acoustic impedance of air is extremely low relative to other tissues, which creates a black image (anechoic) on the screen. When ultrasound waves encounter the interface between air and tissue, they are mostly reflected, limiting further tissue penetration. This large

TABLE 1 Advantages and Limitations of TFAST, Radiography, and CT

COST	RADIATION	TIME TO ACQUIRE IMAGES (MINUTES)	OPERATOR SKILL NEEDED	SEDATION REQUIRED	TRANSPORT NEEDED	USEFUL FOR SERIAL MONITORING
TFAST						
Low	None	~3	High	None	No	Yes
RADIOGRAPHY						
Moderate	Mild	~5-10	Low	None to moderate	Yes	Yes
CT						
High	Moderate	<5	High	Minimal to moderate	Yes	No

CT=computed tomography, TFAST=thoracic focused assessment with sonography for trauma

TABLE 2 Usefulness of TFAST, Radiography, and CT for Diagnosing Emergent Thoracic Injuries

PULMONARY CONTUSION	PNEUMOTHORAX	PLEURAL EFFUSION	RIB FRACTURE
TFAST			
Mild to moderate	Moderate	Moderate	Mild
RADIOGRAPHY			
Moderate	Moderate	Moderate	Moderate
CT			
Excellent	Excellent	Excellent	Excellent

CT=computed tomography, TFAST=thoracic focused assessment with sonography for trauma



impedance mismatch is similar to that seen with performing an ultrasound with no coupling gel. The presence of air between probe and skin reflects ultrasound waves, preventing skin penetration and resulting in nondiagnostic images. Because of the large impedance mismatch between air in the lungs and surrounding tissue, TFAST is limited to detecting lung pathology within the peripheral 1 to 3 mm of lung parenchyma.^{1,2}

Usually, air and bone are obstacles for sonographers; however, with TFAST, air and bone can be leveraged to be advantageous. The sonographer can use acoustic shadowing from the ribs as well as inherent contrast between the intercostal muscles and air-filled lung as valuable landmarks. Those landmarks can help identify the pleural line, which represents overlapping parietal and visceral pleura and appears as a single bright line (hyperechoic). The pleural line is crucial because

TABLE 3 Common Terms and Definitions

TERM	DEFINITION
Acoustic impedance	The resistance an ultrasound wave encounters as it passes through tissue
Bilateral	Both sides of the body
B-lines	An ultrasound reverberation artifact that appears as hyperechoic lines extending from the pleural line into lung parenchyma without decreasing in intensity while moving with the lungs
Computed tomography (CT)	A noninvasive imaging modality that utilizes ionizing radiation to create detailed cross-sectional images
Chest tube site (CTS)	The highest point of the thorax (dorsal third) between the 7th to 9th intercostal spaces, aligned with the xiphoid process
Diaphragmatico-hepatic (DH)	Caudal to the xiphoid
Dorsoventral (DV)	From spine to abdomen
Effusion	Abnormal fluid accumulation within a body cavity such as the thorax, pericardium, and abdomen
Focused assessment with sonography for trauma (FAST)	A rapid, goal-directed ultrasound exam that evaluates internal structures to answer specific diagnostic questions and guide potentially invasive procedures
Glide sign	Represents normal motion of the lung sliding along the chest wall during respiration
Horizontal beam (HB)	An x-ray beam oriented horizontally (requires tube head and imaging detector to be movable)
Hemothorax	A condition in which blood has collected in the thorax
Kilovoltage peak (kVp)	The peak voltage of x-rays produced, which directly affects quality (penetrating power) of x-rays
Milliampere-seconds (mAs)	The quantity of x-rays produced over a given time
Mediastinum	The central chest compartment containing all organs but the lungs, bordered by mediastinal pleura
Parietal pleura	The outer membrane that lines the inner chest wall and diaphragm
Pericardial effusion	Abnormal accumulation of fluid in the pericardium
Pericardial site (PCS)	Between the 5th and 6th intercostal spaces (typically), where the heartbeat is felt at maximum intensity
Pleural effusion	Abnormal accumulation of fluid in the parietal and visceral pleura (pleural cavity)
Pneumothorax	Abnormal accumulation of air or gas outside of the lungs but within the pleural cavity
Pulmonary contusion	Injury or bruising of the lungs
Step sign	Discontinuity in the pulmonary pleural line
Thoracic focused assessment with sonography for trauma (TFAST)	Point-of-care ultrasonography that quickly checks for fluid or air in the thoracic cavity
Ultrasound (US)	A noninvasive imaging modality that uses sound waves to create real-time images of internal structures
Ventrodorsal (VD)	From abdomen to spine
Vertical beam (VB)	The standard orientation of an x-ray beam from the tube head to the imaging detector
Visceral pleura	Thin membrane that covers the surface of the lungs



B-lines occur as air and fluid approach each other at the surface of the lung; those artifacts appear as hyperechoic streaks that originate from the pleural line and extend into the far field without fading and while moving with the lung.



lung-related ultrasound artifacts originate from the lung surface and vary depending on the condition of the lung and pleural space. Nonetheless, because TFAST depends on visualizing fluid between the parietal and visceral pleura, or analyzes lung surface artifacts, it should not replace other imaging modalities that assess deeper parenchymal structures.

