The Use of Ultrasound for Dogs and Cats in the Emergency Room

AFAST and TFAST

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KEYWORDS

• FAST • AFAST • TFAST • Vet Blue • Ultrasound • Emergency • Trauma

KEY POINTS

- AFAST with the abdominal fluid score (AFS) should be repeated at 4 hours in stable patients and sooner in unstable patients.
- An increase in the AFS over time suggests ongoing intra-abdominal hemorrhage.
- A decreasing AFS may be used to monitor resolution (because most cases resolve within 48 hours after bleeding ceases).
- TFAST has high sensitivity and specificity for the rapid diagnosis of pneumothorax (PTX); and the search for the lung point for assessing the degree of PTX as partial versus massive helping determine its clinical significance.
- The detection of pneumothorax (PTX) using TFAST is helpful in blunt and penetrating trauma, and has better sensitivity in patients that are breathing slow and deep.
- To aid in diagnosis of pleural and pericardial effusions, the sonographer should adhere to the axiom that "one view is no view" and clinically use at least two views (eg, using pericardial site [PCS] and DH views) while imaging.

INTRODUCTION TO FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA

Since the early 1990s, focused assessment with sonography for trauma (FAST) has been studied extensively in humans, and has become the initial diagnostic test of choice for the assessment of free fluid (eg, typically indicates hemorrhage) in the peritoneal, pleural, and pericardial spaces in unstable patients suffering blunt trauma.[1]

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It has been used to assess patients with penetrating injury and to detect retroperitoneal, solid organ, and hollow viscous injuries,[1] and has been used serially with and without abdominal fluid scoring systems.[2] The advent of FAST in veterinary medicine is in its infancy. Preliminary studies show it has clinical use in diagnosing and managing intra-abdominal injury, especially when used serially and when identifiable free fluid is quantified.[3,4] To differentiate thoracic FAST from abdominal FAST examinations in dogs and cats, the two have been referred to as TFAST and AFAST, respectively. The AFAST examination is analogous to the FAST examination in human medicine and the two terms are used throughout this article when referring to veterinary and human studies, respectively.

AFAST FOR BLUNT TRAUMA: DETECTION OF FREE FLUID

The AFAST examination is an ideal initial screening test for early recognition of intraperitoneal blood because it is rapid, noninvasive, safe, portable, and can be repeated if the patient's status changes.[3–5] The purpose of AFAST is to rapidly identify free fluid in the peritoneal space (and less frequently the pleural and pericardial spaces) of patients with trauma, particularly in those patients that are unstable.[3–5] It should be performed as soon as possible following the triage examination after the patient enters the intensive care unit, concurrent with other therapies and diagnostics.[2,4] Multiple human studies have demonstrated that the FAST examination is very sensitive and specific at detecting blunt trauma-induced injury as evidenced by free abdominal fluid, comparable with more invasive or expensive tests, such as diagnostic peritoneal lavage and computed tomography.[2,6] Furthermore, the sensitivity and specificity of the FAST examination for detection of free fluid remains high even when performed by nonradiologists.[2,7,8] Human and veterinary studies have demonstrated that radiographic serosal detail is not sensitive or specific at detecting abdominal fluid following blunt trauma.[4,9] For these reasons, the FAST examination has become the initial imaging test of choice for blunt trauma in human emergency medicine, is part of the advanced trauma life support protocol, and is part of the American College of Emergency Physicians Use of Emergency Ultrasound Guidelines.[10]

Two prospective veterinary studies have confirmed the value of AFAST in detecting free abdominal fluid after blunt trauma in dogs.[3,4] One of these studies also demonstrated the value of performing serial AFAST examinations and an abdominal fluid score (AFS).[4] The serial AFAST examination allows detection of delayed accumulations of abdominal fluid not apparent on the initial AFAST scan and has been used to detect changes in the quantity of abdominal fluid over time when combined with the AFS.[4] The AFS has also been shown to correlate well with markers of injury (eg, alanine aminotransferase, blood lactate) and the need for blood transfusion, especially when evaluated serially.[4] In bluntly traumatized dogs, the AFS semiquantitates the degree of intra-abdominal blood loss. In dogs without pre-existing anemia, AFS of one or two is unlikely to develop anemia (barring other sites of hemorrhage). In contrast, dogs with AFS of three or four frequently become anemic with 25% of this subset developing hematocrit values less than 25%. However, a recent abstract failed to show similar findings of an AFS in cats.[11] With the success of AFAST and the use of serial AFAST and AFS scores in dogs, the authors have developed algorithms that incorporate AFAST and the AFS to help direct diagnostic and therapeutic decisions in dogs suffering from blunt trauma (**Fig. 1**). The use of the AFS in small animal patients with regards to its integration into trauma algorithms, value as an end-point of resuscitation, ability to localize organ injury, and ability to direct fluid therapy or surgical intervention requires further investigation.

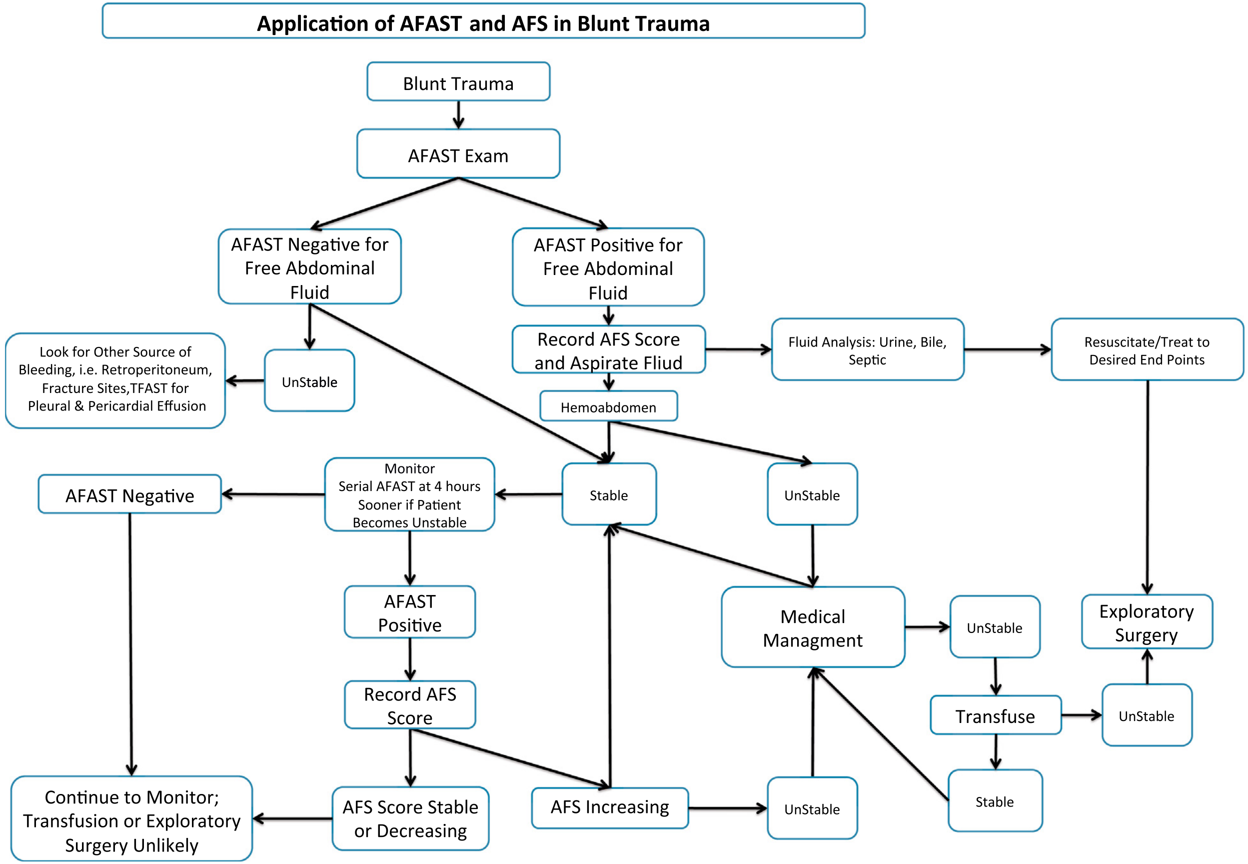

Fig. 1. Algorithm incorporating AFAST and AFS in dogs after blunt abdominal injury.

AFAST FOR BLUNT TRAUMA: DETERMINING THE CAUSE OF INJURY

Hemoabdomen and uroabdomen are two of the most frequent intra-abdominal injuries reported in dogs suffering from abdominal trauma.[3,4,12,13] Because these injuries typically result in free fluid accumulation, both are easily detectable through AFAST examination and have been confirmed in dogs after blunt trauma, centesis, and fluid analysis.[3,4] Because it is not possible to differentiate blood from urine or other fluid types on abdominal ultrasound, fine-needle aspiration and fluid analysis is recommended in patients that are AFAST positive.[3–5] The success of centesis is increased with the use of ultrasound guidance compared with blind techniques.[14] In addition, centesis could help differentiate less common conditions, such as traumatic biliary and intestinal tract rupture, if detected on initial or serial AFAST examinations by facilitating sample collection for stat fluid analysis and cytology.[3]

In small animals, splenic and hepatic injuries are the most common causes of intraperitoneal hemorrhage.[15,16] Human studies demonstrate that FAST has a limited role in the detection of solid organ injury. The sensitivity for sonographic detection of hepatic and splenic injury after blunt trauma varies from 41% to 80%, depending on the organ affected, location of the lesion, organ size, and presence of overlying bowel and gastrointestinal gas.[17–19] Contrast-enhanced ultrasound has increased the ability of ultrasound to detect solid organ injury in human patients with trauma, with sensitivity and specificity of 96.4% and 98%, respectively.[20] The use of contrast-enhanced ultrasonography after trauma in veterinary patients remains to be determined. Challenges in the detection of solid organ injury include greater expertise needed to detect parenchymal changes that indicate solid organ injury and the added time needed to evaluate organs in detail.

The detection of retroperitoneal injury has also demonstrated low sensitivity in human FAST studies.[21,22] Serial FAST examinations may improve detection of solid and retroperitoneal injury; however, missed injuries may still occur, and computed tomography scans are currently recommended in humans with negative FAST examinations suspected of solid organ or retroperitoneal injury.[21–23] In veterinary medicine, the AFAST examination has not been evaluated for the detection of solid organ or retroperitoneal injury after blunt abdominal trauma.

AFAST FOR PENETRATING TRAUMA

Human studies evaluating the FAST examination indicate that it is less sensitive at detecting intra-abdominal injury in cases of penetrating trauma.[24–26] In particular, bowel injuries, which are common in penetrating trauma, are not readily detected on initial sonographic evaluation. Penetrating abdominal trauma in humans often results in localized injury. The FAST examination omits large portions of the abdomen so it does not reliably exclude localized injury. However, it should be noted that humans with penetrating abdominal injury and positive FAST examinations are usually referred for emergency exploratory laparotomy.[24–26] Therefore, a positive FAST examination still has use; however, intra-abdominal injury after penetrating trauma cannot be ruled out based on a negative FAST examination.[24,26] Serial FAST examinations in humans (12–24 hours posttrauma) improve the sensitivity of FAST at detecting intestinal injury after trauma.[27] Keep in mind that the mechanism of injury after penetrating trauma differs between humans and veterinary patients because bite wounds comprise a large number of veterinary penetrating trauma cases compared with projectile penetrating trauma in most humans cases. The role of the AFAST and serial AFAST examinations in projectile and nonprojectile penetrating abdominal trauma in veterinary patients requires further investigation.

AFAST AND AFS SCANNING TECHNIQUE

The purpose of the FAST examination is the detection of free fluid indicating injury. The AFAST examination involves visualizing the diaphragm, liver, gallbladder, spleen, kidneys, intestinal loops, and urinary bladder for the detection of free fluid in the peritoneal cavity. Free fluid is anechoic (black on ultrasound) and tends to collect in the most dependent areas as triangles surrounded by organs (**Figs. 2–5**).

Changing the depth of the scan at the subxiphoid location allows evaluation of the area distal to the diaphragm as far as the level of the heart (see **Fig. 2**). This allows detection of free fluid in the pleural and pericardial spaces during the AFAST examination (**Fig. 6**). However, the sensitivity and specificity of detecting free fluid in the pleural and pericardial spaces by the subxiphoid view has not yet been evaluated in dogs or cats.

The basic four-view protocol provides the foundation for the AFAST examination (**Fig. 7**). The technique has been validated in right and left lateral recumbency in dogs.[3,4] Currently, there are no studies investigating if either position has greater accuracy than the other. At this time, either left or right lateral recumbency can be used and may be decided by the position in which the animal presents (eg, animals that present in left lateral recumbency can be scanned in left lateral to minimize stress to the patient with movement or manipulation). However, if given the choice (eg, the patient presents in sternal recumbency or is ambulatory) there may be theoretical advantages of choosing one side over the other, depending on the objectives of the examiner.[5] Right lateral recumbency may be preferred if standardized electrocardiography evaluation of the patient is desired; if the volume status of the patient is to be echographically evaluated (eg, using an echocardiography table); or if the left retroperitoneal space is to be evaluated in detail.[4,5] Right lateral recumbency may also be preferred to prevent iatrogenic puncture of the spleen when performing centesis, although this should be less of a concern if ultrasound guidance is used.[4,5] Left lateral recumbency may be preferred if the right retroperitoneal space is to be evaluated. Certain injuries, such as flail chest, fractures, or injury to the vertebral column, may also dictate the FAST examination position.[4] Dorsal recumbency is not typically recommended because thoracic injury is common after blunt trauma and pulmonary function may deteriorate when patients with significant thoracic injury are placed in dorsal recumbency.[3,4] Also, the AFS system has not been validated in dorsal recumbency.[4]

The median time to perform AFAST in dogs is reported to be 3 to 6 minutes using the four standard views, consisting of the (1) subxiphoid view to evaluate the

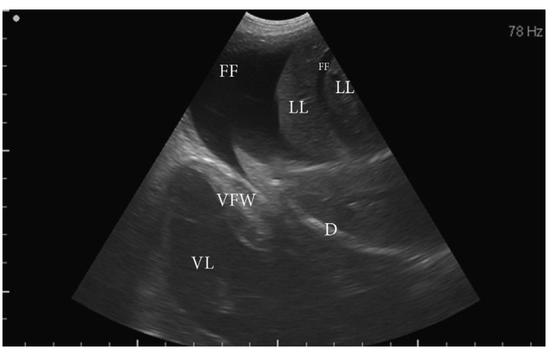

Fig. 2. Positive AFAST at the subxiphoid or DH view demonstrating anechoic free fluid (FF) between the liver lobes (LL) and diaphragm (D). The heart can be seen in the far field distal to the diaphragm as indicated by the ventricular free wall (VFW) and the ventricular lumen (VL). In this case the pleural and pericardial space are negative for free fluid.

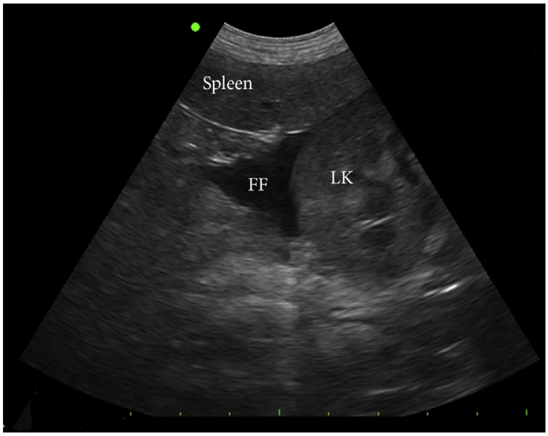

Fig. 3. Positive AFAST at the left flank or SR view demonstrating an anechoic accumulation of free fluid (FF) between the spleen (S) and left kidney (LK).

hepatodiaphragmatic interface, gallbladder region, pericardial sac, and pleural spaces; (2) a left flank view to assess the splenorenal (SR) interface and areas between the spleen and body wall; (3) a midline bladder view to assess the apex of the bladder; and (4) the right flank view to assess the hepatorenal (HR) interface and areas between intestinal loops, right kidney, and the body wall (see **Fig. 7**).[3,4] The time to complete the examination in dogs did not include evaluation of the pleural or pericardial spaces by the subxiphoid view; evaluation of free fluid in these sites may potentially prolong the examination. To assist sonographers in associating the AFAST examination with underlying anatomic structures, these four sites have been named the diaphragmaticohepatic (DH), SR, cystocolic (CC), and HR sites, respectively (see **Fig. 7**).[4,5] An advantage of consistently evaluating the underlying organs at each site during the AFAST examination is that incidental findings may be detected, which have been discovered in up to 7.8% of people undergoing FAST examinations.[28]

The order in which the scan is completed will not likely affect the ability to detect injury, but a systematic approach that identifies target organs consistently will likely expedite the process and assist examiners in becoming familiar with the anatomy associated with each site. The examination is typically evaluated in a clockwise

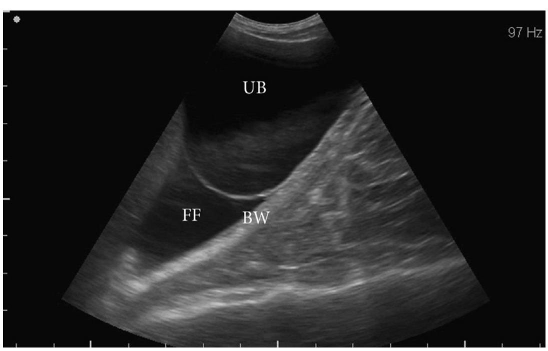

Fig. 4. Positive AFAST at the bladder or CC view showing a triangular accumulation of anechoic free fluid (FF) between the urinary bladder (UB) and the body wall (BW).