TFAST Examination

Performance of TFAST may be executed with the patient in right or left lateral recumbency, yet the preferred patient position is sternal or standing to enable air to rise and fluid to fall to gravity-dependent areas.³

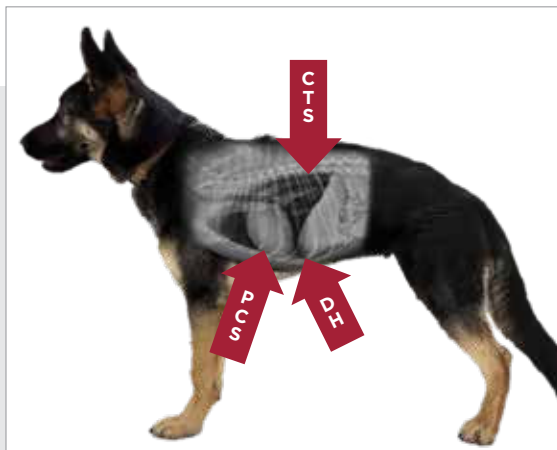


FIGURE 1. Scan locations for thoracic focused assessment with sonography for trauma.

CTS=chest tube sites at the 7th to 9th intercostal spaces on dorsolateral thoracic wall (bilateral); DH=diaphragmatico-hepatic view below the xiphoid; PCS=pericardial sites at the 5th to 6th intercostal space on the ventrolateral thoracic wall (bilateral)

The examination starts with bilateral views of the dorsolateral thoracic wall at the 7th to 9th intercostal spaces, clinically known as chest tube sites (**FIGURE 1**). A linear or curvilinear probe (preferably microconvex for smaller patients) is held in a stationary horizontal position to allow for the greatest degree of visualization of the interface between the parietal and visceral pleura. That positioning enables the sonographer to assess lung pathology and look for a glide sign, which denotes normal motion of lung gliding along the chest wall and indicates that pneumothorax is unlikely. Nonetheless, the absence of a glide sign does not guarantee the patient has a pneumothorax.

The right and left chest tube sites are also used to observe B-lines. B-lines occur as air and fluid approach each other at the surface of the lung; those artifacts appear as hyperechoic streaks that originate from the pleural line and extend into the far field without fading and while moving with the lung. More than 3 B-lines are usually seen with interstitial pulmonary infiltrates, such as contusions or pulmonary edema.⁴

A step sign, which describes discontinuity in the pulmonary pleural line, may suggest rib fractures, pleural effusion, diaphragmatic hernia, or pulmonary masses; additional imaging when the patient is stable is warranted.

Next, the sonographer moves to bilateral views of the pericardial site at the 5th to 6th intercostal space on the ventrolateral thoracic wall (**FIGURE 1**). Bilaterally, that location is used to detect the presence of pleural and pericardial fluid.

The transducer is then placed below the xiphoid with increased depth and cranial angulation for a diaphragmatico-hepatic view, which detects pleural and pericardial effusion (**FIGURE 1**). The diaphragmatico-hepatic view also offers clearer visualization of the pleural and pericardial spaces with less air interference. A racetrack sign, a smooth dark gray (hypoechoic) band conforming to the contour of the heart's muscular apex, may indicate pericardial effusion. A diaphragmatico-hepatic view is also used to assess for a glide sign and B-lines; an absent glide sign in this area leads to suspicion of pneumothorax.^{2,3}

Documentation of findings is crucial for accurate records and future monitoring for resolution or recurrence. For a more in-depth description of TFAST, see go.navc.com/3vCe5wu.



THORACIC RADIOGRAPHY

Thoracic radiography is noninvasive and relatively inexpensive. Taking radiographs before stabilizing a patient in respiratory distress is not recommended due to the need for transport to the radiology department, which can induce stress and exacerbate oxygen demands. Thoracic radiography also requires manipulating potentially painful patients, which may cause more stress to the patient as well. Radiation exposure must also be considered, especially for personnel if hands-free techniques are not used.