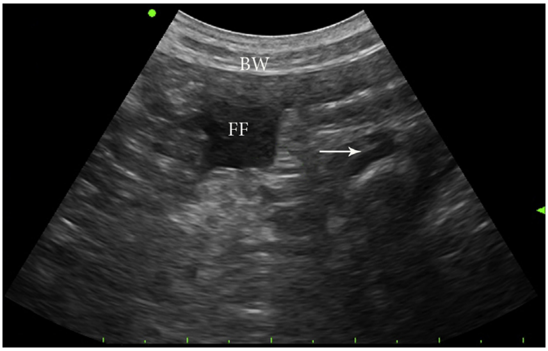

Fig. 5. Positive AFAST at the right flank or HR view demonstrating anechoic free fluid (FF) between loops of intestine (*arrow*) the body wall (BW) and omentum.

rotation, moving from the subxiphoid, to the non–gravity-dependent flank, to bladder, to gravity-dependent flank.[4] At each site, the ultrasound probe can be moved a few inches in several directions and fanned through an angle of 45 degrees until target organs are identified.[3] The subxiphoid or DH site is a good initial starting point because it allows the gallbladder to be identified.[3–5] The gallbladder can be visualized by tilting the probe to the right of midline, and adjusting the gain until the fluid-filled gallbladder appears anechoic.

The initial veterinary AFAST study used two ultrasonographic planes at each site: longitudinal and transverse.[3] This study demonstrated strong agreement between the two planes with only 1 of 400 sites scanned showing discrepancy in results. A subsequent veterinary study evaluated the four sites in only one plane, typically the longitudinal plane, which took less time to perform (eg, 3 minutes median time vs 6 minutes).[4] With comprehensive ultrasound studies, it is recommended to scan organs in two different planes, each plane at a 90 degree angle to the other. However, the AFAST examination can be effectively performed with limited scanning planes because the goal is to detect the presence of free fluid and not to do a comprehensive

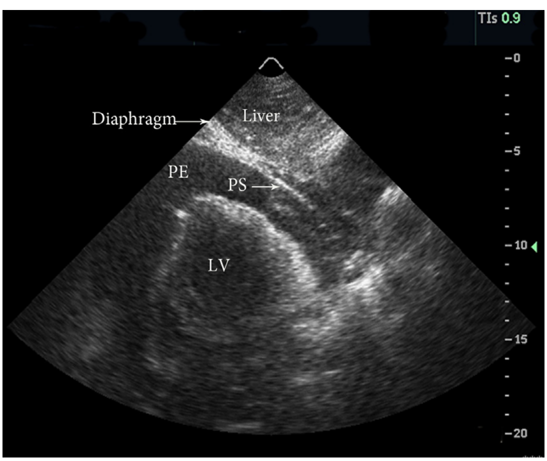

Fig. 6. Positive AFAST for pericardial effusion (PE) identified as anechoic fluid surrounding the left ventricle (LV) by the subxiphoid or DH view. The pericardial sac (PS) is seen in the far field distal to the liver and diaphragm.

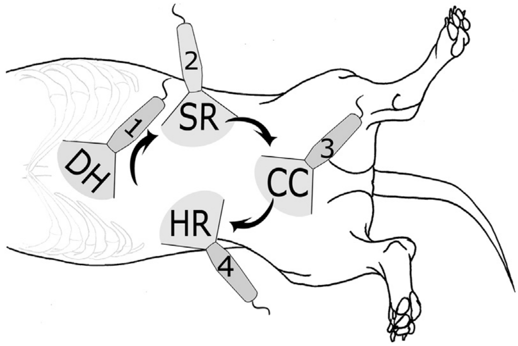

Fig. 7. The AFAST examination, shown here in right lateral recumbency, involves four views of the abdomen: (1) the diaphragmaticohepatic view by placing the probe at the subxiphoid, (2) the splenorenal view by placing the probe at the left flank, (3) the cystocolic view by placing the probe on midline over the bladder, and (4) the hepatorenal view by placing the probe at the right flank. At each site, the ultrasound probe is moved a few inches in several directions and fanned through an angle of 45 degrees until target organs are identified. CC, cystocolic; DH, diaphragmaticohepatic; HR, hepatorenal; SR, splenorenal. (*From* Lisciandro GR. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. J Vet Emerg Crit Care 2011;21(2):108; with permission.)

survey of involved organs. However, with equivocal results, evaluating multiple planes may help confirm the presence of free fluid. If solid organ or retroperitoneal injury assessment is desired, then multiple planes at each site may improve detection of such injuries. It should be stressed that detection of solid organ and retroperitoneal injury is not the initial goal of the AFAST examination.

The AFS is easily accomplished by recording the number of sites (among the four standard views) in which free fluid is detected with the animal in lateral recumbency (eg, AFS 0, negative all sites; AFS 1, positive in one site; AFS 2, positive in any two sites; AFS 3, positive in any three sites; AFS 4, positive in all four sites) (**Table 1**).[4] By recording and serially tracking the AFS scores, it is possible to document the progression or resolution of intra-abdominal hemorrhage, which in conjunction with other clinical examination findings, may help direct therapeutic clinical decisions (see **Fig. 1**). Serial AFAST examinations should be performed every 4 hours, or more frequently if clinical findings (eg, deterioration in hemodynamic status) dictate otherwise.[4,29] In Lisciandro and colleagues,[5] AFS was performed in right and left lateral recumbency in dogs and cats; however, it is unknown if patient position, with respect to organ injury, affects the AFS score. Further investigation of the AFS in regards to patient position and clinical decision-making in dogs and cats is warranted.

AFAST BEYOND BLUNT ABDOMINAL TRAUMA-INDUCED INJURY

The subxiphoid site of the FAST examination in humans is sensitive and specific for identification of pleural and pericardial effusions.[30,31] Two studies in dogs presenting for trauma have identified the presence of pleural fluid by the subxiphoid view.[3,4] The authors have detected pleural effusions in dogs with trauma and pericardial effusions in dogs without trauma by the subxiphoid view, and the sensitivity and specificity of this view at detecting pleural and pericardial effusion in dogs and cats is currently being investigated (application of the DH view, either during TFAST or AFAST in

Table 1
Abdominal focused assessment with sonography for trauma, triage, and tracking (AFAST[3]) template for medical records

Patient positioning	Right or left lateral recumbency	
Gallbladder	Present or absent, contour (normal or not) and wall (normal or not)	
Urinary bladder	Present or absent, contour (normal or not) and wall (normal or not)	
Diaphragmaticohepatic view	Pleural fluid	Present or absent (mild, moderate, severe) or indeterminate
	Pericardial fluid	Present or absent (mild, moderate, severe) or indeterminate
	Hepatic veins	Unremarkable or distended or indeterminate
Positive or negative at the four views (0 negative, 1 positive)		
Diaphragmaticohepatic site	0 or 1	
Splenorenal site	0 or 1	
Cystocolic site	0 or 1	
Hepatorenal site	0 or 1	
Abdominal fluid score: 0–4 (0 negative all quadrants to a maximum score of 4 positive all quadrants)		
Comments: ________________.		

The AFAST[3] examination is an ultrasound scan used to detect the presence of free abdominal fluid and other conditions to better direct resuscitation efforts and patient care. AFAST[3] allows indirect assessment for evidence of intra-abdominal injury or disease and intrathoracic injury or disease. The AFAST[3] examination is not intended to replace a formal abdominal ultrasound.

Data from Lisciandro GR, Lagutchik MS, Mann KA, et al. Evaluation of an abdominal fluid scoring system determined using abdominal focused assessment with sonography for trauma in 101 dogs with motor vehicle trauma. J Vet Emerg Crit Care 2009;19(5):426–37.

detecting pericardial effusion and cardiac tamponade; Greg Lisciandro, unpublished data, 2012). Given the subxiphoid view is part of the standard AFAST examination, it is recommended to continue to evaluate the pleural and pericardial spaces of patients with trauma for the presence of fluid by this view.

In humans, the application of bed-side emergency ultrasound performed by nonradiologists has expanded from the simple detection of free fluid in patients with trauma to the detection of numerous intra-abdominal pathology from a variety of causes in critically ill patients without trauma.[10,32–34] In veterinary medicine, the AFAST examination readily lends itself to the identification of injuries beyond trauma, and the AFAST examination has been applied to patients without trauma for the detection of free abdominal fluid and other intra-abdominal pathology, especially in cardiovascularly unstable patients.[5,35] To emphasize the importance of the AFAST examination in triage of patients without trauma and its importance of following patients serially, it has been referred to as the "AFAST[3]"examination to include the three "T's" of trauma, triage, and tracking (eg, monitoring).[5] To this extent, it has been used to assess patient volume status by evaluating the width of the caudal vena cava and hepatic veins.[5] However, there are no published clinical studies that have investigated the use of the AFAST examination at diagnosing non–trauma-related internal injury when performed by nonradiologists in veterinary medicine.

In summary, many abdominal injuries are not readily detectable on physical examination despite the fact some are serious enough to result in hypoperfusion and shock. Rapid assessment of the abdomen to detect occult or potentially lethal injuries should be a high priority in all unstable patients in which the underlying cause is not readily apparent. In humans, FAST examination has proved useful for detecting trauma and non–trauma-related injury in the abdominal, pleural, and pericardial spaces. Preliminary studies in dogs suggest that the AFAST examination has value in assessing the presence of abdominal injuries, and possibly pleural and pericardial injuries in patients with trauma. The AFAST examination may also prove valuable at detecting non–trauma-related injuries in unstable veterinary patients (eg, hemoabdomen secondary to neoplasia). Finally, the AFAST examination is not an extensive examination of all internal organs but rather a focused examination looking at specific sites of the abdomen to try and answer specific questions: Is free fluid indicative of internal injury present? How much fluid is present? What does this fluid signify? Is the quantity of fluid static, increasing, or decreasing over time?

TFAST FOR BLUNT AND PENETRATING TRAUMA: DETECTION OF FREE AIR AND FREE FLUID

The clinical use of the novel veterinary TFAST scan was documented in a large prospective study of 145 dogs incurring both blunt and penetrating trauma.[36] The primary objective was to determine the accuracy, sensitivity, and specificity of using TFAST for the rapid detection of pneumothorax (PTX), dubbed the most preventable cause of death in traumatized people.[26,37] Secondary objectives included the detection of other injuries, including those within the pleural and pericardial spaces and involving the thoracic wall. The sensitivity and specificity for the detection of PTX by the most experienced sonographer was greater than 95% (using thoracic radiography as the gold standard), thus proving that thoracic ultrasound could be used as a first-line screening test in blunt and penetrating trauma.[36]

More recently, the clinical uses for TFAST have extended beyond trauma (as similar with AFAST). The original TFAST acronym has since evolved into TFAST^3.[5] Patient care and clinical course are potentially improved by rapidly detecting conditions and complications in various subsets of patients using TFAST^3 as an extension of the physical examination including nontrauma, postinterventional, and postsurgical at risk (pleural effusions [hemothorax, pyothorax] and PTX) cases.[1,38–40] As a result of correlating TFAST lung findings with thoracic radiographs (TXRs), a more comprehensive novel lung surveillance called the Vet Blue Lung Scan that extends beyond the TFAST^3 chest tube site (CTS) is currently being evaluated with favorable results (Vet Blue is reliable in veterinary patients; Greg Lisciandro, unpublished data, 2012). The Vet Blue Lung Scan, nicknamed Vet Blue ("blue" for cyanosis, and "BLUE" for bedside lung ultrasound examination[41]), is a rapid point-of-care lung ultrasound scan used as a first-line screening evaluation in respiratory distressed or respiratory compromised veterinary patients (discussed later). In the properly trained physician, lung ultrasound has been shown to exceed chest auscultation and supine chest radiography in sensitivity and specificity for PTX, pleural effusion, lung consolidation, and interstitial syndrome in human patients.[40–46]

These abbreviated ultrasound techniques may be mastered by the nonradiologist veterinarian and serve to rapidly detect life-threatening and potentially life-threatening conditions and complications in hospitalized veterinary patients that have historically been either missed (occult) by traditional means of physical examination, laboratory, and radiographic findings or incurred delay in arranging formal ultrasound studies. By using these abbreviated ultrasound techniques to rapidly answer clinical questions, clinical course is positively affected.[4,5,36,38,41,47,48]

PERFORMING THE TFAST^3 EXAMINATION: NOW A FIVE-POINT SCAN

The TFAST^3 examination consists of five points or areas to scan: the stationary horizontally probe-positioned CTS view; the two bilateral dynamically spotlighted PCS views; and the DH view (part of both AFAST^3 and TFAST^3) (**Fig. 8**). The CTS is best used to exclude PTX and survey for lung pathology, whereas the PCS view is used to detect the presence of pleural and pericardial fluid. Additionally, the right PCS view may be used for volume status assessment (by the left ventricular short-axis view) and to evaluate the aortic/left atrial ratio (which is important in patients suspected to have left-sided heart failure or cardiac disease). The DH view is advantageous over the PCS views because of the acoustic window into the pleural and pericardial spaces through the liver and gallbladder. To differentiate between pleural and pericardial fluid, multiple views (eg, right and left PCS and the DH views) prevent potentially catastrophic mistakes of misidentifying an enlarged right ventricle for pleural effusion or pericardial effusion, and for the presence or absence of cardiac tamponade (see **Fig. 6**).

PATIENT PREPARATION AND POSITIONING FOR TFAST^3 AND VET BLUE

Fur does not need to be shaved for the TFAST^3 and Vet Blue techniques; rather, the fur can be parted for probe-to-skin contact with the use of alcohol and acoustic coupling gel. By not shaving, the cosmetic appearance of the patient is preserved and imaging quality is sufficient with newer ultrasound machines. Alcohol should not be used if electrical defibrillation is anticipated.

For positioning, either right or left lateral recumbency may be used in nonrespiratory patients with all but the opposing CTS. To make the latter side accessible, the patient can be moved into sternal for the final view. For patients with respiratory compromise, sternal recumbency should be used. Right lateral may be preferable because it is standard positioning for electrocardiographic and echocardiographic evaluation (see AFAST). Because most patients are evaluated with AFAST^3 and TFAST^3 (referred to

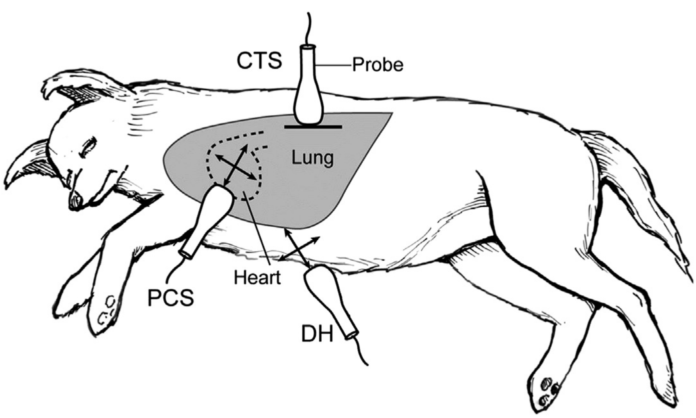

Fig. 8. Depiction of the revised five-point TFAST^3 protocol. (*From* Lisciandro GR. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. J Vet Emerg Crit Care 2011;21(2):113; with permission.)