After a patient is stabilized, thoracic radiographs may be taken to assess the thoracic cavity overall, including pleural space abnormalities (e.g., pleural effusion, pneumothorax, diaphragmatic hernia), pulmonary parenchymal injuries (e.g., contusions), and body wall lesions (e.g., rib fractures, subcutaneous emphysema).^{4,5} Radiographs may also be used to confirm TFAST findings.

Thoracic Radiography Examination

Suggested thoracic radiographic views include dorsoventral (DV) or ventrodorsal (VD) (preferably both if the patient tolerates dorsal recumbency), left to right laterolateral, right to left laterolateral, and VD horizontal beam (HB) in right or left lateral recumbency (**FIGURE 2**).

A traditional 3-view series (DV or VD, left to right laterolateral, and right to left laterolateral) is used to determine the presence of lung contusions, pneumothorax, pleural effusion, and rib fractures. A DV view accentuates more radiopaque lung

parenchyma, provides sharper delineation of lung lobe margins, and prevents pulmonary vessels from obscuring the lung lobe margins. Thus, a DV radiograph is more sensitive than a VD radiograph for detecting pneumothorax. Sternal recumbency for a DV view is also less stressful for a patient with pneumothorax.

For patients with pleural effusion, a VD view is better for detecting pleural effusion and assessing the cranial and right middle lung lobes, cranial mediastinum, and the size and contour of the cardiac silhouette. On a VD view, pleural effusion spreads over a larger area in the dorsal thoracic cavity, reducing the likelihood of obscuring the cranial and right middle lung lobes, cranial mediastinum, and cardiac silhouette. Small-volume pleural effusion is better visualized as pleural fissure lines on a VD view. In comparison, small-volume pleural effusion accumulates dorsal to the sternum and does not extend into the interlobar fissures on a DV view. In both DV and VD projections, minimal pleural effusion can obscure mediastinal structures, and skin folds may be misinterpreted as pneumothorax.

The ability to assess for pneumothorax and pleural effusion with traditional radiographic views is limited due to fluid and soft tissue structure superimposition.

Horizontal Beam Advantages

A VD HB view is used to detect pneumothorax and pleural effusion. The VD HB view is more sensitive for detecting mild to moderate cases of pneumothorax due to improved visualization of the separation between the visceral and parietal pleural surfaces. A VD HB view is also more sensitive for detecting pleural effusion due to the inherent nature of pleural effusion to accumulate in a dependent position, enhancing visualization of any fluid–lung interface.

If TFAST and CT are unavailable, a VD HB view may be most beneficial.^{6,7} Because of superimposition with the gravity-dependent heart, lungs, and mediastinal structures when using HB radiography, a full series is still required for accurate interpretation.⁷

COMPUTED TOMOGRAPHY

CT is a computerized imaging modality that uses rotating x-ray beams to create high-resolution cross-sectional images. Although it may be considered the



FIGURE 2. A patient in right lateral recumbency for ventrodorsal horizontal beam radiography.



A higher mAs generally results in a less noisy image. However, higher mAs means more radiation exposure.



best option, CT is also the most expensive and limited in availability. In addition, CT relies on ionizing radiation and sedation. Anesthesia risks must be considered for all patients but especially hemodynamically unstable patients. CT technology has significantly improved in recent years, however, resulting in shorter imaging times and the ability to acquire images under mild sedation.

CT Examination

Patients are placed in sternal recumbency in the direction (head or tail first) determined by the placement of monitoring equipment, which causes image artifacts if it passes through the gantry. Whenever possible, limbs are extended to minimize streaking artifacts. The thorax is scanned from the caudal end of the L1 vertebra to the cranial tip of the manubrium.

To optimize image quality, various parameters, not all of which will be covered in this article, can be adjusted. A few of these parameters are milliamperes-seconds (mAs), kilovoltage peak (kVp), slice thickness, and window. The radiographic wave current and exposure time are reported as current in milliamperes multiplied by time in seconds, equaling mAs. Longer scan times increase the chance of motion, which can blur images and complicate interpretation. There is an inverse relationship between mAs and image noise (i.e., undesirable change in pixel values causing grainy patterns). A higher mAs generally results in a less noisy image. However, higher mAs means more radiation exposure.

In thoracic cases, mAs typically ranges from 250 for smaller dogs and cats to 320 for larger dogs. kVp determines the energy or penetrating power of x-rays, and it affects tissue contrast. In thoracic cases, kVp is typically set at 120 yet is often increased to 140 for deep-chested dogs. Slice thickness refers to the width of

each image layer captured during a scan. Depending on the patient's size, slice thickness is set between 1.25 mm and 3.75 mm. While thinner slices may seem like the best choice, these slices increase scan time, thereby increasing chance of motion.