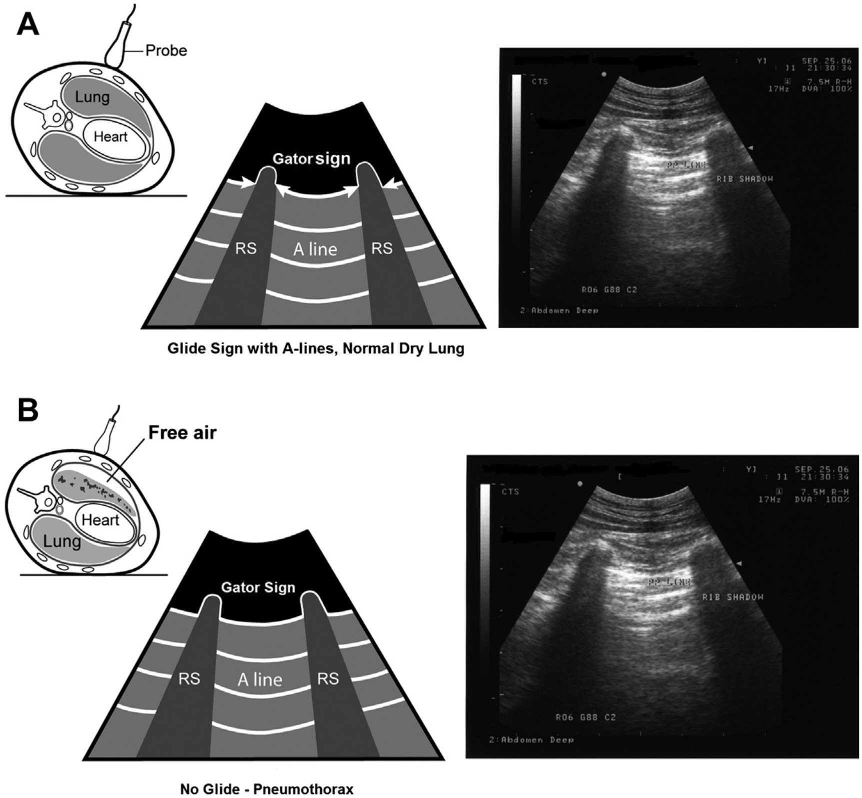

Fig. 9. The glide sign and pneumothorax at the chest tube site. (*A*) Normal CTS view orientation for TFAST[3]. The "gator sign" composed of adjacent ribs with the pulmonary–pleural interface interposed between, is likened to a submerged alligator peering from the water's surface with the eyes as rib heads, and the bridge of the nose in between the eyes representing the pleural- pulmonary interface (PP-line). Along the PP-line, the presence of a glide sign indicates normal apposition of lung against the thoracic wall, thus ruling out PTX. The *bold white arrows* indicate motion to-and-fro during inspiration and expiration, analogous to the cursor of an Etch-a-Sketch moving back and forth through the same line. (*Bold line with arrows*, glide sign). (*B*) CTS view illustrating PTX, where the glide sign is absent, as a real-time finding, depicted by lack of arrows along the pulmonary–pleural interface. Note that A-lines are present in PTX and non-PTX cases. *A* and *B* are identical still B mode ultrasound images to illustrate that a normal pulmonary–pleural interface is indistinguishable from the presence of PTX, and the real-time dynamic presence or absence of the glide sign is the distinguishing feature. (*C*) CTS view illustrating ultrasound lung rockets (ULRs) also called B-lines (previously referred to a comet-tail artifacts) that are defined as laser-like hyperechoic lines that do not fade and extend from the pulmonary-pleural interface to the far field and oscillate (*bold arrows*) swinging like a pendulum with inspiration and expiration. Their presence rules out PTX. A-line, air reverberation artifact; RS, rib shadow. (*From* Lisciandro GR. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. J Vet Emerg Crit Care 2011;21(2):114; with permission.)

as combo FAST [CFAST]) the authors find it most efficient to perform six of eight of the views while the patient is in lateral with similar ultrasound settings.[11] Dorsal recumbency should never be used for several important reasons including the high risk to compromised patients (see AFAST).

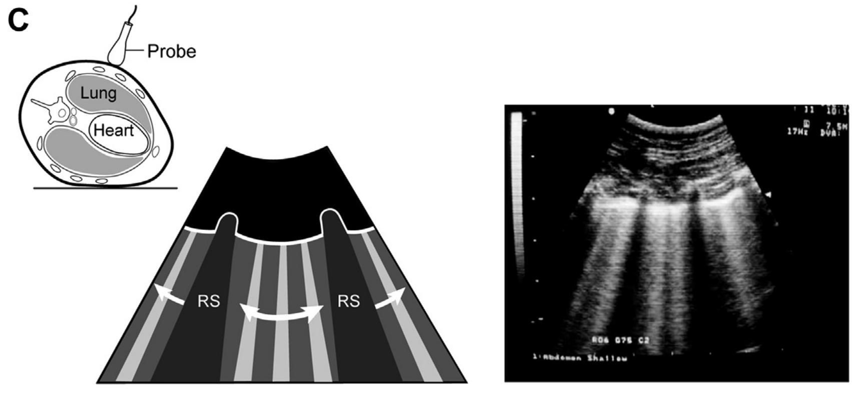

Fig. 9. (*continued*)

THE DIAGNOSIS OF PTX: THE TFAST[3] CTS

The normal to-and-fro motion of the lung sliding along the thoracic wall is called the glide sign.[49] The pulmonary-pleural interface (PP-line) is not to be confused by the distally positioned equidistant reverberation artifacts A-lines (air reverberation artifact) that parallel and extend from the PP-line. When using B-mode, standard two-dimensional ultrasound, still images are the same for a glide sign and PTX because the presence of the glide sign along the PP-line may only be appreciated in real-time (**Fig. 9**A and B). Additionally, the presence of ultrasound lung rockets (ULRs) or B-lines exclude PTX. ULRs, now called B-lines in a recent consensus statement,[46] are defined as hyperechoic (bright) laser-like streaks that do not fade extending through the far field obliterating A-lines. ULRs must also swing like a pendulum, a to-and-fro motion with inspiration and expiration (see **Fig. 9**C). The presence of the glide sign or the presence of ULRs excludes PTX at that respective point on the thoracic wall; thus, by imaging the highest point on the thorax, PTX is best ruled out.[50] An algorithm to diagnose pneumothorax has been developed (see **Fig. 10**).

USING THE LUNG POINT FOR THE DEGREE OF PTX: PARTIAL VERSUS MASSIVE

Historically, the ultrasound diagnosis of PTX has been incorrectly considered an all-or-none phenomenon; however, it is possible to determine the degree of PTX by identifying the location at which collapsed lung recontacts the thoracic wall called the "lung point." To find the lung point the ultrasound probe is positioned sequentially from dorsal to ventral, searching for the presence of either a glide sign or ULRs (evidence that aerated lung is recontacting the thoracic wall). The distance from the CTS to the lung point may be used to subjectively assess the degree of a partial PTX and help determine its clinical relevance.[5,51,52] In the absence of the lung point, a massive PTX is present or the scan is indeterminate (**Fig. 11**).

THE DIAGNOSIS OF LUNG CONTUSIONS

The presence of wet lung (ULRs) in patients with trauma at the TFAST[3] CTS view represents lung contusions until proved otherwise.[53] By extending the TFAST[3] examination using Vet Blue (see below), the severity of lung contusions may be subjectively assessed by recording the number of ULRs at each of the Vet Blue regional lung views. In addition, by using Vet Blue, the detection of occult lung contusions based

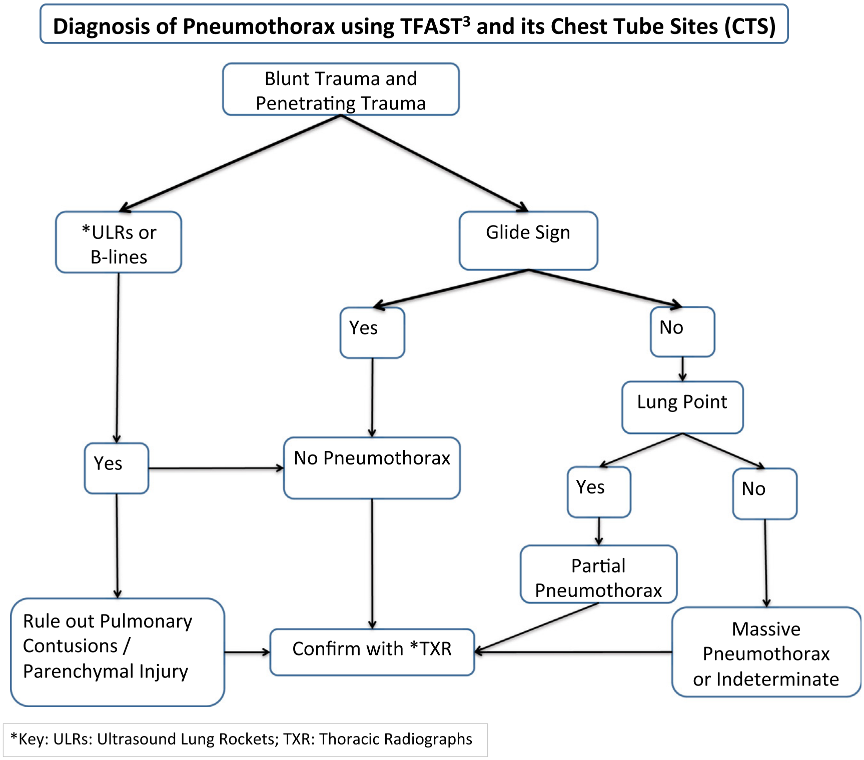

Fig. 10. TFAST diagnosis of pneumothorax using TFAST^3 and its chest tube sites.

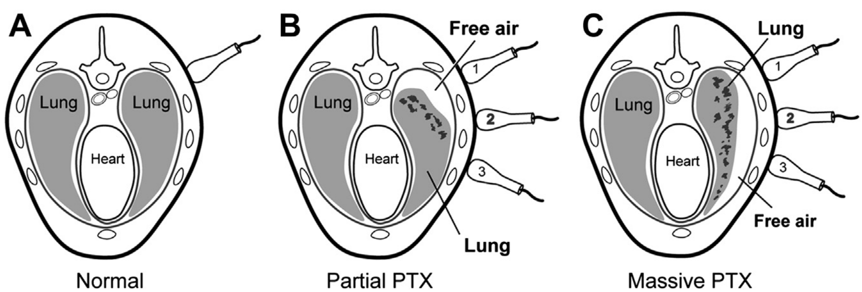

Fig. 11. Depiction of cross-sectional thoraces illustrating the search for the lung point. Cross-sectional canine thoraces depicting the quantification of the degree of PTX as partial or massive by searching for the lung point with the patient positioned in sternal recumbency (safer than lateral recumbency in compromised patients). In the absence of the glide sign or ULRs, the probe is moved sequentially in a ventral manner as numerically labeled from dorsal to ventral. (*A*) Normal thorax in which pneumothorax has been excluded. (*B*) PTX has been identified at position 1 and the lung point at position 2 suggests the pneumothorax to be partial. (*C*) PTX has been identified and a lung point is nonexistent at any of the three probe positions, suggesting massive pneumothorax. (*From* Lisciandro GR. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. J Vet Emerg Crit Care 2011;21(2):115; with permission.)

on the limitations of the TFAST[3] CTS view (a single site) is possible by the more extensive regionally based lung scan (three more sites, four total per hemithorax). Because of the simplicity and short duration of the Vet Blue regional lung scan (<90 seconds), it should be considered an extension of TFAST[3] and used routinely. Moreover, the resolution of lung contusions may be tracked using serial Vet Blue examinations.

THE DIAGNOSIS OF CHEST WALL PATHOLOGY: THE STEP SIGN

The step sign is defined as an inconsistency from the normal expected linear continuity along the PP-line.[5] The observance of the step sign should arouse clinical suspicion for thoracic wall injury, such as intercostal tears, rib fractures, flail chest, subcostal hematoma, hemothorax, and so forth.[5,36] In nontrauma subsets of patients, the step sign may represent types of pleural effusion, lung consolidation, or lung masses (**Fig. 12**). The step sign may be misinterpreted (eg, as a false-positive) if the probe is placed too far caudally on the thoracic wall where the lung, diaphragm, and thoracic wall dynamically come into close proximity.[5,36]

THE DIAGNOSIS OF PLEURAL AND PERICARDIAL EFFUSION

Ultrasound is well established in being superior to physical examination and radiography for the detection of free fluid in the pleural and pericardial space, and is arguably the gold standard for the diagnosis of pericardial effusion.[1,42,54,55] The PCS views are gravity-dependent and can be used for detecting either type of effusion. The DH view (also part of AFAST) is considered the most sensitive view in human protocols, and should be used because of the acoustic window provided into the pleural and pericardial spaces.[1,55] Multiple views improve the probability of an accurate assessment, while lowering the probability of mistaking normal structures for pathology. Ideally, a PCS view and the TFAST[3] DH view should be used, adhering to the axiom that "one view is no view" (**Fig. 13**).

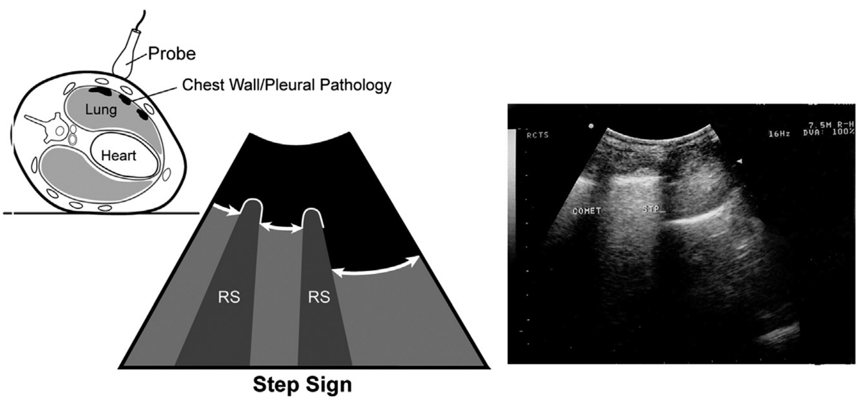

Fig. 12. The step sign. CTS view illustrating the step sign where the glide sign deviates from the expected normal linear continuity of the pulmonary–pleural interface indicated by the offset arrows. Observation of a step sign suggests thoracic trauma, such as partial PTX, hemothorax, rib fractures, intercostals muscle tear, pulmonary contusions, and diaphragmatic hernia. In nontrauma the step sign may represent areas of lung consolidation or masses. A-line, air reverberation artifact; RS, rib shadow. (*From* Lisciandro GR, Lagutchik MS, Mann KA, et al. Evaluation of a thoracic focused assessment with sonography for trauma (TFAST) protocol to detect pneumothorax and concurrent thoracic injury in 145 traumatized dogs. J Vet Emerg Crit Care 2008;18:261; with permission.)

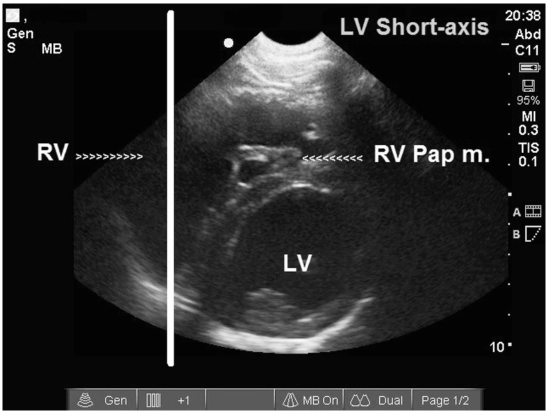

Fig. 13. The pitfall of the pericardial site. Shown is a B mode image of a short-axis view of a canine heart illustrating that by not recognizing normal heart anatomy, the right ventricle may be mistaken for an effusion and its distorted papillary muscle as a mass or other pathology. The *vertical line* emphasizes that by focusing too closely (if the sonographer was only looking at the field to the right of the *vertical line*) an error may be made; however, by zooming away or increasing depth (including the image to the left of the *vertical line* [or the entire B mode image depicted]), the normal anatomy is better appreciated. The image shows the classic left ventricular short-axis "mushroom" view for subjective volume assessment. LV, left ventricle; RV, right ventricle; RV Pap m., right ventricular papillary muscle.

THE DIAGNOSIS OF CARDIAC TAMPONADE

The diagnosis of cardiac tamponade is made when the intrapericardial pressure exceeds right atrial and ventricular pressure, causing their outer walls to paradoxically move inward (eg, collapse) during the cardiac cycle. Generally, in real-time ultrasound imaging, this life-threatening condition may be easily recognized by the nonradiologist veterinarian using TFAST[3]. It behooves the veterinarian incorporating the FAST[3] protocols into their practice to review the causes and treatment of pericardial effusion, including left atrial tears secondary to mitral valve disease in dogs, hemorrhage from right atrial neoplasia, heart base tumors, idiopathic pericardial effusion, and hemorrhage caused by anticoagulant rodenticide toxicity. In comparing 2005 (pre-TFAST[3]) cases with 2011 (post-AFAST[3] and TFAST[3]) cases at the author's practice (GRL) the incidence in detecting pericardial effusion was dramatic (eg, 2 cases vs 24, annual caseload approximately 11,000). Moreover, of the 24 cases, 21 (88%) of 24 were recognized by the DH view, either during TFAST[3] or AFAST[3], and approximately 50% had pericardiocentesis performed because of the diagnosis of cardiac tamponade (many tamponade cases diagnosed via the DH view) (application of the DH view, either during TFAST[3] or AFAST[3] in detecting pericardial effusion and cardiac tamponade; unpublished data, Greg Lisciandro, 2012).