A CT window is selected to optimize the visualization of specific tissues or structures (e.g., lung), working like a digital filter to make subtle differences within a tissue more readily apparent. In thoracic cases, a standard or detail window setting is typically used, then followed by postprocessing reconstructions in specialized windows (e.g., bone, lung). Appropriate adjustments to these settings will result in optimal images.

COMPARING TFAST WITH RADIOGRAPHY AND CT

For pneumothorax detection, TFAST is as sensitive and specific as radiography, yet CT is more sensitive than both TFAST and radiography (**TABLE 2**).⁸ TFAST is limited in its ability to reveal pulmonary contusions and lung abnormalities located at the lung and chest wall interface due to poor ultrasound wave penetration through air-filled lung tissue. Any pulmonary contusion that does not reach the pleural surface at a specific ultrasound window is unlikely to be detected. In addition, some views of lung parenchyma may be obstructed depending on the severity of pneumothorax, making it difficult to assess for pulmonary contusions at those acoustic windows.⁹ TFAST is moderately comparable in sensitivity for pleural effusion detection.⁸

COMPARING RADIOGRAPHY WITH CT

CT is more sensitive than radiography for detecting pneumothorax, pleural effusion, rib fractures, and pulmonary contusions (**TABLE 2**). The higher sensitivity of CT is attributed to eliminating structure superimposition and producing more comprehensive images of the thoracic cavity.¹⁰ One study found that CT detected twice as many cases of pneumothorax and pleural effusion and identified greater severity of pleural effusion than radiography.² With a VD HB radiograph, sensitivity improves for pneumothorax and pleural effusion detection yet remains lower than CT.

One study found that only one-half of rib fractures were detected by radiography versus CT.^{2,6} Identifying rib fractures is crucial; those fractures can compromise breathing, indicate serious thoracic trauma, and serve



as markers for adjacent lung injury.^{2,6} The limited sensitivity of radiography for indicating rib fractures may lead to underestimation of injury severity, potentially hindering treatment decisions and worsening patient outcomes.

Although radiography is less sensitive than CT, it is still helpful for the diagnosis of many emergent thoracic injuries. Radiography is crucial for clinics that do not have access to TFAST or CT and for clients with financial constraints.

SUMMARY

Understanding the applications and limitations of TFAST, radiography, and CT enables a veterinary team to effectively assess and manage a patient with an emergent thoracic injury. These imaging modalities allow the veterinary team to take necessary therapeutic interventions. A comprehensive approach using appropriate imaging techniques underscores the extraordinary power of imaging and the vital role of a dedicated veterinary team in achieving an optimal patient outcome. **TVN**

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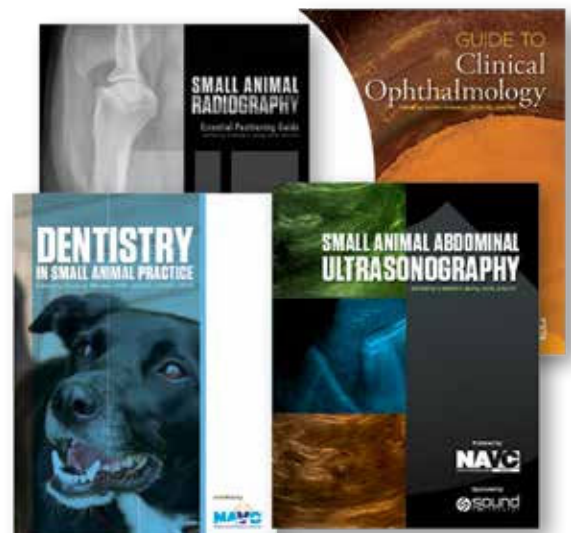


Lydia Trott

Lydia, a graduate of Purdue University's bachelor's degree program in veterinary technology, is a lead diagnostic imaging technologist at Purdue University Veterinary Hospital. Her daily duties include performing advanced imaging exams on small animal, exotic, and large animal patients. She is a member of the Academy of Veterinary Technicians in Diagnostic Imaging and currently serves as chair of the credentials committee and a member-at-large on the executive board. Lydia is also an accomplished ultra-cyclist with Randonneurs USA; when not on the bike, she enjoys camping with her husband, reading a good book on the couch surrounded by her 6 cats, or taking her 2 llamas and 2 dogs down to the creek for a swim.

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