THE VET BLUE LUNG SCAN

In human patients, lung ultrasound has been shown to be superior to chest auscultation and supine radiography for the detection of PTX, interstitial syndrome, and lung consolidation, and has most recently become an important facet of pulmonary and emergency and critical care medicine.[41,43,44,46,56,57] Vet Blue is a rapid point-of-care lung ultrasound scan used as a first-line screening evaluation in respiratory-distressed or respiratory-compromised veterinary patients. The Vet Blue is primarily based on the easily recognizable concept of wet (ULRs) versus dry lung (glide sign and A-lines) (see **Fig. 9**A, C). Normally, in dogs and cats without respiratory disease, ULRs (wet lung) are infrequently detected, and when present, are found in low numbers (one or two ULRs) at a single Vet Blue site (Vet Blue is reliable in veterinary patients; unpublished data, Greg Lisciandro, 2012). Most nonrespiratory dogs and cats have no or infrequent ULRs at any Vet Blue site (**Fig. 14**A and B).

The potentially practice-changing advantage of Vet Blue for the small animal practitioner is that often, patient instability or lack of immediate technical support delays radiographic imaging (which is the historical diagnostic mainstay for veterinarians). As a result, clinical decisions have been traditionally based on insensitive information including patient history, thoracic auscultation, and the characterization of breathing patterns.[58,59] By adding Vet Blue as an extension of TFAST^3 or as a standalone technique, the attending veterinarian has an additional rapid, point-of-care modality for diagnosing lung conditions and anticipating TXR findings; thus, directing more evidence-based therapeutic decisions to the patient's benefit. Moreover, lung ultrasound is unaffected by environmental and patient noise and its imaging is a more objective evaluation (vs the art of thoracic auscultation).

The Vet Blue format should also be considered as an applicable survey for the same T^3 scenarios assigned to AFAST^3 and TFAST^3 (trauma, triage, and tracking [monitoring]). The use of Vet Blue may be advantageous (because of rapid scan, point-of-care testing, minimal restraint, radiation-sparing, and so forth) and effectively monitored (by serial examinations) throughout the patient's therapy surveying the thorax with the ultrasound probe similar as with a stethoscope.[60]

THE USE OF VET BLUE AND LUNG ULTRASOUND: PRINCIPLES AND ASSUMPTIONS

The wet lung (ULRs) versus dry lung concept works well for the rapid inclusion or exclusion of lung contusions in patients with trauma and cardiogenic and noncardiogenic causes of pulmonary edema in nontrauma subsets of patients. In human medicine, this highly sensitive technique is very effectively used as a bedside test in people to confidently rule out cardiogenic pulmonary edema when lung fields are dry; based on the author's experience, Vet Blue proves reliable in veterinary patients (Vet Blue is reliable in veterinary patients; unpublished data, Greg Lisciandro, 2012).[44,46,47,57]

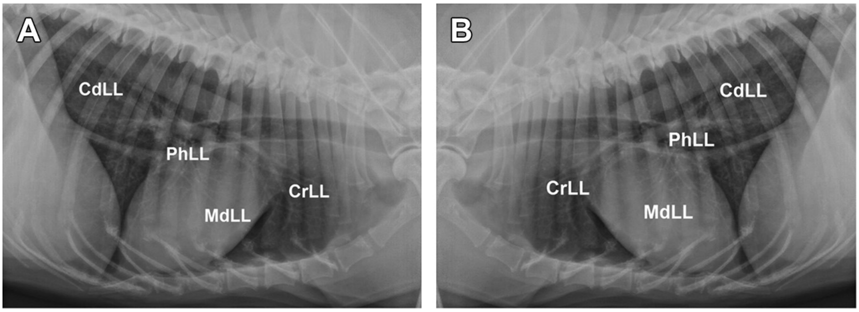

Fig. 14. The Vet Blue Lung Scan. Illustrated here are right (*A*) and left (*B*) hemithoraces. Vet Blue is performed with the probe positioned the same as that of the TFAST^3 CTS view and should be considered as an extension of TFAST^3 and a standalone technique for more comprehensive lung surveillance. The lung is evaluated at regional lung locations as follows: caudodorsal lung lobe region (CdLL) (same as the TFAST^3 CTS view); perihilar lung lobe region (PhLL); middle lung lobe region (MdLL); and cranial lung lobe region (CrLL). The maximum number of ULRs over a single intercostal space at each respective site is recorded.

Equally as important, the recognition of interstitial edema by lung ultrasound precedes alveolar edema (as evidenced by less serious [ULRs] vs more serious lung consolidation, respectively).[44,47,48,50,57] Because lung ultrasound seems to be more sensitive than physical examination findings and TXR, the incorporation of Vet Blue as lung surveillance is beneficial. This may also allow more rapid therapeutic intervention, and thus limit more serious progression to lung failure, as shown in humans.[41,44,46,47,50,57] Finally, it should be noted that several limitations of Vet Blue exist: lung conditions must have reached the anatomic periphery (and thus be accessible by ultrasound visualization); and recognition that lesions located deep within the lung lobes will be missed because ultrasound cannot penetrate or image through aerated lung.[44,46,50] However, in acute respiratory distress, the wet-to-dry lung principles prove very helpful in categorizing causes of acute respiratory distress with high sensitivity and specificity in human patients.[41,43,44,46,47,50,57] By the very achievable goal of learning the recognition of wet versus dry lung, the nonradiologist sonographer begins to recognize additional signs of ultrasonographically detectable lung pathology (discussed later).

THE USE OF REGIONALLY BASED VET BLUE FINDINGS: DIAGNOSING AND MONITORING LUNG CONDITIONS

Many acute non–trauma-associated respiratory conditions have classic distribution patterns of wet versus dry lung (**Fig. 15**). For example, dogs with early stages of left-sided heart failure or volume overload (other than Doberman Pinschers with

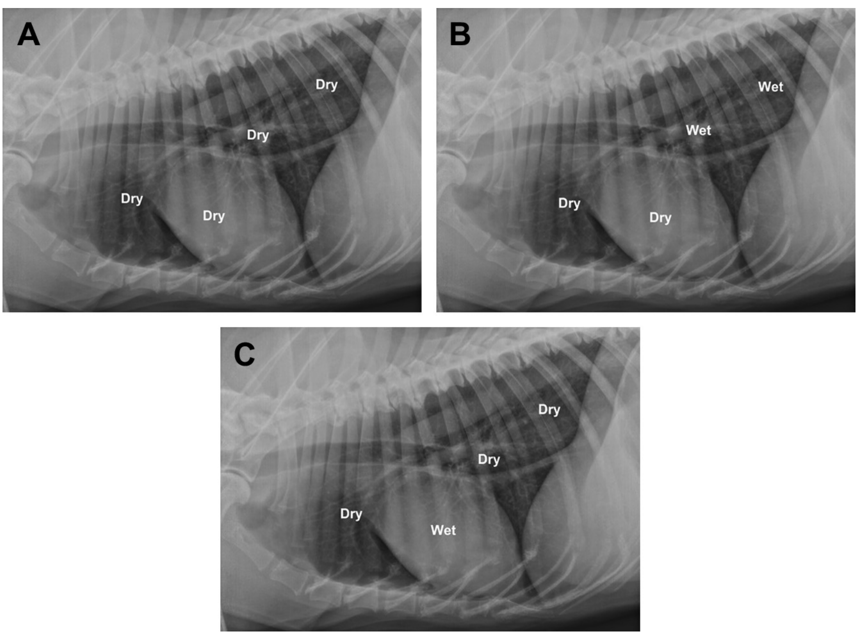

Fig. 15. The basic Vet Blue patterns. Each depicts examples of the distribution of expected findings in acute respiratory distress. (*A*) The finding of dry lung all regions (glide sign with A-lines) effectively rules out any clinically significant degree of cardiogenic or noncardiogenic forms of pulmonary edema and suggests other respiratory and nonrespiratory causes. (*B*) The finding of wet lungs in the dorsal lung regions strongly suggests the presence of cardiogenic and noncardiogenic pulmonary edema (referred to as interstitial syndrome). (*C*) The finding of wet fields isolated to the ventral regions suggests acute pneumonia.

dilated cardiomyopathy) typically have ULRs at the caudodorsal and perihilar lung regions and dry lungs ventrally at the middle and cranial lung lobe regions. The same pattern seems to hold true for acute noncardiogenic pulmonary edema (NCPE) from neurogenic causes, electrocution, or choking or other causes (eg, drowning, acute lung injury, respiratory distress syndrome).

Conversely, ventral wet lung patterns are more suggestive of pneumonias. For example, consider a dog presenting that may have aspirated after choking on an upper airway foreign body. The cause of respiratory distress (or respiratory concerns, if seemingly asymptomatic) may be aspiration pneumonia, NCPE, or both. Each of these scenarios may be expediently addressed using Vet Blue (potentially preempting the need for TXR, particularly if financial constraints exist). If this dog has wet lungs (ULRs) only identified at the right middle lung lobe region, the major cause of its respiratory distress is more likely to be acute aspiration (eg, wet lungs at the classically affected lung lobe) rather than NCPE. If this same dog has a ULR distribution at the caudodorsal and perihilar lung regions, it is more likely to have NCPE; however, the same dog may have Vet Blue findings supportive of both conditions. Finally, if this dog has dry lungs in all fields, then these complications are potentially ruled-out, especially when Vet Blue is used in serial fashion. Because therapy is much different for aspiration pneumonia than NCPE (and no therapy is needed for their nonexistence), a simple Vet Blue examination rapidly and expediently puts the clinician on potentially the correct therapeutic path. However, other differential diagnoses must be considered in patients presenting with respiratory distress when dry lungs are observed in all fields, including feline asthma, upper airway disease, pulmonary thromboembolism, and nonrespiratory causes of distress (eg, nonrespiratory “lookalikes,” such as high fever/pyrexia, cardiac tamponade, hypovolemia, anemia, and severe metabolic acidosis).

THE FUTURE OF SMALL ANIMAL LUNG ULTRASOUND

The wet (ULRs or B-lines) versus dry lung (glide sign or A-lines) concept is easily mastered by the nonradiologist veterinarian. In more chronic conditions (and some acute), additional lung ultrasound signs are seen. These signs are suspected by recognizing deviations from the normal linear continuity of the PP-line (previously referred to as step signs). Lung consolidation may appear as subsets of the step sign and include newly defined terminology by the author including the shred sign, tissue sign, and nodule sign, full definitions of which are beyond the scope of this review but similar to propositions in human medicine.[56]

THE USE OF TFAST^3 AND VET BLUE: CARDIOVASCULAR ASSESSMENT

TFAST^3 and Vet Blue can also be used for cardiovascular assessment during resuscitation, and monitoring for complications associated with fluid therapy.[47,57] A subjective cardiovascular assessment may be made by looking at the left ventricular short-axis (right TFAST^3 PCS [mushroom view]) for volume status and contractility, the caudodorsal and perihilar lung regions of Vet Blue for wet lung (evidence of pulmonary edema), and caudal vena caval size and hepatic venous distention (the DH view) for preload assessment and detection of volume overload (**Fig. 16**).[1]

THE USE OF GLOBAL FAST^3: MONITORING HOSPITALIZED, CRITICALLY ILL PATIENTS, AND AT-RISK PATIENTS

By combining these three focused ultrasound techniques (referred to as global FAST^3 or GFAST^3) as an extension of the cursory ultrasound (AFAST^3, TFAST^3) and the

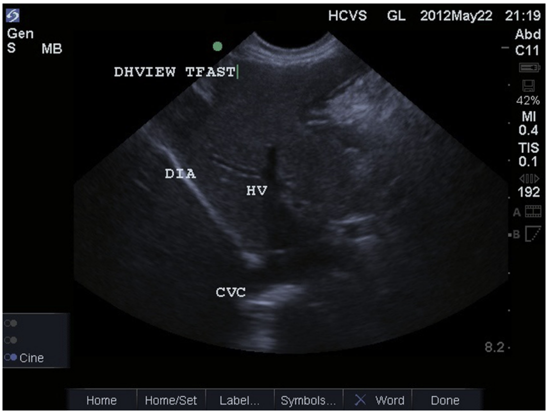

Fig. 16. The use of AFAST[3], TFAST[3], and Vet Blue for cardiovascular status. By combining the right TFAST[3] PCS view for contractility and left ventricular filling (short-axis "mushroom" view) (see **Fig. 13**), and Vet Blue for the presence or absence of cardiogenic pulmonary edema (ULRs) (see **Fig. 9**A, C), the DH view of both AFAST[3] and TFAST[3] for caudal vena caval (CVC) size and degrees of hepatic venous distention (HV) for preload and right-sided cardiac status, the veterinarian can noninvasively subjectively evaluate overall cardiovascular status of the veterinary patient. DIA, diaphragm.

Table 2
Thoracic focused assessment with sonography for trauma, triage, and tracking (TFAST[3]) template for medical records

CTS glide sign[a]	Present (normal): no pneumothorax *or* Absent: pneumothorax
CTS lung rockets[a]	Present (no PTX): interstitial lung fluid (edema, hemorrhage) *or* Absent: no interstitial lung fluid (edema, hemorrhage)
CTS step sign[a]	Present: concurrent thoracic wall trauma (rib fractures, hematoma, intercostal muscle tear) or pleural space disease is suspected or nontraumatic lung conditions *or* Absent: no concurrent thoracic wall trauma or pleural space disease is suspected
PCS view[a]	Absent: no pleural *or* pericardial fluid Present: pleural *or* pericardial fluid *or* both (mild, moderate, or severe)
Cardiac tamponade	Absent Present Indeterminate
LV filling (short-axis)	Adequate, suggesting normovolemia *or* Inadequate, suggesting hypovolemia *or* Indeterminate
Diaphragmaticohepatic view: there is no apparent pericardial or pleural fluid present *or* there is pericardial effusion (mild, moderate, severe) or pleural effusion (mild, moderate, severe)	
Comments: ______________________________.	

Abbreviations: CTS, chest tube site; LV, left ventricle; PCS, pericardial sac; PTX, pneumothorax.

The TFAST[3] examination is an ultrasound scan used to help detect chest wall, lung, and pleural and pericardial space problems as a screening test to better direct resuscitation efforts and patient care. TFAST[3] is not necessarily intended to replace chest radiographs or formal echocardiography.

[a] Right and left sides are listed in templates for the CTS and PCS views.

Data from Lisciandro GR, Lagutchik MS, Man KA, et al. Evaluation of a thoracic focused assessment with sonography for trauma (TFAST) protocol to detect pneumothorax and concurrent thoracic injury in 145 traumatized dogs. J Vet Emerg Crit Care 2008;18(3):258–69.

Table 3
The Vet Blue Lung Scan template for medical records

Record the maximum number of ULRs over a single intercostals space (0, 1, 2, 3, >3) at each respective Vet Blue site in the order of caudodorsal, perihilar, middle and cranial lung lobe regions.	
Left hemithorax (Cd, Ph, Md, Cr)	(x, x, x, x)
Right hemithorax (Cd, Ph, Md, Cr)	(x, x, x, x)
Case examples	
Dry all fields	Left (0, 0, 0, 0) Right (0, 0, 0, 0)
Wet fields dorsally	Left (>3, >3, 0, 0) Right (2, >3, 0, 0)
Wet field ventrally	Left (0, 0, 0, 0) Right (0, 0, >3, 0)
Comments: ______________________________.	

Abbreviations: Cd, caudodorsal lung lobe region; Cr, cranial lung lobe region; Md, middle lung lobe region; Ph, perihilar lung lobe region.

The Vet Blue Lung Scan is a lung ultrasound examination used to help detect and monitor lung conditions; and not necessarily intended to replace thoracic radiographs or formal non-thoracic ultrasound or echocardiography.

“modern stethoscope” (Vet Blue), the nonradiologist veterinarian has the ability to rapidly and expediently arrive at a more probable working diagnoses, decrease morbidity because of delay of diagnosis, avoid mistreating otherwise occult conditions, and improve patient care.[60] These global techniques survey four spaces (eg, peritoneal, retroperitoneal, pleural, and pericardial) in addition to the lung. By using these FAST techniques, the veterinarian may positively direct therapy with evidence-based medicine in the emergent setting or as a cage-side, point-of-care test in hospitalized at-risk or critically ill veterinary patients.

TEMPLATES FOR MEDICAL RECORDS AND TERMINOLOGY

Technique standardization for the AFAST^3, TFAST^3, and Vet Blue examinations is key for veterinarians to not only effectively communicate findings, but also to be able to evaluate the proficiency and clinical use of these ultrasound examinations. These objectives are best met through the use of standardized templates. Included in **Table 1**; **Tables 2** and **3** are suggested goal-directed templates for each of the three ultrasound scans, which may be modified according to the veterinarian’s skills. The semantic renaming of abdominal FAST^3 to AFAST^3, thoracic FAST^3 to TFAST^3, the combination of AFAST^3 and TFAST^3 as CFAST^3, and lastly the most comprehensive scan of CFAST^3 and Vet Blue as GFAST^3’ is suggested to avoid the confusing slew of acronyms in human medicine.[5]

SUMMARY

By combining AFAST^3, TFAST^3, and Vet Blue (to global FAST^3 or GFAST^3), the nonradiologist veterinarian now has reliable, brief ultrasonographic examinations to better direct, diagnose, and monitor therapy that is achievable with minimal training. In addition, these diagnostic tests can help the clinician diagnose potentially serious, life-threatening conditions through the use of point-of care, radiation-sparing tests within minutes on the triage table or during hospitalization of emergent and critically ill veterinary patients.

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